SAPIENZA
UNIVERSITÀ DI ROMA

School of Statistical Sciences

PhD in Demography

XXVI cycle

Health, survival and proximity to death: exploring health and mortality risks among Italian older adults

Author:

Elena Demuru

Supervisor:

Viviana Egidi

Coordinator:

Elisabetta Barbi

Department of Statistical Sciences

December 15th, 2015

To my wonderful parents,

for always giving me the love and support

I need to pursue my dreams.

List of acronyms

ADL	Activities of Daily Living
CI	Confidence Intervals
HCE	Health Care Expenditures
HDS	Hospital Discharge Sheet
HR	Hazard Ratio
IADL	Instrumental Activities of Daily Living
ISTAT	Italian National Institute of Statistics
LRT	Likelihood Ratio Test
NHIS	National Health Interview Survey
OR	Odds Ratio
RRR	Relative Risk Ratio
SRH	Self-Rated Health
WHO	World Health Organization

Table of contents

1. Introduction

During the 20th century, the developed regions of the world have been experiencing what can be defined as a real demographic revolution. Indeed, both mortality and fertility rates decreased to reach very low levels, causing the structure of the population to change considerably over time. Nowadays, the proportion of younger people is already much lower in comparison with that of adult and middle-aged people, who will enter old age in some years.

Mortality rates, moreover, have kept falling even in the most recent years, not only below age 65 but also and especially in the older segment of the population. In Western Europe - one of the regions in which mortality rates at older ages have decreased the most over time - a reduction of more than 50% and 30% has been observed from 1970 to 2010 respectively between 65 and 79 and at 85 years of age and above (Global Burden of Disease Study, 2010). As an obvious consequence, people currently live much longer than in past times.

Increased longevity is often seen more as a difficult challenge than as a great achievement. As a matter of fact, too many doubts still remain about the quality of life in old age and the sustainability of social systems in ageing countries. In particular, a great concern has arisen about the future health status of individuals at older ages and - hence - about the possibility that it will gradually become impossible to satisfy the needs for adequate health care services of an ageing population. This scenario could indeed occur if increased longevity was not associated with considerable improvements in the health conditions of older people, causing individuals to live for many years in poor health conditions. However, no consensus has ever been reached on this subject despite many studies have been carried out with the aim of understanding if and how the health status of the population has been changing over time along with decreasing mortality.

In this context of uncertainty about the ability of older people to age successfully - and thus live in good health until shortly before death - it becomes interesting to focus on the last years of life and try to shed light on whether negative health outcomes are concentrated in a relatively small number of years before death or not. This can be done by estimating the strength of the association between health and survival, which is precisely the main goal of this thesis.

1.1 Objectives of the study

More in particular, the focus of this work is on the health conditions in the last seven years of life among Italian adult and older people (aged 50 years and older). This issue is approached from two opposing perspectives that can be defined respectively as “looking forward” and “looking backward”.

The “looking forward” perspective is that usually adopted in applications of survival analysis: given that a person is in a certain state at a specific point in time, the interest is in estimating his/her probability of surviving over the subsequent years. A first aim of the thesis is indeed to study the survival of people according to their health status in order to: 1) provide some indication about the average length of poor health before death; 2) understand which dimension of health (among chronic morbidity, functional status and self-perceived health) has the highest predictive value on mortality and, on the other hand, which one is most likely to affect the quality of life for longer periods of time.

The “looking backward” perspective is diametrically opposed: given that a person dies at a specific point in time, the interest is in estimating his/her probability of being in a state of poor health in the preceding years. In this case, the main objective is to analyse the health status of older individuals according to their proximity to death in order to: 1) estimate the prevalence of poor health in the population during the years immediately before death; 2) quantify the differences in health-related quality of life between same-age decedents and survivors (i.e. respectively those who are expected to die within few years and those who are destined to live longer); 3) measure the strength of the association between proximity to death and health status; 4) reassess the role of age as a determinant of poor health while controlling for proximity to death.

Using both perspectives allows to gain valuable insights on the health status of individuals during old age. On the one hand, by “looking forward” it is possible to estimate the differences in survival by health status, and thus understand whether poor health is likely to affect individuals for long periods of time or not. On the other hand, by “looking backward” it is possible to understand whether the prevalence of poor health depends more on age or on proximity to death and is thus high among people at older ages mainly due to the fact that they are closer to death.

The analysis of all these issues has a particular importance because the consequences of increased longevity and population ageing would be less dramatic than expected if older people were able to spend most of their time in good health. Some indication that this could actually happen already exists: as it will be widely illustrated in Chapter 2, it is being increasingly recognised that cognitive and physical declines as well as the use and costs of health care services could be mostly concentrated at the end of life. It could thus be that closeness to death rather than age is the main cause of the deterioration of health and the consequent increased need for health care services.

1.2 Outline of the thesis

Excluding this introduction, the thesis is structured in five chapters. A brief overview of the contents of each of them is given below.

Chapter 2 describes the background of the study and critically reviews the literature on health and mortality. More in particular, it begins with an overview of the possible implications of increased longevity on health status: it first illustrates the three major theories developed over the years (i.e. compression of morbidity, expansion of morbidity and dynamic equilibrium) and then summarises the results of the many studies that have been carried out all over the world in order to test these theories. Afterwards, the chapter discusses the main results of the studies that are currently available on both survival in different health states and on health in the last years of life - which are respectively carried out following the "looking forward" and "looking backward" approach.

Chapter 3 describes the data source used for the study, i.e. the so-called "New Italian Longitudinal Study". This consists of the mortality follow-up of the Health Interview Survey (HIS) carried out at the national level by the Italian National Institute of Statistics (ISTAT), and is the first data source that combines information on health status and death for a nationally representative sample of the population residing in Italy. As no documentation has been published yet, a detailed description of the linkage procedures followed by ISTAT to create this data source is provided in this chapter. Furthermore, a definition of all variables considered in the study (i.e. measures of the different dimensions of health, socio-demographic characteristics and proximity to death) - is provided together with a description of the sample in terms of these variables. To conclude, the results of a validation analysis of data are presented.

Chapter 4 presents the results of the analysis performed from a “looking forward” perspective. More in details, a comparison is first made between the survival experiences over the years of follow-up of participants in the 1999-2000 Italian HIS who were in different health conditions at interview according to two demographic characteristics: gender and age. Afterwards, the results of a multivariate analysis are reported that allows to quantify - for the total population and separately for men and women - the impact of the different dimensions of poor health on the risk of death while controlling for other important socio-demographic characteristics that are known to affect mortality. The methods used in this part of the study (i.e. Kaplan Meier survival curves, relative survival curves and extended Cox proportional hazards models) are also briefly described in a dedicated paragraph before reporting the results.

Chapter 5 presents the results of the analysis performed according to a “looking backward” perspective. In particular, the prevalence of poor health in the population according to the number of years of proximity to death in different age and gender groups is first studied using a descriptive approach. Then, estimates from multivariate regression models are reported that quantify the strength of the association between the different dimensions of poor health and proximity to death. Reflecting the structure of the previous chapter, a paragraph that briefly describes the methods used for analysing the data in this second part of the study (i.e. binary and multinomial logistic regression models) is also included here.

Chapter 6 provides a discussion of the results presented in the previous chapters and draws the conclusions of the study. In particular, separate discussions are first included for the analyses based on the two approaches. Then, a combined discussion of the main results of the two analyses is provided in order to give an overall view and, at the same time, illustrate the importance of using both approaches to gain more comprehensive insights into the health conditions of older people. Moreover, the strengths and limitations of the study are also discussed in this chapter.

Finally, an Appendix is also included that reports some additional tables and figures (as indicated in the text).

2. Background and literature review

2.1 A spectacular increase in life expectancy

As it is widely known, life expectancy has dramatically increased over the last century in all developed countries (Human Mortality Database, 2015).

During the first half of the 1900s, this phenomenon was mainly caused by reductions in mortality from infectious diseases at younger ages, that resulted from both improvements in hygienic and living conditions and the development of medical knowledge. As described by Omran (1971) in his *theory of the epidemiologic transition*, the growing prevalence of chronic diseases in the older population over the ‘50s and ‘60s was then expected to prevent the average length of life from further increasing. However, this never happened: not only life expectancy at birth continued to increase during the second half of the 20th century, but remaining life expectancies at older ages also started to rise considerably. Death rates have been indeed constantly declining among older people since the beginning of the ‘70s (Rau et al., 2008), and there is consistent evidence that major contributions to the recent growth of life expectancy have been precisely given by decreasing mortality due to chronic diseases (Meslé et Vallin, 2000).

As a result of these trends, the average life span has increased to very high values, once considered unreachable. In Japan - that is currently the leading country in terms of survival - female and male newborns of 2012 could expect to live for 86.4 and 80.0 years, while women and men aged 65 years old could expect to live for another 23.8 and 18.9 years respectively (Human Mortality Database, 2015). In Italy, female and male newborns of 2013 could expect to live for 84.6 and 79.8, whereas women and men aged 65 years could expect to live for another 22.0 and 18.6 years respectively (ISTAT, 2015).

Over the past decades, researchers have been questioning whether or not a fixed limit to the life span exists. The experience of Japanese women contradicted those who believed that 85 years was the maximum life expectancy ever achievable by humans (Fries, 1980; Olshansky, 1990). Some opened to the possibility that the maximum life span could actually be much higher (Caselli et Vallin, 2001), and others even supposed that there is no limit to life expectancy. Oeppen and Vaupel (2002) - in this regard -

pointed out that all predictions have been repeatedly exceeded, proved that record life expectancy (i.e. the highest life expectancy observed in a specific year) has been increasing linearly by a factor of 3 months per year since 1840 and suggested that this trend could be extrapolated to the future. Even if the approach used in this study can be criticised (Vallin and Meslé, 2009) and some authors still support the idea of the existence of a maximum length of life (Carnes, 2003), current empirical evidence gives room to believe that life expectancy will keep rising at least in the next future.

2.2 Effects of increased longevity on health: an open debate

Longevity is undeniably one of the most important achievements of the mankind. However, it poses a variety of questions on its consequences in different fields of life that still remain unanswered. One of these is related to the possible evolution of health status with advancing age. Age is in fact known to be an important determinant of morbidity, but it is still not clear whether gains in life expectancy will translate into extra years of poor or good health.

Given the importance of the issue, researchers have started to investigate the possible effects of increased longevity on health as soon as sufficiently long time series of data became available. The American literature is particularly rich and varied, both on the theoretical and empirical sides: the main theories have been developed and tested in the United States since the 1980s thanks to the availability of the information gathered from the National Health Interview Survey (NHIS) every year since 1957. Elsewhere, suitable data were not collected - at least not on a regular basis - until the first years of the 1990s. Only afterwards, studies have been performed also in other countries to test the main theories of change in health status due to longevity. These studies show a variety of situations.

An overview of theories and a summary of evidence are given in the following pages in order to illustrate all possible scenarios resulting from increasing life expectancy and understand which one appears to be the most plausible based on the literature.

2.2.1 *Theories*

Three different scenarios have been mainly hypothesised to illustrate potential changes in the time spent in poor health along with increasing life expectancy: the "compression of morbidity", the "expansion of morbidity", and the "dynamic equilibrium".

The first scenario is the most optimistic: it implies that health conditions at older ages improve over time. The underlying idea is in fact that longevity is not necessarily associated with longer period of poor health, especially if medical expertise in treating chronic diseases progresses and efforts are made to promote prevention and healthy lifestyles.

In its original version, the theory of compression of morbidity assumed that there is a fixed limit to the growth of life expectancy and that the onset of chronic diseases can be postponed to older ages, causing a compression of poor health into a shorter period of time before death and thus a reduction of the prevalence of disability at an aggregate level (Fries, 1980). Under this assumption, both the mortality and morbidity curves of the population by age would progressively undergo a process of "rectangularisation": not only an increasing amount of people would reach the maximum life expectancy, but also those people would be living until then in a good health status.

In a later update, the theory opened to the possibility that the average length of life could further increase in the near future and discerned between absolute and relative compression of morbidity. The first occurs when the onset of disease is postponed more than death: i.e. when morbidity rates decrease more than mortality rates in absolute terms. The latter occurs when the time spent in a state of morbidity decreases as a percentage of life expectancy (Fries, 1983).

At the beginning, this very first theory of healthy aging have been criticised as being not supported by available data and thus prone to overlook the need for being prepared to face a considerable deterioration of the health status of the population due to further increases in the proportion of older individuals (Fries, 1984). In fact, at the time when the compression of morbidity hypothesis was formulated, most studies focusing on trends in health conditions at older ages during the 1970s proved that the prevalence of disability as well as chronic diseases had been increasing in the United States (Colvez and Blanchet, 1981; Verbrugge, 1984). However, the situation radically changed in the following years (Freedman and Martin, 1998; Manton et al., 1997), allowing the author of the theory to release updates that document the persistence up to the most recent years of various signals - such as declining disability rates at older ages - that a compression of morbidity is actually being achieved in the US (Fries, 1989, 2000, 2003; Fries et al., 2011).

At the opposite extreme, the theory of expansion of morbidity postulates that the extra years of life expectancy gained by individuals over time will unavoidably translate into longer durations of poor health in old age.

In a famous article entitled “The failures of success”, Gruenberg (1977) anticipated the core ideas of this theory: based on the experience of Western countries during the first half of the 20th century, he stated that progresses in medicine mainly result in a higher survival with chronic diseases and in a consequential increase in the prevalence of such diseases in the population. The main outcome of increasing longevity would thus be a dramatic deterioration of the health status of older people prompted by wide spreading severe chronic conditions - e.g. diabetes, atherosclerosis, hypertension and senile mental disorders.

The expression “expansion of morbidity” was coined much later by Olshansky and colleagues (1991), who directly argued Fries’ theory of compression of morbidity and formulated structured hypotheses on factors contributing to the deterioration of health in ageing societies. In particular, they assumed the existence of two mechanisms of expanding morbidity: not only improved survival with chronic diseases - as stated by Gruenberg fourteen years before - but also a shift from fatal to nonfatal conditions as causes of disability. Slightly afterwards they also illustrated the possible implications for health care systems (Cassel et al., 1992) and stressed that the need for health services, and especially for structured long-term care facilities, is destined to increase notably over time.

The third theory, called “dynamic equilibrium”, is a compromise between optimistic and pessimistic views about potential evolutions of the health status of the population along with increasing longevity. It posits that decreases in mortality in old age occur as a consequence of an ongoing delay in the progression of diseases that is gradually postponing the onset of severe disability to older ages (Manton, 1982). According to Manton, mortality and morbidity are in fact strictly interrelated and one cannot change without modifying the other. Given this course of events, it can be expected that the amount of time spent in severely poor health conditions will remain constant over the years, while individuals will live in a state of moderate illness for longer periods of time. At the population level, the dynamic equilibrium implies that the levels of severe disability decrease over time despite an increase in the prevalence of chronic conditions.

2.2.2 Summary of empirical evidence

As stated by Robine and Michel (2004), the simultaneous occurrence of elements from different theories makes it particularly challenging to forecast health trends in ageing societies. Improving survival of the population with chronic diseases and high levels of frailty among the oldest-old are predictive of an expansion of morbidity. On the other hand, the ability to delay the progression of chronic diseases could keep stable the amount of time lived in poor health. Finally, improving health conditions among older people give room to believe that a compression of morbidity is actually possible.

As a result, despite many studies on health and mortality trends in the older population have been conducted over the years, evidence does not support one hypothesis among the others and researchers often disagree on what will happen in the future (Mor, 2005; Jagger, 2000).

In order to test the theories of health change described in the previous paragraph, indicators of healthy life expectancy (i.e. the average number of years expected to be lived in good health) are usually computed according to the method first proposed by Sullivan (1971). This allows to synthesise information on health and mortality in a single measure and thus to evaluate how the health conditions of a population are changing in relation to mortality. The majority of studies focus on life expectancy free of disability, but healthy life expectancies can be calculated based on any other measure of health.

Manton et al. (2006) observed an increase in the number of years spent without ADL or IADL disability in the United States between 1982 and 1999. Conversely, they noticed a decrease in the number of years spent with disability. As a consequence, the so-called health ratio - i.e. the ratio of the years without disability to the total life expectancy - rose from 72.8% to 78.5% at age 65 and from 33.9% to 46.9% at age 85. Thus, the life span free of disability substantially lengthened in less than 20 years in the United States. Such trends fully support the compression of morbidity hypothesis.

In later articles, however, Manton also emphasised the existence of elements that are indicative of a dynamic equilibrium. In particular, he built a stochastic model to describe changes in the intensity of disability over age by referring to two different cohorts of individuals: those aged 65-74 and 75-84 in 1982. The results of the application of this model showed that the younger cohort had significantly improved in terms of both disability dynamics and mortality due to disability in respect to the older cohort. This means that younger individuals were less severely disabled and died less because of their compromised functional status, while they were more likely to have moderate disabilities in respect to people in the older cohort (Manton, 2008; Manton et al., 2008).

Using the same definition of disability but different data, Cai and Lubitz (2007) also found elements supporting both hypotheses of compression of morbidity and dynamic equilibrium for the years 1992 to 2003. In particular, they observed an increase in life expectancy without disability and a parallel decline in life expectancy with disability that are consistent with a compression of disability. However, they also found that only the years of severe disability decreased substantially in the reference period while those of moderate disability remained stable, and such trends are predictive of a dynamic equilibrium. Similarly, Graham et al. (2004) found evidence of dynamic equilibrium in New Zealand, where moderate disability increased along with decreasing severe disability.

Crimmins and Sánchez (2010) argued that other definitions of poor health should be taken into account to evaluate trends in the health status of the population. Indeed, they demonstrated that data prove that an expansion of morbidity is actually occurring in the United States if disability is defined as the loss of mobility functioning or the prevalence of major chronic conditions (above all cancers, cardiovascular diseases and diabetes) is used as a measure of poor health in the population.

In the European Union, up-to-date information comes from the work done within the "Joint action on healthy life years" (JA:EHLEIS). This was recently founded with the aims of monitoring healthy life expectancies in Europe and ensuring the comparability of these indicators between member states (Robine et al., 2013). For each country of the Union and every year since 2005, life expectancy in good self-perceived health and without chronic diseases have been computed together with the so-called healthy life years (HLY). These are precisely the years expected to be lived without long-standing limitations in the activities of daily living as measured by the Global Activity Limitations Indicator (GALI) - a question commonly asked in the European Survey on Income and Living Conditions (EU-SILC).

Robine and Cambois (2013) summarised the results obtained for the years 2005 to 2010. Overall, substantial improvements emerge only as far as the perception of health is concerned: life expectancy in poor self-rated health has been substantially decreasing over the last years. On the other hand, the years spent with chronic diseases increased and those spent with activity limitations remained stable. The situation thus appears to be complex: one cannot conclude that morbidity is compressing nor expanding because each indicator describes a different picture.

Moreover, important disparities between countries emerge (Jagger et al., 2013) that further complicate the interpretation of results. Differences are observed in values of healthy life expectancy and in gender gaps, confirming a variability of health conditions across Europe that had already been found previously (Hank, 2011). In particular, in a study focusing on 13 states and the time interval between the years 1995 and 2001, a variety of situations emerged (Jagger et al., 2009). Only Austrian and Italian data showed a significant compression of disability. Trends in Denmark, Finland, Ireland and Portugal are compatible with the theory of dynamic equilibrium. Elsewhere, either results were not significant or the time lived with disability appeared to have expanded over time with different age and sex patterns.

Other independent studies have been also conducted over time to understand whether a compression or an expansion of morbidity is occurring in single European countries. These studies adopted various definitions of morbidity, often reaching different conclusions.

Doblhammer and Kytir (2001) found strong evidence that older Austrians have been experiencing an absolute compression of poor self-perceived health between 1978 and 1998. They indeed proved that life expectancy in good self-rated health increased during those years both in absolute terms and as a percentage of the total life expectancy.

An analysis of Spanish data revealed that life expectancy without severe disability increased substantially between 1986 and 1999, while the number of years to be lived with disability declined; trends were similar across age groups and for both men and women (Sagardui-Villamor et al., 2005). Disability was defined in this study as having impairments in vision, hearing, walking or as not being able to perform basic activities of daily living. All these types of disability show positive trends in Spain, except ADL disability that increased considerably among older women.

In France, it emerged that life expectancy without moderate disability - identified according to different definitions - have remained fairly stable while the average time spent without severe limitations has increased since the last decade of the 20th century (Cambois et al., 2008).

For what concerns Italy, a recent study analysing data from the national HIS for the time interval 1991-2005 (Egidi, 2014) found that the time lived by older persons both in a state of poor self-perceived health or with functional limitations has been compressing into shorter periods of time before death. In this case having functional limitations is defined as facing severe difficulties in at least one area of basic activities between sensory functions, mobility and ADLs. More specifically, an absolute compression of poor self-rated health seems to have occurred as the number of years in poor self-perceived health has been decreasing substantially over time. On the other hand, a relative compression is visible when considering functional health: the number of years spent with impairments in functional abilities has not changed among men and has even slightly increased among women. Albeit encouraging, the analysis of the Italian situation thus reveals an important gender gap in favour of men.

To sum up, diverging patterns of health change in old age emerge between countries (Lafortune et al., 2007) or even within the same country when using different definitions and measures of poor health. In general, there is increasing evidence that functional and self-perceived health are compressing before death among older people. This often happens in spite of an increased prevalence of major chronic conditions (Christensen et al., 2009). A possible explanation is that diseases are having less debilitating effects, thus delaying the loss of independence in usual activities of everyday life: there is indeed some indication that death is being postponed because people are reaching old age in better health in respect to past times (Vaupel, 2010). However, there is still no consensus on the future evolution of health in ageing populations.

2.3 Potential impacts of longevity on health care systems in an ageing population: the role of health change at older ages

Due to the combination of increasing life expectancy with decreasing levels of fertility, the proportion of older people in the population has been constantly rising since the second half of the last century. In more developed countries[1], the share of people aged 60 years and older has already reached 23% on average (United Nations, 2013) and is projected to grow further - especially as the cohorts of baby boomers are currently surpassing the threshold of old age - to reach 32% in 2050. In this context, whether morbidity will extend or not over a long period of time during old age is a matter of great concern. If an expansion of morbidity occurs - in fact - an increasingly high number of individuals will spend most of their old age in a state of poor health. More and more resources will be then required in order to satisfy their needs of assistance and health care costs will be probably unsustainable.

Assuming that health conditions at older ages do not change over time, some researchers claimed that the process of population ageing is the main responsible for the increase in health spending observed in different countries (OECD, 1988; Schneider and Guralnick, 1990). In their view, the growth of the older population implies an equal growth of the needs for health care and related costs. For this reason, developed countries should be prepared to face the enormous needs of an ageing population. This argument is supported by the fact that - as it has been demonstrated on several occasions (Cislaghi and Zocchetti, 2008) - health care expenditures are strongly correlated with age: they are very low during childhood and adolescence and increase afterwards, with accelerations around 50 and 60-65 years of age.

However, this pessimistic view does not take into account that health status at older ages can improve over time (Gabriele and Raitano, 2009). If the onset of diseases is delayed and the duration of morbidity either remain stable or decreases over time, the consequences of population ageing on health systems could be less dramatic than expected. In both these cases, in fact, increased longevity would result in a higher proportion of older people in good health who would not necessarily be a burden on health care systems (Rice and Fineman, 2004). Indeed, it has been demonstrated that better health results in a longer life but not in a higher amount of total cumulative health

[1] According to the definition used by the United States, in this case the group of more developed countries include all countries in Europe and northern America plus Japan, Australia and New Zealand.

expenditures over the lifetime (Lubitz et al., 2003), meaning that old age is not characterised by an increased need for health care services unless individuals are in poor health conditions.

This has been demonstrated in a study by Caley and Sidhu (2010), who built three models to estimate future health care costs in the United Kingdom under different scenarios. The first model assumes that an expansion of morbidity occurs at the same rate as life expectancy increases: future costs are obtained by applying current age-specific costs to the same age groups in the future. The second model estimates future costs by applying current age-specific costs to equivalent future age groups calculated under the assumption that health care costs will be delayed by a period of time equal to the annual increase in life expectancy. Finally, the third model accounts for the effect of a slight expansion of morbidity that has been observed in the U.K. based on national data for the years between 1986 and 2006. As in the second model, future costs are obtained by applying current age-specific costs to equivalent future age groups. The latter, however, are calculated by multiplying the annual increase in life expectancy by a factor that represents the increase in disability-free life expectancy as a percentage of the total increase in life expectancy. The application of each of the three models described above resulted in an increase of health care costs over the next years, but at a widely different rate. As expected, the first model led to the highest estimate of the future total annual costs and the second model to the lowest: 4,892,448 and 4,284,361 English sterlings respectively in 2031, with a difference of 12%.

Similarly, Westerhout and Pellikaan (2005) estimated and compared the impact of population ageing on the financial systems of the European countries under three different scenarios: “living longer”, “living in better health” and “living longer in better health”. This latter scenario, in particular, implies an equal increase in both the total life expectancy and in the number of years that one can expect to spend in a good health status. Effects were explored in terms of changes in health care expenditures - distinguishing between acute and long-term care - as a percentage of the Gross Domestic Product (GDP). What emerged is that the impact of longevity on financial systems will be limited if individuals are able to age in good health. Indeed, the study proves that the negative effects of longevity on expenditures for acute health care can be perfectly counterbalanced by parallel improvements in health status (+0.4 and -0.4 of GDP respectively in the “living longer” and “living longer in better health” scenarios). At the same time, it proves that the increase in spending for long-term care would be less marked if people live longer and healthier (+0.4 and +0.1 of GDP respectively in the "living longer" and "living longer in better health" scenarios).

It is clear that a compression of morbidity into the years immediately before death would be the best option for the future of health care systems. It is thus important to understand how health is reacting to the increase in life expectancy in order to estimate the actual magnitude of the consequences of population ageing. Since data on health trends still do not offer a clear picture of the evolution of health at older ages, interest has been rising among researchers in the patterns of health and illness at the end of life. These include not only purely epidemiological aspects, such as the impact of health-related factors on mortality or the trajectories of morbidity at the end of life, but also economic issues related to health care expenditures and service use in the last years of life. Studies on these topics report results that form the basis for this thesis.

2.4 Health and survival among older people

Many studies have been performed with the aim of assessing the risks of death associated with poor health among older people. These studies use a variety of indicators to describe the functional, objective and subjective health status of older individuals, and thus provide a wide knowledge about the different dimensions of health at the end of life.

By analysing the risks of dying according to health status, it is indeed possible to understand which aspects of poor health contribute the most to reducing survival at older ages and, on the contrary, which are the ones that have less significant effects on mortality. This information provides important insights into the predictors of death in old age and could also allow to identify those illnesses that are most likely to affect individuals for several years before death.

Among the different measures of poor health, disability - independently on the definition adopted - is commonly found to strongly predict death.

Scott et al. (1997) computed a measure of disability as the sum of scores quantifying the number and severity of limitations in a set of 10 activities of daily living (ADL) and instrumental activities of daily living (IADL). This measure was found to have a significant impact on 5-year mortality over 65 years of age in a sample of participants in the Functional Health Supplement of the 1986 American Health Interview Survey. In particular, an increase of 1 unit in the total score of disability resulted in a 6% increase in the risk of dying among both men and women. On the other hand, poor self-rated health was found to significantly affect mortality only up to the 3rd year of follow-up. For what concerns basic socio-demographic variables - included in regression models as control variables - results generally confirmed those of previous studies. In particular, age considerably increased the risk of dying, while marital status played an important role as a predictor of mortality only among men.

Using data on a sample of older individuals (aged 60 years and older) who lived in a southern area of the Piedmont region in Italy, Corrao et al. (1991) had similarly estimated a significant impact on 5-year mortality of another measure of disability. This was called "index of independence" and computed based on the answers to the OECD questionnaire on limitations in the areas of mobility, communication and self-care. Its effect on mortality was studied in three different groups of older people, defined according to the number of declared chronic conditions (no diseases, one chronic disease and 2 or more chronic diseases), and it was found to be significant in all considered groups and increasing with worsening health status.

On the other hand, chronic morbidity and multimorbidity do not seem to have a clear impact on mortality.

Based on data from the FINE study (an extension of the so-called "Seven Countries Study" performed to investigate the risk factors for cardiovascular diseases), the effects of chronic morbidity on 10-year mortality were assessed in three cohorts of Italian, Finnish and Dutch men aged 65-84 (Menotti et al., 2001). The following groups of chronic diseases were included in the analysis: coronary heart disease, heart failure, cerebrovascular accidents, intermittent claudication, chronic obstructive pulmonary disease, diabetes mellitus and cancer. All these conditions proved to have a more limited independent impact on mortality than that expected by the authors. In particular, the relative risks of dying of individuals who suffered from each of the considered diseases were often not significant in Italy and never surpassed a value of 2 in the other two countries during the whole period of follow-up. As a confirmation of these results, the presence of one chronic disease as well as multimorbidity strongly predicted death only in Finland and the Netherlands: in these countries, the relative risks of dying exceeded the values of 2 and even 3 respectively for individuals with 2 and 3 or more chronic diseases. Thus, this study show that results can differ considerably across countries.

Using data from the Australian Longitudinal Study of Aging, Caughey et al. (2010) showed that older people (aged 65 years and older) who suffered from 3 or more chronic diseases had an increased risk of dying compared to their healthier counterparts. However, the median survival time differed considerably according to combinations of diseases. In particular, the shortest survival times were observed among those individuals with mental health problems and cardiovascular diseases.

Other analyses have shown that the effect of multimorbidity on mortality is smaller when functional status is also taken into account.

Mor et al. (1994) used multinomial regression analysis to evaluate the effects of a set of socio-demographic and health-related variables on functional status after 6 years of follow-up in the 1984 cohort of older participants (aged 70 years and older) in the American Longitudinal Study of Aging. The following functional outcomes were included in regression models: IADL disabled, moderately ADL disabled, severely ADL disabled, institutionalised and dead. Independent variables included age and gender as well as the number of chronic illnesses, self-rated health and both IADL and ADL disability status in 1984. Results indicated that the number of chronic illnesses was associated with a 30% increase in the risk of death within 6 years of follow-up. However, a much higher increase in the risk of dying during the same interval of time was associated with disability. Relative risk ratios of death were indeed equal to 6.6 for individuals who had any kind of difficulties in performing at least one instrumental activity of daily living, and 8.6 and 30.0 respectively for those who had moderate and severe limitations in any activity of daily living.

In a study of a cohort of people aged 77 to 100 years who were living in the Kungsholmen district of Stockholm, for instance, Marengoni et al. (2009) found that multimorbidity does not have a direct impact on mortality but rather plays an important role in favouring the onset of functional limitations. The latter are those that actually reduce survival in old age. In this study, disability was measured by the index of ADL proposed by Katz et al. (1963) while multimorbidity was defined as the co-occurrence of 2 or more chronic conditions out of a list of 20 (among which diabetes, various heart diseases, major depression, dementia and neurological disorders).

Using similar measures of disability and multimorbidity, St John et al. (2014) found that the effect of multimorbidity on mortality was attenuated by disability in a cohort of people aged 65 years and older who were living in the Canadian state of Manitoba. Indeed, the impact of the presence of multiple chronic conditions on mortality lost its significance when an indicator of disability was included in regression models aimed at evaluating the ability of multimorbidity to predict death.

Results of studies about differential survival according to health status at the oldest ages confirm the findings described above.

Disability was indeed found to be more predictive of mortality than multimorbidity among people aged at least 80 years who were interviewed in the Aging and Longevity Study in the Sirente area, in southern Italy (Landi et al., 2010). When controlling for a variety of socio-demographic and health-related variables, individuals who had at least one limitation in ADL but lived with less than 2 chronic diseases had a risk of dying 2.4 times higher compared to those who were healthy (i.e. those who were neither disabled nor affected by multiple chronic diseases). On the other hand, individuals who suffered from 2 or more chronic diseases but did not have any limitation in ADL had a risk of dying 1.7 times higher compared to those who were healthy. Finally, individuals who both had limitations in ADL and suffered from 2 or more chronic diseases had a risk of dying 3.9 times higher in respect to healthy elders.

Similar results were obtained in a study on the determinants of mortality during 15 months of follow-up in a cohort of nonagenarians who were interviewed in the Danish 1905-cohort study (Nybo et al., 2003). This study demonstrated that severe disability, bad physical and cognitive performances and poor self-rated health are strong predictors of death among the oldest old, whereas the number of self-reported chronic conditions was not found to be significantly associated with mortality. Interestingly, marital status and education - two basic socio-demographic demographic characteristic that are known to be important determinants of death in the total older population - did not have a significant impact on mortality above 90 years of age among neither men nor women. The same holds true for two health-related behaviours, namely smoke and alcohol consumption.

Poor self-rated has proved on several occasions to be a strong independent predictor of mortality, even when the objective health status and other socio-demographic covariates are controlled for (Idler and Benyamini, 1997; Benyamini and Idler, 1999). Many are indeed the studies that prove this finding: the first were published during the 1980s, and this field of research has expanded considerably since then.

Mossey and Shapiro (1982) were among the first to investigate the issue. Based on data from the Manitoba Longitudinal Study of Aging and focusing on individuals aged at least 65 years, they demonstrated that the risk of death within 7 years was almost 3 times higher for individuals who perceived themselves in poor health compared to those who perceived themselves in excellent conditions. The authors pointed out that poor self-rated health had a similar association with both early and late mortality, i.e. that occurred respectively in the first 3 years and in the last 4 years of follow-up.

Afterwards, many other researchers in different countries found evidence of a strong association between self-rated health and mortality in old age using mainly longitudinal epidemiologic survey data. For instance, Jagger and Clarke (1988) showed that a poor and fair general health status significantly contributed to reduce survival within 5 years among residents of the English city of Leicester aged 75 years and older. Kaplan et al. (1988) demonstrated that individuals who perceived themselves as sick and very sick had an increased mortality risks compared to those who felt healthy in a cohort of individuals aged 65 years and older who were living in the city of Kiryat Ono in Israel. Idler et al. (1990) found that a poor general health status - compared to an excellent health status - was associated with a much higher risk of dying in 5 years in a group of people aged 65 years and older who were living in New Heaven in Connecticut: odds ratios were equal to 5.3 and 3.0 respectively among men and women. Similar values resulted from the analysis of mortality in the same interval of time among people of the same age who were living in the Iowa County in the American state of Iowa.

In the United States, an important impact of poor health on mortality among older people was also found based on nationally representative data from the American Longitudinal Study of Aging. Focusing on individuals above 70 years of age, Wolinsky and Johnson (1992) found that the risks of dying within 4 years were 70% higher and doubled respectively among men and women in poor health compared to those in excellent health. In the same cohort of individuals, Rakoswi et al. (1993) found an average increase of 80% in the risk of dying within 6 years for people in poor health relative to those in excellent health. Mor et al. (1994) also found that individuals in fair or poor health had a threefold risk of dying within 6 years compared to those in excellent health. These results were confirmed also in later studies based on the same data (Wolinksy et al., 1994; Lee, 2000).

From this brief overview, it appears that the finding of a significant association between poor perceived health and mortality holds true in studies with different lengths of follow-up that evaluate self-rated health through questions with different wordings. This was also confirmed more recently in a meta-analysis of results from numerous studies on this topic (DeSalvo et al., 2006), in which it is demonstrated that individuals in poor health status generally have a twofold risk of dying compared to those who perceive themselves in good health.

In some cases, however, self-rated health did not predict death in old age or significant differences in the association between perceived health and mortality emerged between different age and gender groups.

Idler and Angel (1990) analysed the impact of the general perceived health status on mortality over 12 years of follow-up separately for American men and women aged 45 to 74 years. They used data from the Epidemiologic Follow-up Study of the American Health and Nutrition Examination Survey, which consists of the mortality follow-up of a survey that collects epidemiologic information on a nationally representative sample of residents in the United States. Results are thus particularly interesting as they can be generalised to the total American population. What first emerged is that, as expected, mortality risks over the period of follow-up were higher for men compared to women. Furthermore, poor-self rated proved to be an efficient predictor of mortality only among men aged 45 to 64 years in adjusted regression models that accounted for the confounding effect on mortality of socio-demographic variables, health behaviours and diagnosed physical conditions. On the contrary, no significant effects were observed among men aged 65 to 74 years and women of all ages.

Using different definitions of self-rated health and data from the Longitudinal Aging Study Amsterdam on individuals aged 55 to 85 years, Deeg et al. (2003) also demonstrated that a poor health status was a better predictor of death among men rather than among women. In particular, they found a strong significant association among men between the mortality observed during 3 and 7.5 years of follow-up and a bad current perceived health status[2] at baseline as measured by an item of the RAND General Health Perceptions Questionnaire (Brook et al., 1979). The same association was never statistically significant among women. In this case, moreover, the general perceived

[2] The item selected from the RAND questionnaire to describe the current perceived health status is called "current health" and has the following possible answers: 1. I am somewhat ill; 2. I am as healthy as anybody I know; 3. My health is excellent; 4. I have been feeling bad lately.

health status measured by the question "How is your health in general?" was not found to be a predictor of death among neither men nor women. As in the study by Idler and Angel (1990), these results were produced by the application of fully adjusted regression models that account for a number of socio-demographic and health-related variables.

Others studies proved the existence of a significant association between self-rated health and mortality only among women. McCallum et al. (1994) made this finding based on data from the Canadian Aging and the Family Project Survey that was carried out on a sample of individuals aged at least 60 years. Participants in this survey were interviewed in 1981 and followed up for death until 1989. Among women, the increase in the risk of dying for people in good, fair and poor health relative to those in excellent health rose significantly with worsening health status. On the other hand, only those men who rated their health as poor had a significantly higher risk of death comparing to those who declared to be in an excellent general health status. These were the results of the application of two separate regression models in which only a set of socio-demographic characteristics were included as control variables. Poor self-rated health lost its ability to predict death among both men and women when other covariates were included in the models to account for the effects of major illnesses, disability, depression and social support on mortality. Among women, however, the impact of good and fair rated health on survival remained significant. Similar gender differences in the association between self-rated health and mortality were also found by Lyyra et al. (2009) based on data on older residents in a city in central Finland.

2.5 Studies of the last years of life

A completely different approach is used in studies that analyse health-related factors during the last years of life by starting from death and looking backward in time. Until now, these studies have mainly focused on economic issues, such as health care costs. Researchers in the field of health economics were indeed the first to react critically to the view of population ageing as a driver of considerable increases in health care expenditures by raising the point that proximity to death rather than age could be the main determinant of health care expenditures. In this way, they drew attention to the last years of life of older people: a wide literature currently exists on the costs of care as well as on the utilisation of health care services at the end of life. Relatively few studies have analysed the health status of older individuals according to proximity to death, but this field of research has been expanding rapidly in the most recent years.

2.5.1 Health care expenditures and the "red herring hypothesis"

In general, two different types of studies on health care expenditures (HCE) in the last years of life can be found in the available literature (Payne et al., 2007): studies that make use of analytical models to investigate the relationship between HCE, age and time remaining before death, and studies on the costs of dying that quantify the HCE devoted to decedents and/or compare them to those devoted to same-age survivors.

Studies of the first type are mainly aimed at understanding whether the role of age or proximity to death is more important in determining levels of HCE and provide evidence to support or argue the so-called "red herring hypothesis", i.e. the claim that HCE are determined by the time remaining before death (i.e. proximity to death) rather than by the time elapsed since birth (i.e. chronological age). This argument was developed by Zweifel et al. (1999). In particular, these researchers first put into evidence the fact that the apparent increase in HCE over age did actually reflect an increase in mortality rates among older people due to a postponement of the average age at death resulting from rising life expectancy. Then - by applying regression models to longitudinal data on Swiss aged 65 years who were in their last two years of life - they found that age did not have any significant effect on HCE at the individual level when proximity to death was controlled for. They thus concluded that the increase in HCE observed over time was due to an increase in the number of individuals who were close to death rather than to an increase in the number of individuals at older ages. Deaths are indeed most frequent in old age and - as a consequence - the effects on HCE of a higher prevalence of individuals in the last years of life might be wrongly interpreted as the effects of population ageing. The latter might thus be a sort of "red herring" that diverts attentions from the real causes of the increase in HCE.

Some researchers criticised the methodological aspects of the study performed by Zweifel and his colleagues, proposing possible solutions (Salas and Raftery, 2001; Dow and Norton, 2002). Afterwards, the strong impact of closeness to death on HCE has been confirmed by different authors who tried to overcome this issue in their studies.

In a preliminary descriptive analysis, Seshamani and Gray (2002) analysed detailed individual-level data on National Health Service, Hospital and Community Health Service and Family Health Service expenditures for the periods 1985-87 and 1996-99 among people aged 65 years and over who were living in England and Wales. They found that the ratio of the per capita expenditures for older versus younger people had declined in all different sectors of health care, meaning that HCE for older people had increased at a slower rate. Moreover, they found that the increase in the number of individuals aged 65 years and older in the population had contributed only slightly to the increase in HCE.

For these reasons, they decided to further deepen the issue and published - two years later - two studies in which they directly addressed the question whether age or proximity to death has the stronger impact on health care expenditures in England and Wales. In the first, they revisited the analysis performed earlier by Zweifel et al. (1999) by applying a different regression model to longitudinal data gathered in a hospital in Oxfordshire, and found that both age and proximity to death affected quarterly hospital costs. However, they also noticed that the increases in quarterly costs by age were negligible compared to those that occurred with approaching death over the last year of life (Seshamani and Gray, 2004a). Similar results were obtained in the second study, in which the authors performed an analysis on the complete longitudinal hospital data set - comprising information collected during 29 years of follow-up and thus not only focusing on data on the last year of life as in the previous analysis (Seshamani and Gray, 2004b). In particular, it emerged a tenfold increase in HCE from 5 years prior to death to the last year of life and only a 30% increase from 65 to 85 years of age. These results clearly support the red herring hypothesis.

Only one year later, Werblow et al. (2007) responded to the critics by performing on Swiss data a new analysis that used more appropriate regression models and included decedents as well as survivors. A conceptual criticism was indeed that the results of their previous study could be distorted by the exclusion of survivors from the analysis, given that age could have a differential impact on HCE among decedents in respect to individuals who were expected to live longer. They found that the effect of age - albeit significant - was limited among both decedents and survivors. On the contrary, proximity to death appeared to have a strong positive impact, meaning that HCE increased considerably when people were approaching death. Moreover, they analysed for the first time the impact of closeness to death on HCE in different sectors of health care, finding that most components of HCE have a much stronger association with proximity to age rather than with age.

Studies on the costs of dying give insights on the share of health spending that is attributable to end-of-life care and generally follow a more descriptive approach.

For the United States, Hoover et al. (2002) quantified the annual total HCE for older decedents and survivors respectively in 62,989 and 219,082 millions of American dollars between 1992 and 1996. It thus emerged that the costs of the health care services provided to decedents accounted for 22% of total annual HCE. Most notably, they found that the average annual per capita expenditures were 5 times higher for older people in their last year of life in respect to those who were more distant from death. Moreover, the mean annual Medicare[3] costs for end-of-life care did not vary by age at death while a statistically significant increase with age was observed for Non-Medicare expenditures. Similarly, Hogan et al. (2001) had found that the annual per capita Medicare expenditures for older decedents were 6 times higher than those for survivors of the same ages.

Much higher costs for decedents rather than for survivors were also found in other studies, from which it emerges - however - that the difference between decedents and survivors always reduces as age increases. Based on Medicare data for selected years between 1978 and 2006, for instance, Riley and Lubitz (2010) found that HCE were generally 6 times higher for decedents (defined as being in their last year of life) than for survivors (defined as being more than one year far from death). This result confirmed that emerging from one of their previous works (Lubitz and Riley, 1993), that classified HCE according to the calendar age of Medicare beneficiaries and thus allowed to deduce that the ratio of HCE ratio of decedents to survivors was highest between 65 and 69 years of age and lowest after 85 years of age - respectively equal to 10.6 and 4.1.

The results of a descriptive analysis performed by Yang et al. (2003) on Medicare data for the years between 1992 and 1998 indicate that the levels and patterns of increase by age of HCE differ considerably between decedents and survivors. The authors indeed found that health expenditures were always significantly higher after 65 years of age among individuals who were living their last year of life in respect to those who had still more than 1 year to live. However, this gap reduced over time as HCE showed a slightly increasing trend among survivors while remaining fairly stable among decedents. Another

[3] Medicare is an American social insurance program administered by the federal government of the United States.

finding was that monthly HCE started to increase approximately 2 years before death, with an important acceleration in the last 6 months of life. The observed pattern of increase by time to death was similar across different age groups (65-74, 75-84, 85 years and older). These results underline the importance of proximity as a determinant of HCE to a point that authors concluded that it is actually the main factor driving the increase in health care costs among older people.

Based on these results, some studies included the time remaining till death as a covariate in models built to forecast health care expenditures in the next years. Stearns and Norton (2004), for instance, predicted future HCE in America for the year 2020 based on observed Medicare data for the period between 1992 and 1998. They found that neglecting the effect of proximity to death led to an overestimation of HCE that is equal to 9% and 15% respectively in the case that current and projected life tables for 2020 are used in the analysis. Following a similar approach, Breyer and Felder (2006) predicted HCE in Germany up to the year 2050 and found that accounting for the differences between decedents and survivors caused a reduction of about 20% in the predicted HCE. Similarly, Steinmann et al. (2007) calculated that taking into account the impact of proximity to death significantly reduced the levels of expected HCE for the years between the years 2000 and 2030 in Switzerland. It is important to specify that all these studies agree that the positive effect of population ageing on HCE is still evident even when including a measure of closeness to death in forecasting models. However, in this case it appears to be strongly reduced: thus, the expectations about the catastrophic consequences of an increasingly large proportion of older individuals in the population should be reshaped.

2.5.2 Health care service use

Some studies focused on the role of proximity to death in determining health care service utilisation among older people and showed that people in the last years of life generally consume health care services much more frequently in respect to survivors. For instance, Wolinksy et al. (1994b) found that decedents used substantially more hospital services in comparison to survivors. Considering different types of health care resources, Experton et al. (1996) found that older decedents were much more likely to use all of them compared to same-age survivors. In particular, relative risks were equal to 7 for any hospital admission, 3 for emergency rooms visits, 8 for physician visits, 4 for nursing home facilities and 2 for home care services.

Larsson et al. (2008) analysed longitudinal data from the Kungsholmen project and found that the effect of proximity to death on health care utilisation in the Swedish oldest population (including individuals aged 83 years and older) varied according to the type of care. In particular, the proportion of people receiving home help services remained stable over the last 5 years of life and even decreased in the period closest to death - i.e. over the last 24 months. On the contrary, the proportion of people using institutional care services increased steadily over the last years of life, passing from approximately 10% to 50% from 5 years prior to death to the last 3 months of life. Finally, the proportion of people using hospital inpatient care remained stable at a low level (between 10% and 15%) until the beginning of the last year before death, and then showed a steep increase over the last 9 months of life. Logistic regression analysis confirmed that proximity to death had a strong impact on the use of hospital and institutional care, but not on the receipt of home help services. In particular, a 10% increase in the probability to use institutional care was associated to a 1 year increase in proximity to death, while a 75% increase in the probability to use hospital care services was associated with being in the last 9 months of life. In both cases, the effect of closeness to death was more important than that of age, whose effect was even not significant for hospital care use.

In a case-control analysis of Finnish register data on individuals aged 70 years and older who died between 1998 and 2000, Forma et al. (2009) found that decedents - i.e. people in the last 2 years of life - used both hospital inpatient care and long-term care services much more frequently in comparison to survivors of the same gender and age group. This was true for men and women aged 70-79, 80-89 and 90 years and older, but differences were wider in the younger age group and reduced with increasing age. On the other hand, the use of home care services was significantly different between decedents and survivors only among men aged 70-79 or 80-89 years and among women aged 70-79 or 90 years and older. In the latter age group, however, female survivors were those who received home care more frequently in respect to decedents. Moreover, the study demonstrated that the vital status at the end of study had an impact on the use of health care services. In particular, hospital service use did show an increasing pattern with age only among survivors, while it decreased among older decedents. Conversely, the use of long-term care was always increasing, but the increase was more pronounced among decedents. For what concerns the extent of service use, decedents were hospitalised more often and for longer times than their matching counterparts, whereas survivors had longer stays in long-term care as compared to decedents. Finally, while levels of acute and long-term care use were similar between survivors and decedents at the beginning of the study period, they increased considerably among decedents and remained fairly stable or increased only slightly among survivors. This result confirmed that of a previous study in which the analysis of health care service use in the last years of life included only decedents (Forma et al., 2007). More recently, moreover, Forma et al. (2011) found significant differences in the use of health care services during the last two years of life between people with and without dementia. In particular, those individuals who suffered from dementia were more likely to use long-term care rather than hospital services prior to death.

Asada et al. (2012) also found that proximity to death was a significant predictor of the use of general practitioner services, specialist services and hospital care in the Canadian older population. The effect of proximity to death remained significant in models controlling for age, health status and behaviours, socioeconomic condition and geographical area of residence, and was always equal or higher than the effects of other covariates.

From all these studies, it can be concluded that it is important to consider proximity to death in studies of the determinants of health care use in the older population in order to have a correct idea of the effect of ageing on the health care - and financial - systems of the most developed countries. While there is increasing consensus on the differences between decedents and survivors in terms of acute care utilisation, however, the impact of proximity to death on long-term care arouses particular concern among researchers.

Murphy and Martikainen (2013) performed an analysis of the same register data used by Forma et al. (2009) for the period 1998-2003 and stressed two different points: one is that observed differences between decedents and survivors were much wider in terms of the number of days spent in hospital rather than in long-term care facilities, the other is that the use of long-term care show a steeper increase with age among decedents in respect to the use of hospital acute care. For this reasons they stated that while proximity to death is more important than age as a predictor of acute health care use, it has a much weaker impact on the consumption of long-term care services. Thus, they concluded that the view that population ageing will have a less substantial impact than expected on the needs of health care services is too optimistic, and that the effect of proximity to death will simply shift the balance from acute to long-term care and not necessarily involve a reduction in the extent to which health care services are used by older people.

Weaver et al. (2009) also concluded that population ageing alone can cause to some extent an increase in health care expenditures, as their analysis of Swiss data on people aged 65 years and older showed that age remained a significant predictor of health care consumption even after controlling for proximity to death. However, they also found that the marginal effects of proximity to death on the use of long-term care services among decedents in the last two years of life as compared to survivors was higher than the additional effect of age. According to their study, it would take at least 10 years for age to have the same effect as entering the last two years of life. The effect of population ageing could be thus be more limited than expected.

2.5.3 Health status

Most studies on health status during the last years of life focused exclusively on decedents to quantify the proportion of individuals in good or poor health before death and to identify the basic characteristics that are associated to health status. These studies provide a general insight on the prevalence of poor health among older people before death. For instance, Lentzner et al. (1992) analysed the functional status of older individuals deceased in 1986 for whom the National Mortality Followback Survey collected information on health status during their last year of life as well as on basic socio-demographic characteristics. They estimated a similar proportion of individuals who were either fully functional or severely restricted in ADL - respectively 12% and 10% - in the year prior to death. However, higher proportions were found in the oldest age group (85 years and older) and among women. When including the cause of death in the analysis, it emerged that those individuals who died from acute myocardial infarction were most often fully functional, whereas those who died from cancer had the lowest chance to be free of disability before death. Multivariate logistic regression models applied to data in order to understand which characteristics are associated with being fully functional or severely limited in ADLs in the year before death proved that women, people living outside marriage and those who had a pre-existing chronic conditions were less likely to experience healthy ageing and thus to reach the last year of life in good conditions.

Based on the same data, Liao et al. (2000) then examined changes in health status before death from 1986 to 1993 among individuals aged 65-84 and 85 years and older. They found that the proportion of individuals with limitations in ADL decreased significantly after 85 years of age, especially among women. As an example, the share of people with limitations in 2 or more ADLs passed from 82.2% to 70.7% and from 69.8% to 60.1% respectively among women and men. Rates of cognitive impairments also declined in the oldest age group, but differences between the two years were not statistically significant among older men. Finally, a decrease was also observed in an overall sickness score calculated as a summary measure of the use of health care services, disability and cognitive impairments in both the considered age groups. The authors concluded that a decreasing prevalence of poor health prior to death could result in a future reduction of the total health care expenditures.

Health conditions in the last years of life of older people living in a set of European countries were investigated by Jürges and Hank (2009) based on data from the Survey on Health, Ageing and Retirement in Europe (SHARE). In particular, they estimated the prevalence of ADL disability close to death in three different age groups (50-74, 75-84 and 85 years and older) and found that nearly 50% of people in the youngest age group was fully functional, while only 17% had at least one severe limitation in ADL. A higher proportion of people experienced severe disability in the older age groups (26% and 32% respectively at 75-84 and 85 years and over), while the share of people who were fully functional during the year before death decreased with increasing age (37% and 28% respectively at 75-84 and 85 years and over). People with a low educational level and women were generally more frequently disabled, as well as residents in Southern European countries. However, a logistic analysis performed on SHARE data proved that geographical differences were not significant (Hank and Jürges, 2010).

A study by Zhao et al. (2010) calculated different indicators of health status in the last year of life in a cohort of oldest old people aged 85 years and older who were living in the city of Cambridge. It emerged that the prevalence of functional limitations rose from 59% between 85 and 89 years of age to more than 85% at 90 years of age and over. At the same time, the prevalence of cognitive impairment - defined by a low Mini-Mental State Examination score - rose from 41.7% to 69.4% from one age group to the other. Despite the high levels of disability and the fact of being close to death, 67% of people aged 90 years and older rated their health as very good, good or fair, a percentage only slightly different from the 60.5% calculated among people aged 85 to 89 years.

As far as the impact of proximity to death on health status is concerned, until now most studies have focused on changes in the cognitive performance over the last years of life. These studies have proved that decedents generally have both lower performances and faster declines in cognitive abilities as compared to their surviving counterparts. Following the terminology used by Riegel and Riegel (1972) in their groundbreaking study on this topic, such phenomenon is widely known as the “terminal decline” or “terminal drop”. The two authors, in particular, used this expression to define the drop in cognitive performances that they had observed within the last 5 years in a cohort of older people living in the North of Germany during the ‘50s. As the drop in cognitive functions observed among decedents was not reflected by significant cognitive declines among same-age survivors over the period of follow-up, Riegel and Riegel (1972) concluded that the decline over age observed in the population based on cross-sectional data was due to the increase in the number of individuals exhibiting a drop before death and is thus not due to the individual ageing process. Similar results were obtained also in other studies that proved that proximity to death is strongly associated with cognitive decline as it explains a high proportion of the variance of intellectual performance in old age (Bosworth et al., 1999). Moreover, it was shown that the terminal drop is independent of the causes of death (Small et al., 2003) and is evident at all ages (Small and Bäckman, 1999).

Relatively few studies analysed the impact of proximity to death on other indicators of health status. The first was carried out by Guralnick et al. (1991) based on longitudinal data that provided information - at baseline interview and annual follow-ups - on the health conditions of older people who were living in East Boston, New Haven and in the Iowa and Washington Counties. Measures of health status included the average number of self-reported chronic diseases and the prevalence of ADL disability. Both were evaluated at baseline and at two subsequent follow-ups, separately for decedents (i.e. those individuals who died between the second and the third follow-up) and survivors (i.e. those individuals who survived to the third follow-up) in three different age groups: 65-74, 75-84 and 85 years and older. From the descriptive results chronic illnesses emerged to be much more frequent among decedents rather than among survivors, and the number of diseases to have a steep increase among decedents when approaching death. An increase in the average number of chronic diseases over the period of follow-up was also observed among survivors, but it was considerably smaller as compared to that observed among decedents. In line with the findings related to health care costs and service use, however, the gap between decedents and survivors reduced in the oldest age group. The same results were obtained when focusing on the prevalence of ADL disability but - differently from the case of chronic conditions, whose number did not always increase with age - significantly higher proportions of individuals had limitations in ADL in the older age groups. Multivariate logistic regression then showed that decedents were 3 to 4 times more likely to report ADL disability than survivors of the same gender and age in the three considered areas. No clear trend with age emerged, but odds ratio were generally higher among women.

Based on descriptive and regression analyses of data from the Dutch GLOBE longitudinal study on inequalities in health linked to mortality records, Klijis et al. (2010) estimated the impact of proximity to death on the prevalence and severity of ADL disability among individuals who were living in the Netherlands. Three different age groups were considered: less than 60, 60-69 and 70 years and older. Proximity to death was calculated as the difference between the dates of interview and death and thus measured the number of years remaining before death at the moment of interview, ranging from 0 to 12. From a preliminary descriptive analysis, it emerged that the prevalence of ADL disability in the total population rose from 12% to 38% from 12 years before death to the last years of life. Both incidence and severity, moreover, increased with approaching death. Proximity to death was then included as a covariate in regression models built to identify determinants of functional status and the results of these models were compared to those obtained including only age in the analysis. Both age and proximity to death were included as numerical variable. First of all, models with proximity to death had a better goodness of fit compared to those that did not include a measure of distance from death. Moreover, closeness to death proved to be more strongly related to poor health than age: in the general older population, indeed, odds ratios of disability were equal to 7.1 for age and 20.0 for proximity to death. Finally, the authors showed that the impact of proximity to death on health status was highest in the oldest age group and among men. Disability thus tended to concentrate substantially in the years before death, especially at older ages. This allowed the authors to conclude that further increases of life expectancy at higher ages could merely result in a shift of disability towards older ages and not in longer periods spent in a state of severe functional impairments during old age. For this reason, in a later publication they stated that accounting for a dynamic equilibrium in forecasts of health conditions at older ages will result in better estimates of the future prevalence of poor health in the population (Klijis et al. 2011).

More recently, Stenholm et al. (2014) compared self-rated health status of survivors and decedents - defined as individuals in the last year before death - in the United States based on a nested case-control analyses of data from the American Health and Retirement Study. Among all individuals who died between 1998 and 2010, those aged 30 years and older were included in the analyses. In order to identify differences between the adult and older population, however, health status was investigated in three different age groups: 30-64, 65-84 and 85 years and older. Moreover, the study focused on individuals for whom at least two rating of health were available: one 11 to 12 years before death, the other in the last two years of life. Surviving matches were identified based on age, sex and race. It resulted that the prevalence of poor health was much higher among decedents in comparison to survivors, and that - especially for men - the difference according to vital status was wider in the two years closest to death. This means that the increase in the prevalence of poor health was steeper among decedents rather than among survivors. Indeed, relative risks of the first to the second were equal to 2 and 1.5 respectively among male and females decedents, and to approximately 1.4 among both male and female survivors. In particular, the proportion of men in poor self-rated health rose from slightly less than 30% to almost 60%, while the corresponding proportion of women rose from about 40% to 60% from 11-12 to 1-2 years before death. A similar pattern of increase was observed in all considered age groups.

The results of the studies mentioned above prove that the analysis of health at the end of life in the older population deserves further attention because of the implications that a concentration of poor health in the last years before death could have on the organisation of society. In Italy, the knowledge in this field is limited by the absence of data that allows to have information on both health and mortality for the same individuals. Until now, the only data sets available referred to restricted groups of people (in general, those living in a specific area of the country or having a specific diseases or condition). The New Italian Longitudinal Study - i.e. the data source used for the aims of this thesis, described in details in Chapter 3 - offers the possibility to focus on health in the last years of life for the first time at the national level.

3. Data and study design

3.1 The new Italian Longitudinal Study: an overview

The "New Italian Longitudinal Study" (NILS) is a system of data collection and analysis that is being developed in order to monitor socioeconomic differentials in mortality and hospitalisation in the Italian population (Marinacci et al., 2013). It foresees the creation of longitudinal data from cross-sectional health surveys through record linkage with the national causes of death and hospital discharge registers. No other data combining information on health status, health service use and mortality are indeed available at the population level.

The pilot project of the NILS, named "Mortality and hospitalization differences according to lifestyles, health conditions and health service use in the 1999-2000 sample of the ISTAT Health Interview Survey", started in 2006 thanks to the cooperation of four different institutions. The autonomous region of Valle d'Aosta was entrusted with the project management; the Epidemiology Unit of the Local Health Unit TO3 (LHU-TO3) in the Piedmont region was in charge of the project execution; ISTAT was responsible for health and mortality data and the Italian Ministry of Health for hospitalization data. All the above-mentioned institution signed a formal agreement that allowed them to exchange and treat the sensitive data required to perform the record linkage between different archives. Their work resulted in the successful completion of the death and hospitalisation follow-up of the nationally representative sample of participants in the 1999-2000 Italian HIS, and thus in the availability of what can be called the "1999-2000 HIS linked mortality and hospitalisation data file". The latter is a data set that reports, for each individual in the HIS sample, all socio-demographic and health-related information collected through the survey together with information on death and hospitalizations - if occurred - up to the end of 2007.

After this positive experience, the linkage of health survey data to death and hospital records has become a permanent part of the Italian National Statistical Program. The same institutions involved in the first project have recently signed a new agreement and are currently working to release an updated version of the 1999-2000 HIS linked data file (i.e. including deaths and hospitalisations occurred up to 2012) and to create the 2004-2005 HIS linked data file. At the present moment, however, only the 1999-2000 HIS linked data file including deaths and hospitalisations data up to 2007 remains available for analysis. This data set allows to know the health status of individuals according to the number of years remaining till death and is therefore suitable for the aims of this thesis. A description of the three data sources and the record linkage procedure used for its construction is given in the following paragraphs.

3.1.1 Data sources

As anticipated, the variables included in the linked data file derive from three different data sources: the National Health Interview Survey, the National Hospital Discharge Register and the National Causes of Death Register.

The Italian National Health Interview Survey is called "Health conditions and use of health services". It has been carried out by ISTAT approximately every five years since 1994 and it is part of an integrated system of statistical surveys - the "Multipurpose Surveys System"[4] - that is the main source of information about the demographic, economic and social aspects of life in Italy.

The HIS collects data on a sample comprising about 50,000 households, for a total of more than 100,000 individuals who reside in the national territory. The sample selection follows a two-stage design stratified at the first stage, in which municipalities of residence and families are respectively the first and second stage units. In particular, municipalities are classified into two categories based on the number of residents. Bigger municipalities are called "auto-representative" and are always included in the sample. All the others, called "non auto-representative", are grouped into strata. A fixed number of municipalities are then selected from each stratum with a probability that is proportional to their demographic size. Afterwards, households are systematically sampled from each selected municipality. Thanks to its structure, the HIS sample is representative of the Italian population at the national, regional and sub-regional levels.

Data are gathered through face-to-face interviews - conducted by trained interviewers - that are evenly distributed over the first month of each trimester of the reference year:

[4] The "Multipurpose Surveys System" consists of 7 different surveys: "Aspects of daily life" (annual), "Trips and Holidays" (quarterly), "Health conditions and use of health services", "Citizens and Leisure Time", "Safety of Citizens", "Families and Social Subjects" and "Time use" (carried out every five years).

September, December, March and June. Only a part of the questionnaire, due to the sensitive nature of the questions asked, is self-administered.

Surveyed topics include health status, lifestyles (with a particular attention for health-related behaviours) and the use of health services and drugs (ISTAT, 2007a). More specifically, individuals are asked to indicate whether they have chronic conditions, long-standing functional limitations or impairments and to describe their general health status using one out of five categories from very poor to very good. Other questions from the 12-item Short Form Health Survey (Ware et al., 1996) are also included in the questionnaire. Lifestyles include smoking habits, diet, and physical activities. Health service utilisation is investigated through questions on recent medical examinations and tests. In addition, the HIS collects basic socio-demographic and economic data, such as the educational level or the household income.

The National Hospital Discharge Register is managed by the Italian Ministry of Health and contains information on all hospitalizations - in both private and public facilities - that have occurred in Italy since the second half of the ‘90s.

Data are collected through the Hospital Discharge Form (HDF). This form has to be filled in for each patient who is being discharged from a hospital by the physician in charge of his/her care during the stay. Hospitals are required to send at least every three months the information contained in the HDFs to the offices of the region - or the autonomous province - in which they are located. The regions carry out checks for completeness and accuracy and then send the data to the Ministry of Health, which publishes annual reports about the use of hospital services in Italy.

The national archive of HDFs is a very important data source that can be used for different purposes: not only to evaluate the quality of care, quantify the economic impact of hospital care and thus support health care planning, but also to study the epidemiological profile of hospitalized patients. The HDF indeed contain both clinical and organizational information on the hospital stays: on the one hand, symptoms and diagnoses, surgeries, diagnostic and therapeutic procedures, prostheses or implants insertions; on the other hand, operating units of admission and discharge, transfers, and related costs. Diagnosed diseases are coded according to updated versions of the 9th revision of the International Classification of Diseases (ICD). Obviously, basic demographic characteristics are also reported in the archive, while data on drug administration are not included (Ministero della Salute, 2013).

The National Causes of Death Register has been managed by ISTAT since 1929 and contains information on all deaths that occur in Italy, whatever the habitual residence of the deceased. This means that deaths of residents that occur abroad are excluded from the register, while deaths of foreigners that occur in the national territory are included.

Data are collected through the death certificate, which has to be filled for each person who dies with data on both the death and the deceased. In particular, this document - according to the international form recommended by the WHO - consists of two parts. In part A, the certifying physician reports some basic personal information about the deceased - i.e. name, surname, age, place of death - together with a detailed description of the dying process. He is indeed required to list in the form every disease - or trauma - and condition that contributed to death. The *underlying cause* of death is defined by WHO as “the disease or injury that initiated the events resulting in death”; the *immediate cause* is “the final disease or condition resulting in death”; the *intermediate causes* represent any fatal complication of the underlying cause and the contributory causes are all other diseases or conditions that are considered by the physician to have significantly contributed to death. In part B, the civil registry officer reports the most important socio-demographic data of the deceased: dates of birth and death, place of birth, habitual residence, marital status, educational level, working position and citizenship. Death certificates currently exist in two different versions according to the age of the deceased: younger or older than 1 year. In the former case, part B has to be filled in with personal and demographic data of parents.

Once both parts have been completed, one copy of the death certificate is sent to the regional offices. These carry out the first checks and then send the data to ISTAT, where - after the data entry has been performed by an external company - causes of death undergo an automated coding process. The latter aims at identifying the underlying cause and translating the alphabetical diagnoses into standard codes based on the International Classification of Disease (ICD). The 10^{th} revision of ICD has been adopted since 2003 in substitution of the 9^{th} revision, used until that year. The automation of the coding process, initiated in 1995, has led to a notable improvement of data quality by removing any possibility of personal interpretations that are typical of manual coding procedures (ISTAT, 2013).

3.1.2 The record linkage procedure

Since no documentation is currently available, a brief description of the linkage procedure used by the institutions involved in the project is reported below.

It has been decided to perform a deterministic record linkage and to use as linkage key the personal fiscal code - called "Codice Fiscale" in Italian. This is a unique identity code that is assigned to every Italian citizen at the moment of birth and to foreigners when they obtain a residency permit. Given how it is calculated, the fiscal code allows to unequivocally identify the same person across different data sources. It is in fact composed of a sequence of a total of 16 characters and numbers derived from some fundamental personal data: name, surname, gender, date and place of birth. If two people born on the same day and in the same place have similar names and surnames, a modified fiscal code is calculated for one of them by substituting some characters with numbers according to specific rules established by the Italian Revenue Agency.

As a first step, it was thus necessary to retrieve the fiscal codes - or the personal information needed to calculate them - of the individuals in the data sets. Neither the fiscal codes nor the personal data of participants in the 1999/2000 HIS were available in digital format. Names and surnames were retrieved from the certificates of family status[5] of participants, which had been provided in paper form to ISTAT before the beginning of the survey by local administrative offices. The Epidemiology Unit of the LHU-TO3 recorded the certificates in electronic format[6] while carrying out quality checks and correcting errors in order to ensure the lowest possible error rate in data entry. It then proceeded to the calculation of fiscal codes. Afterwards, ISTAT linked the fiscal codes to the health interview survey data file through a unique key made of different variables that could be found in both the HIS data file and in the archive of certificates of family status. In this way, a fiscal code was univocally assigned to each record. This phase was named "intermediate linkage".

It was possible to link a total of 128,818 out of 140,011 participants in the 1999/2000 Italian HIS with a complete fiscal code. This number corresponds to the 92% of the total sample. Quality checks were carried out by ISTAT with the aim of comparing the most

[5] The certificate of family status is an administrative document that contains personal information about all members of a household that resides in a municipality.
[6] A digital archive containing all personal data of participants in the Italian National Health Interview Survey - including the fiscal codes - is available starting from the 2004/2005 edition of the survey. In the future, the fiscal code will be thus calculated only if it is missing or invalid. In such cases, moreover, it will be much easier to retrieve the necessary information.

important socio-demographic and health-related characteristics of the linked individuals and the total sample (results of these checks for some measures of health status are reported in Appendix A). The two groups appear to be very similar between each other, and the negative effects of the exclusion of 11,193 individuals from the data set are thus limited.

Finally, the HIS data set was linked to the mortality and hospitalisation files in two separate steps by the Epidemiology Unit of the LHU-TO3 and the Ministry of Health respectively. Due to severe confidentiality obligations, indeed, the latter institution was not able to share with the others any of the personal data that were essential for identifying individuals in the data set of information derived from Hospital Discharge Forms. For this reasons, it decided to manage independently the record linkage with this data source.

The final procedure followed by the Epidemiology Unit of the LHU-TO3 to link health and mortality data consisted of 23 consecutive steps (ISTAT, 2007b). At the first two steps, only the pairs of records with completely corresponding fiscal codes - provided by death certificates or calculated - were considered a match and thus linked. At each of the other steps, two records were linked if at least a part of their fiscal codes was equal. To this end, partial fiscal codes were obtained by deleting each time a different set of characters and substituting them with a neutral symbol (i.e. a dash). The steps were performed in a sequence that had been established *a priori* based on the discriminatory power of the sets of characters deleted from the fiscal codes, starting from the lowest and ending with the highest. Deleting highly discriminatory sets of characters could in fact lead to false matches as it notably increases the risk of linking records that are not actually related to the same person. This is also confirmed by the fact that more than 85% of records were linked using complete fiscal codes.

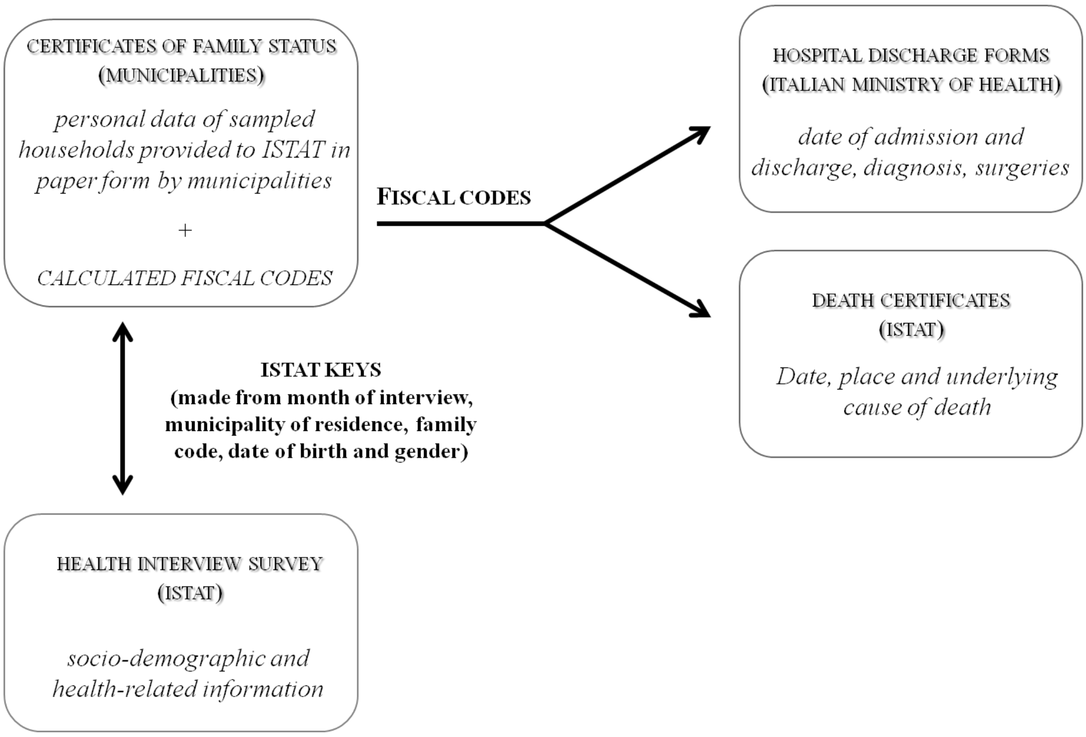
Obviously, quality checks were carried out at each step of the record linkage procedure in order to make sure that each linked pair of records actually referred to one and the same individual. This was done with the aid of a function of the SAS software called *SPEDIS*. This function returns a value of zero if two strings are identical, while it assigns penalty points for any observed difference. Thus, the higher is the value returned by *SPEDIS*, the bigger are the differences between the two input strings. In the specific context of the mortality follow-up of the Italian HIS, the *SPEDIS* function was used to compare - for all linked pairs of records - the strings of names, surnames, gender, dates and places of death derived from the HIS and the mortality data sets. Specific thresholds for the values of the function were determined in order to identify and eliminate all possible false matches.

To link the HIS data file with hospital records, the Ministry of health followed the same procedure, with some necessary adaptations. In this case, the period of follow-up is different: it starts in 2001 and ends in 2008. Moreover, 2,217 individuals were excluded from the linkage procedure and hospital records were thus linked for 126,601 out of the 128,818 individuals for whom a complete fiscal code had been previously calculated by ISTAT.

The output of the whole process of record linkage consisted of two different data sets that were subsequently merged by ISTAT to create the 1999/2000 HIS linked mortality and hospitalisation data file. This has a very high informative potential, as it allows to analyse the impact of various socio-demographic and health-related factors on mortality in the Italian population, even controlling for different causes of death. Until now, longitudinal surveys on health status have been only conducted in restricted geographical areas and for specific purposes. As a result, they are never representative of the entire population and often provide a limited number of variables. The New Italian Longitudinal Study thus significantly broadens the possibilities to investigate the relationships between health and mortality in our country.

To sum up, figure 3.1 displays the data sources and how they were linked together.

Figure 3.1 - Diagram of the record linkage performed to create the 1999/2000 HIS linked mortality and hospitalisation data file



3.1.3 Access to data and available information

Access to the New Italian Longitudinal Study is currently restricted to researchers working for one of the four institutions that are involved in the project. To get permission to use the 1999/2000 linked data file, it was necessary to write a detailed research proposal and submit it to ISTAT. An agreement was then signed that authorised me to use the data for the specific aims that were described in the proposal.

Upon signature of this agreement, I had access to the complete data set except for the two variables region and province of residence that were deleted due to confidentiality reasons. They are indeed considered as personally identifiable information, i.e. as variables that can be used - in combination with others such as gender and age - to identify or locate a single person. Moreover, only the underlying cause of death is reported in the data set, while the other causes listed in the death certificates are not.

For the aim of this thesis - that focuses on health status and mortality - I used only the 1999-2000 linked mortality data file, thus excluding data on hospitalisations.

3.2 Study population

The study population consists of 47,392 individuals who were aged at least 50 years at the moment of interview and did not die from violent causes - such as poisoning or car accidents - during the period of follow-up[7].

There are both statistical and conceptual reasons for limiting the study to individuals aged 50 years and older. Statistically, this choice of age is justified by the fact that the prevalence of both poor health and mortality before age 50 is very low and its values are thus subject to random variations below this age. Conceptually, using a threshold of 50 years of age allows to focus on both older adults aged 50-64 years and older individuals - i.e. on those individuals whose health conditions raise major concerns as they grow as a proportion of the population.

On the other hand, I decided to exclude violent deaths from the analysis because they occur independently on the health status in which individuals spend their last years of life. In these cases, it does not make sense to analyse the relationship between health and mortality.

3.3 Variables

3.3.1 Time after interview / Proximity to death

In order to perform the analyses, I created a variable that measures the length of the interval of time between interview and death. This variable can be defined alternatively as *time after interview* or *proximity to death* according to whether the forward or backward perspective is respectively adopted: while in the first case its values give information on how long after interview death occurred, in the second case they quantify the amount of time that remains until death at the moment of interview.

The variable defined above is calculated as the difference between the two dates of interview and death. It should be noted that, due to the structure of the data, a

[7] If occurred from 1999 to 2002, violent deaths are those with ICD-9 codes 800 to 999 (chapter "Injury and poisoning"). If occurred from 2003 to 2007, violent deaths are those with ICD-10 codes S00 to T98 (chapter "Injury, poisoning and certain other consequences of external causes"). The latter indicate the consequences of ICD-10 codes V01 to Y98 (chapter "External causes of morbidity and mortality"), that are never used for the underlying cause of death but are specified in a separate variable as a complementary information.

characteristic of the variable is that the same values are assigned to individuals who died in different calendar years. Interviews have indeed been conducted every three months over a period of one year - i.e. in September and December 1999 and in March and June 2000. As the complete dates are not available - in particular, month and year are known but the exact day is not - I had to hypothesise that both interviews and deaths were equally distributed over the days of each month.

Two versions of the same variable exist. In one version the period of time between interview and death is expressed in number of months, while in the other version it is expressed in number of years. While the variable in month is indeed more suitable for the aims of the analysis presented in Chapter 4, the variable in years is more appropriate for the aims of the analysis presented in Chapter 5.

If expressed in months, the variable ranges from 1 to 92. The lowest value is assigned to those persons who died within one month from the interview. The highest value is assigned either to individuals who survived the whole period of follow-up or to those who died more than 91 months after the interview. Individuals are indeed considered censored if they were still alive 91 months after the interview.

If expressed in years, the variable ranges from 1 to 8. The lowest value is assigned to those persons who died within 1 year after the interview. The highest value is assigned either to individuals who survived the whole period of follow-up or to those who died more than 7 years after the interview. Individuals are indeed considered censored if they were still alive 7 years after the interview. Individuals who died less than one year after interview correspond to people in their last year of life. Similarly, individuals who died 1 to 2 years after interview correspond to people in their second to last year of life, and so on.

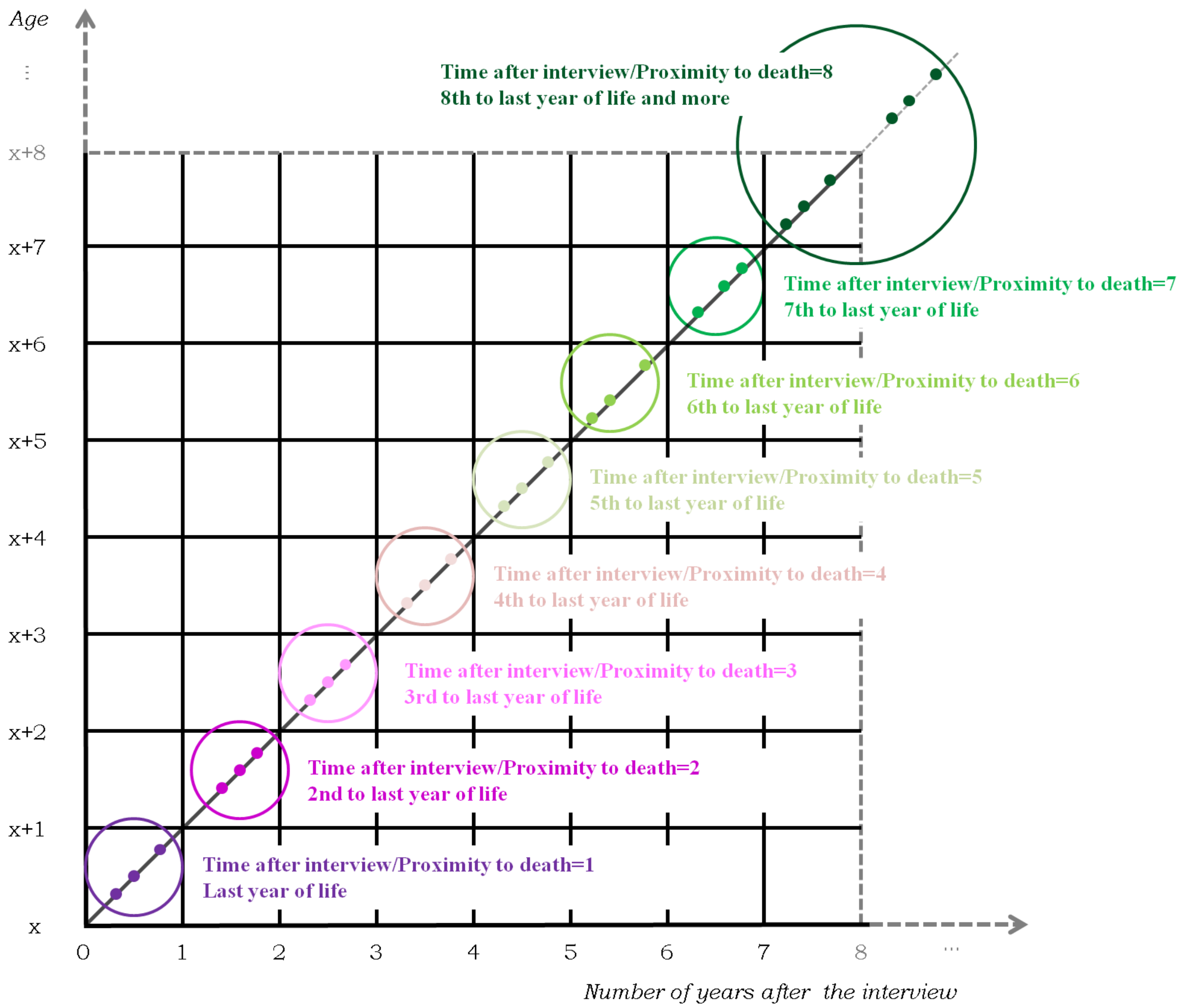
Table 3.1 provides a detailed list of the combinations of dates of interview and death that correspond to each value of the variable *time after interview / proximity to death* by taking as an example - for the sake of simplicity - the case in which the period of time between interview and death is expressed in years. Figure 3.2 then illustrates the structure of the data using a Lexis diagram that allows to “visualise” all groups of individuals with different values of the variable.

Table 3.1 – Dates of interview and death and calendar years corresponding to different values of the variable *time after interview / proximity to death*

Date of interview	Date of death	Calendar years of death	Time after interview / proximity to death (years)
September 1999 December 1999 March 2000 June 2000	from September 1999 to August 2000 from December 1999 to November 2000 from March 2000 to February 2001 from June 2000 to May 2001	1999 2000 2001	1
September 1999 December 1999 March 2000 June 2000	from September 2000 to August 2001 from December 2000 to November 2001 from March 2001 to February 2002 from June 2001 to May 2002	2000 2001 2002	2
September 1999 December 1999 March 2000 June 2000	from September 2001 to August 2002 from December 2001 to November 2002 from March 2002 to February 2003 from June 2002 to May 2003	2001 2002 2003	3
September 1999 December 1999 March 2000 June 2000	from September 2002 to August 2003 from December 2002 to November 2003 from March 2003 to February 2004 from June 2003 to May 2004	2002 2003 2004	4
September 1999 December 1999 March 2000 June 2000	from September 2003 to August 2004 from December 2003 to November 2004 from March 2004 to February 2005 from June 2004 to May 2005	2003 2004 2005	5
September 1999 December 1999 March 2000 June 2000	from September 2004 to August 2005 from December 2004 to November 2005 from March 2005 to February 2006 from June 2005 to May 2006	2004 2005 2006	6
September 1999 December 1999 March 2000 June 2000	from September 2005 to August 2006 from December 2005 to November 2006 from March 2006 to February 2007 from June 2006 to May 2007	2005 2006 2007	7
September 1999 December 1999 March 2000 June 2000	from September 2006 on from December 2006 on from March 2007 on from June 2007 on	2006 2007 and beyond	8

Figure 3.2 – Structure of the mortality follow-up of the 1999/2000 health interview survey data and definition of the variable *time after interview / proximity to death*

As in a classic representation of a Lexis diagram, diagonal lines represent individuals under observation and dots represent events. The diagonal line represent all people who were interviewed at age x and in a specific moment in time; dots represent deaths of interviewees occurred during the period of follow-up. Elements in grey represent data that are still not available at the present moment (the data set is currently being updated with deaths occurred between 2008 and 2012).



3.3.2 Socio-demographic characteristics

Some basic socio-demographic variables are considered in this study. These include *gender, age, educational level, marital status and geographical area of residence*. According to several studies that can be found in the existing literature, each of these variables has an important and independent role as a determinant of both health and mortality. It is thus particularly important to account for the effects of all of them, especially in a study that focuses on the relationship between poor health and death.

Gender is well-known to affect health status and mortality in an opposite manner: compared to men, women usually live longer but in worse health. Demographers have been studying this phenomenon (the so-called male-female health-mortality paradox) for years but still have not found a reasonable explanation for its occurrence (Verbrugge L.M., 1985; Oksuzyan et al., 2008).

For what concerns age, it affects mortality in the sense that the risk of death increases with advancing age (even if a deceleration can be observed at extremely old ages). On the other hand, different dimensions of health are affected by age in different ways: while the prevalence of objective morbidity is usually highest among older individuals, it has been demonstrated that self-rated health improves at oldest ages (Ferraro, 1980; Mulsant et al., 1997; Jylhä et al., 2001). This could be due to a tendency of individuals in this stage of life to adapt their expectations to an increased risk of poor health (Leinonen et al., 2002). In order to take into account these differences in the reporting of health, I divided age into 4 different groups: 50-64, 65-74, 75-84 and 85 years and older.

Education has proven to be another important predictor of both poor health and death (Mackenbach et al., 2003; Cutler et al., 2008). Other characteristics being equal, individuals with low education have poorer health and higher risks of dying compared to those with high education. In this study, individuals are grouped into 3 categories: low education (i.e. primary and lower), medium education (i.e. lower secondary) and high education (i.e. upper secondary and higher).

Several studies have demonstrated that marriage has a positive effect on both health and mortality (Gove, 1979; Goldman et al., 1995). This means that people who are married generally have lower risks of both poor health and death in comparison with those who are not. For this reason, I used in this analysis a dichotomous variable called marital status that has 2 categories: married and not married. The latter includes single, separated, divorced and widowed individuals.

Finally, the geographical area of residence can also have an influence on health and mortality. In the Italian context, mortality differences have been traditionally observed between regions (Caselli and Egidi 1979; Lipsi and Caselli 2002). At the same time, regional differences have been also observed in health conditions (Mazzucco, 2009). Based on these considerations, I decided to use a variable that has the 3 following categories: northern, central, and southern Italy[8]. These three areas include regions with similar characteristics.

Table 3.2 - Summary of the socio-demographic variables

Variable	Categories
Gender	Men Women
Age	50-64 65-74 75-84 85+
Educational level	Low Medium High
Marital status	Married Not married
Area of residence	North Centre South & Islands

3.3.3 Measures of health status

According to WHO (1946), health is a multidimensional concept that can be defined as "a state of physical, mental and social well-being and not merely the absence of disease or infirmity". Following this definition, a broad range of indicators have been developed since the second half of the last century by researchers in order to describe the diverse dimensions of health. These comprise morbidity as well as functional abilities, mental and cognitive health and the perception of own general status.

[8] Both islands - Sicily and Sardinia - are included in the South according to the definition traditionally adopted by ISTAT.

Nowadays, questions designed to investigate the different dimensions of health are included on a regular basis in the questionnaires of various epidemiologic and social surveys carried out at a national - or even international[9] - level. Similarly to any other national health survey, the Italian HIS asks questions about health and a large variety of health-related aspects of life. Several indicators are thus available for use in the 1999/2000 HIS linked mortality data file. For the specific purposes of my thesis I selected three different measures, respectively capturing the functional, objective and subjective health status.

Functional health status

Functional status is assessed by the Italian HIS through a series of questions asking individuals whether they have limitations in different areas of physical functioning (ISTAT, 2007a). Disability is indeed defined by ISTAT as having difficulties in the areas of communication, mobility or self-care. These include, respectively: limitations in sight, hearing and speaking; restrictions in walking, climbing stairs and kneeling; difficulties to perform the basic activities of daily living (ADL). For the aims of this thesis, I decided to use a definition of disability that is only based exclusively on ADLs.

First defined by Katz (Katz et al., 1963), ADLs consist of a set of basic self-care activities that "people perform habitually and universally": bathing, dressing, toileting, transferring in and out of bed and eating. Questions about the ability to perform each of these activities - with the only exception of toileting - are included in the Italian HIS questionnaire. In particular, individuals are asked to indicate whether they are able to move in and out of bed, move in and out of a chair, dress and undress, take a bath or a shower, wash hands and face, eat and cut food by themselves. As a consequence, in this work an individual is considered to be ADL disabled if he/she has difficulties in carrying out at least one out of the six tasks mentioned above.

Moreover, a distinction has been made between moderate and severe ADL disability. Participants in the Italian HIS can indeed report either to have some difficulties in performing an activity of daily living or to be able to perform that activity only with the

[9] This is the case of the EU Statistics on Income and Living Conditions (EU-SILC). The questionnaire of this survey include the "Minimum European Health Module", i.e. a set of 3 questions aimed at collecting comparable information on perceived health and the presence of both long-standing health problems and activity limitations.

help of someone else. While in the former case they are considered to have moderate limitations, in the latter case they are defined as being severely limited in ADLs.

The choice of using ADL disability rather than a broader definition (i.e. a definition based on limitations in all areas of functioning on which data are available) is justified by considerations relating to both the context of study and the approaches commonly used in the international literature. Disability is indeed most frequently defined as having limitations in ADL, especially in studies that focus on older people. On the other hand, broader measures have been generally used to estimate disability in the total adult population (Gudex and Lafortune, 2000). Moreover, not only ADL disability has proven to be a reliable measure of physical functioning at older ages, but also an important predictor of health care service utilisation and health expenditures (Chan et al., 2002). These characteristics make it a suitable measure for the aims of this thesis.

Objective health status

In order to assess objective health, participants in the Italian HIS are asked to indicate whether they suffer from chronic illnesses among those listed in a dedicated section of the questionnaire. The list of diseases has repeatedly changed over time (ISTAT, 2007a). In the 1999/2000 edition of the survey, it included 29 chronic conditions (Table 3.3).

In this study, I used this information to build a measure of multimorbidity. The latter is defined as the co-occurrence of three or more chronic diseases out of those listed in the survey questionnaire. More in particular, an individual is considered to suffer from a chronic disease if he/she was affected by the disease at the moment of interview and the disease had been previously diagnosed by a physician. If the same individual reports to be simultaneously affected by three or more diseases, then he/she is considered to be in a state of multimorbidity.

Several definitions of multimorbidity can be found in the available literature on health topics. This variability depends for the most part on data sources, as different surveys often collect information on different diseases. In addition, the number of diseases also varies: multimorbidity is alternatively defined as the co-occurrence of either two or more or three or more diseases. I preferred this second option for two reasons. First of all, the study focuses on older people who are more exposed to chronic conditions. Moreover, the list of diseases includes a high number of conditions, among which some are less severe than others. A threshold of three diseases thus appears to be more discriminating.

Table 3.3 - Chronic conditions included in the 1999/2000 Italian HIS questionnaire

1	Allergic diseases
2	Diabetes
3	Cataract
4	Hypertension
5	Myocardial infarction
6	Angina pectoris
7	Other heart diseases
8	Thrombosis, embolism, cerebral haemorrhage
9	Varicose veins, varicocele
10	Haemorrhoids
11	Chronic bronchitis, emphysema, respiratory insufficiency
12	Bronchial asthma
13	Diseases of the skin (psoriasis, vitiligo, etc..)
14	Thyroid diseases
15	Arthrosis, arthritis
16	Lumbosciatica
17	Osteoporosis
18	Abdominal hernia
19	Gastric or duodenal ulcer
20	Liver stones, gallstones
21	Cirrhosis of the liver
22	Chronic hepatitis (excluding type A)
23	Kidney stones
24	Hypertrophy of prostate
25	Cancer (including lymphoma and leukaemia)
26	Migraine
27	Parkinsonism, Alzheimer, epilepsy, loss of memory
28	Other diseases of the nervous system (depression, anorexia, bulimia)
29	Other chronic conditions

Subjective health status

Subjective health is assessed in the Italian HIS through the question “How is your health in general?”, that has five possible answers: “very bad”, “bad”, “fair”, “good” and “very good”.

This question is included in the questionnaires of many health interview surveys as well as of other epidemiologic or social surveys carried out in different countries both at a national and local level. It is indeed widely used worldwide to evaluate self-rated health - i.e. the perception that individuals have of their global health status, to which both physical and emotional conditions contribute. This simple indicator has proved to be a valid and reliable measure of health status: many studies prove its strong association with objective health (Kaplan et al., 1996; Goldberg et al., 2001) and - as already discussed in Chapter 2 - its importance as a predictor of mortality.

In this study, the two categories of self-rated health labelled "good" and "very good" are collapsed into one category: "good or very good". This choice is justified by the fact that the two original categories are very similar between each other both in terms of survival and association with proximity to death. All the other categories are considered separately.

It is worth noting that the Italian translation of the category name "fair" adopted in the 1999/2000 edition of the health interview survey (*"discretamente"*) is not completely neutral. Rather, it has a slightly positive connotation, suggesting that individuals who rate their health as "fair" actually perceive themselves in relatively good health. And indeed - as it has been previously demonstrated by Egidi and Spizzichino (2006) based on data for Italy from the European Community Household Panel - people in fair health are generally similar to those in good health.

Table 3.4 - Summary of the measures of health status

Variable	Categories
ADL disability	Fully functional Moderate disability Severe disability
Multimorbidity	0 to 2 chronic diseases 3 or more chronic diseases
Self-rated health	Good or very good Fair Bad Very bad

3.4 Basic description of the study population

Out of the 47392 individuals composing the study population interviewed in 1999/2000, 39355 survived the period of follow-up and 8037 died by the end of 2007. From Table 3.5, it emerges that, as expected because of their lower mortality, women are overrepresented among people who survived to follow-up. The proportion of men and women is more balanced among deaths, but women are still slightly overrepresented. Moreover, the age distribution of people who survived to follow-up - as well as of the total population - reflects the structure of the Italian population aged 50 years old and older in the survey years. On the other hand, deaths are more equally distributed across age groups, with the highest proportion found among individuals aged 75-84 years old. Finally, the distributions of the population according to educational level and geographical area of residence are similar between people who survived and those who died during follow-up. The same cannot be said for marital status, as the proportion of married people is much higher among survivors rather than among decedents.

As expected, moreover, very high proportions of individuals in good health are observed among those who survived: almost 90% was fully functional, and more than 65% either had no disease or suffered from less than 3 chronic diseases (Table 3.5). Moreover, most of them perceived themselves in a good or very good and fair health status: 33.6% and 54.3% respectively. The higher proportion of people in fair health is in line with what has been said about the Italian translation of the neutral term. Relatively lower - but still high - proportions of people in good health are observed among deaths. A more in depth discussion of these aspects is reported in Chapter 5.

Table 3.6 reports the number of individuals in the sample according to the number of years after interview / proximity to death. A value of 8 and over - which identifies the group of survivors in Chapter 5 - means that an individual was at least 8 years far from death at the moment of interview. The exact number of years of proximity to death is indeed unknown for most people belonging to this group. The 1,074 interviewees who actually died before by the end of 2007 have been grouped together with survivors, because individuals are considered censored if still alive after 7 years. The number of decedents is more equally distributed across other values of years after interview / proximity to death. Finally, Table 3.7 reports the distribution of the study population according to gender, age and years after interview / proximity to death.

Table 3.5 - Socio-demographic characteristics and health status of survivors and decedents composing the study population

	Vital status at the end of follow-up					
	Alive		Dead		Total	
	Number	%	Number	%	Number	%
Gender						
Men	17,647	44.8	4,159	51.7	21,806	46.0
Women	21,708	55.2	3,878	48.3	25,586	54.0
Age group						
50 - 64	23,210	59.0	1,319	16.4	24,529	51.8
65 - 74	11,114	28.2	2,311	28.8	13,425	28.3
75 - 84	4,367	11.1	2,800	34.8	7,167	15.1
≥ 85	664	1.7	1,607	20.0	2,271	4.8
Educational level						
High	6,133	15.6	651	8.1	6,784	14.3
Medium	8,219	20.9	954	11.9	9,173	19.4
Low	25,003	63.5	6,432	80.0	31,435	66.3
Marital status						
Married	28,888	73.4	4,373	54.4	33,261	70.2
Not married	10,467	26.6	3,664	45.6	14,131	29.8
Area of residence						
North	16,565	42.1	3,219	40.1	19,784	41.7
Centre	7,354	18.7	1,491	18.6	8,845	18.7
South and Islands	15,436	39.2	3,327	41.4	18,763	39.6
Adl disability						
Fully functional	34,993	88.9	4,546	56.6	39,539	83.4
Moderate disability	3,131	8.0	1,553	19.3	4,684	9.9
Severe disability	1,231	3.1	1,938	24.1	3,169	6.7
Multimorbidity						
0 to 2 diseases	26,565	67.5	4,069	50.6	30,634	64.6
3 or more diseases	12,790	32.5	3,968	49.4	16,758	35.4
Self-rated health						
Good or very good	13,219	33.6	1,113	13.8	14,332	30.2
Fair	21,357	54.3	4,107	51.1	25,464	53.7
Bad	4,109	10.4	2,088	26.0	6,197	13.1
Very bad	670	1.7	729	9.1	1,399	3.0
Total	**39,355**	**100**	**8,037**	**100**	**47,392**	**100**

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 3.6 – Number of individuals composing the sample in each year of proximity to death according to vital status at the end of follow-up

Years after interview / Proximity to death	Vital status at the end of follow-up		
	Alive	Dead	Total
1	0	878	878
2	0	960	960
3	0	981	981
4	0	1,023	1,023
5	0	1,057	1,057
6	0	1,016	1,016
7	0	1,048	1,048
8 and over	39,355	1,074	40,429

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 3.7 – Number of individuals composing the sample according to sex, age at interview and proximity to death (in years)

Gender	Age	Years after interview / Proximity to death							
		1	2	3	4	5	6	7	8 and over
Men	50-64	74	96	102	87	114	112	128	11247
	65-74	135	164	154	169	184	187	180	5059
	75-84	128	165	178	183	172	191	177	1663
	85+	112	94	83	95	63	49	39	222
	Total	449	519	517	534	533	539	524	18191
Women	50-64	54	39	44	53	67	64	67	12181
	65-74	74	96	107	102	133	121	152	6408
	75-84	136	147	157	169	195	190	219	3097
	85+	165	159	156	165	129	102	86	552
	Total	429	441	464	489	524	477	524	22238
Total	50-64	128	135	146	140	181	176	195	23428
	65-74	209	260	261	271	317	308	332	11467
	75-84	264	312	335	352	367	381	396	4760
	85+	277	253	239	260	192	151	125	774
	Total	878	960	981	1023	1057	1016	1048	40429

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

3.5 Validation of data

As a preliminary step, I compared the survival of the 1999/2000 HIS linked sample with that of the Italian total population during the period of follow-up. The aim was to assess the quality of mortality estimates in the New Italian Longitudinal Study.

A validation of data is indeed necessary to confirm the reliability of the analysis results reported in the following chapters. Due to the linkage procedure adopted, false matches[10] could have occurred during the linkage procedure that could affect the representativeness of the sample. Moreover, a possibility exists that losses to follow-up due to missing fiscal codes - even if this was the case for only a small percentage of participants in the survey (8%) - could also cause representativeness issues.

In this phase of validation, men and women are considered separately. Both are classified into 5-years age groups, with the only exception of individuals aged 85 years and older who are all comprised in the same group. A total of 8 age groups are thus included in the analysis: 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84 and 85 years old and older. Finally, it is important to specify that - obviously - all deaths occurred in the sample are taken into account, including those due to violent causes that are excluded from other analyses.

Methods

First of all, I estimated cumulative survival probabilities for the 1999/2000 HIS cohort through the Kaplan-Meier product limit method. I also computed confidence limits for the estimated probabilities in order to identify intervals of acceptable values to be compared with those of the reference population. Following the example of a study that compares the mortality of the 1986-2000 cohorts of the American HIS with that of the total U.S. population using similar methods (Ingram et al., 2008), a 99% confidence level was preferred over 95% because of the high number of comparisons being made.

Then, I calculated the corresponding cumulative survival probabilities of the Italian population. In order to do this, I used an adapted version of a SAS program originally created by a professor of Karolinska University in Stockholm to estimate the relative

[10] In particular, a false negative match occurs when a deceased participant is erroneously considered alive. A false positive match occurs when a participant is erroneously considered to be dead but he/she is actually alive.

survival of people with cancer (Dickman et al., 2004)[11]. Of the whole program, I only used a procedure aimed at estimating the survival curve of the population based on survival probabilities taken from national life tables.

Two input files were needed to run the SAS program: the “1999/2000 HIS sample mortality file” and the “population mortality file”. The former contained a single observation for each interviewee, with information on gender, age, date of interview, vital status at the end of follow-up, survival time and calendar year of death (if occurred). The latter contained - for each year between 1999 and 2007 - the life-table survival probabilities of the Italian population according to age, sex and calendar year.

The estimation procedure followed the following steps (Dickman, 2004).

1. For each individual included in the 1999/2000 HIS sample mortality file, the survival time was split into as many observations as the number of completed years of follow-up (i.e. 7).
2. Values of attained age and calendar year at the end of each interval of time were calculated. Attained calendar year was calculated by adding the number of years elapsed since interview to the date of interview.
3. The expected probabilities of surviving each time interval were merged from the population mortality file according to the values attained ages and calendar years. In this way, it was possible to account for the ageing of the HIS cohort over the period of follow-up.
4. For each observation, two indicators were created: one for death (equal to 1 if the individual has died and to 0 otherwise) and one for censoring (equal to 1 if the individual is alive and to 0 otherwise).
5. For the desired combinations of covariates, all observations referring to the same interval of time were collapsed to form a single observation. At this point, the expected probability of survival for that particular interval of time was easily obtained as the average of the individual-specific expected survival probabilities.

[11] The SAS program is freely accessible on the personal website of its author, and a detailed description of each step is also given to facilitate its use.

6. Cumulative expected survival probabilities (${}_nP_0$) were calculated as the product of the interval-specific estimates, according to the following formula:

$$ {}_nP_0 = \prod_{i=0}^{n-1} p_i \ , $$

where *n* is the number of time intervals in which the follow-up period is divided and p_i is the estimated survival probability for the *i-th* interval.

The differences between the survival probabilities of the 1999/2000 HIS cohort and those of the population (since now on referred to as observed and expected survival probabilities respectively) are considered to be statistically significant when the survival of the population lies out of the confidence limits computed for the survival of the sample.

Results

Observed and expected survival curves are represented in Figures 3.3 to 3.10 for men and women of each age group. Confidence limits at 99% level of significance are also shown in the graphs in order to immediately visualise when the expected survival does not lie in the interval of acceptable values for the observed survival. For a deeper analysis, however, it is necessary to examine the exact values. These can be found in Appendix B: Tables B.1 to B.4 report the differences between observed and expected survival probabilities at different years of follow-up, and Tables B.5 to B.8 the 99% confidence limits for the observed survival probabilities.

The results of the validation analysis are extremely encouraging. Observed and expected survival curves are always very similar to each other. In addition, the expected survival generally lies within the 99% confidence limits for the observed survival. This proves that the differences are either very low or not statistically significant.

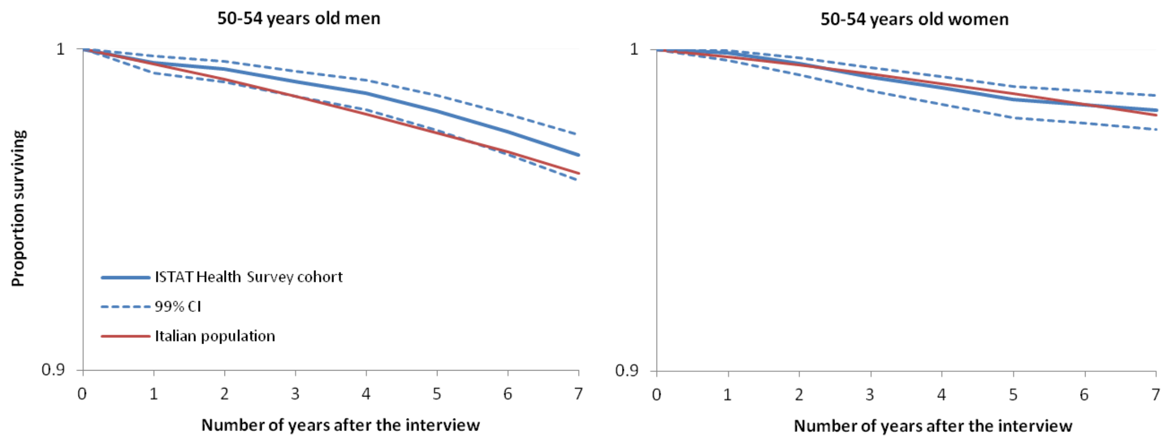
Differences between expected and observed survival are negligible in the younger portion of the study population, i.e. among individuals aged 50 to 69 years old: the only significant differences are observed among men aged 50-54 at the end of 4th and 5th years of follow-up, and is equal to 0.007.

The results of the validation analysis for older age groups are more complex, but still indicate a good quality of the mortality estimates in the 1999/2000 HIS linked mortality data file. Compared to younger ages, statistically significant differences emerge more frequently in groups of older individuals. Among men, this is the case for the age groups 75-79 in the first 3 years of follow-up and 85 years and older in the last year. Among women, this is the case for the age groups 70-74 in the first year of follow-up, 75-79 from the 4th to the 6th year, 80-84 for almost the whole period and 85 years and older in the last 3 years. Albeit significant, these differences are very low, ranging from 0.01 to 0.02 in the first years of follow-up and from 0.04 to 0.05 in the last years. Indeed, in most cases the expected survival probabilities are almost coincident with the lower confidence limits calculated for the observed survival.

Two different aspects must be discussed. First, the observed survival is generally higher than the expected survival. This is indicative of a slight underestimation of mortality levels within the sample that was at least in part expected, due to the fact that national HIS samples do not include institutionalised people. Secondly, at the oldest ages differences tend to increase with increasing length of follow-up. This was also expected, as the risk of institutionalisation in the population increases with age. Thus, the presence of these - besides small - differences does not cause any particular concern.

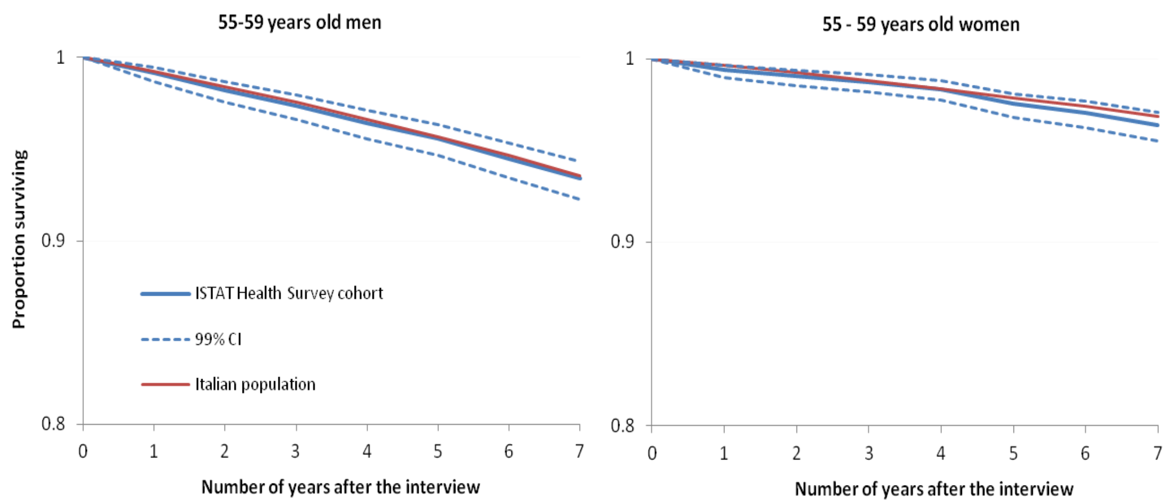
In conclusion, the results of the validation analysis prove that mortality was generally well-ascertained in the 1999/2000 HIS sample. It thus appears that the overall quality of data from the New Italian Longitudinal Study is good and allows an accurate estimation of mortality levels in the Italian population. This holds true for both men and women, but among the latter it is slightly more likely that significant differences between the observed and expected survival are reported. Only for women aged 80-84 years old, a systematic underestimation of mortality occurs over the whole period of follow-up. For this reason, results should be interpreted cautiously for this particular group of interviewees.

Figure 3.3 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 50-54 years old



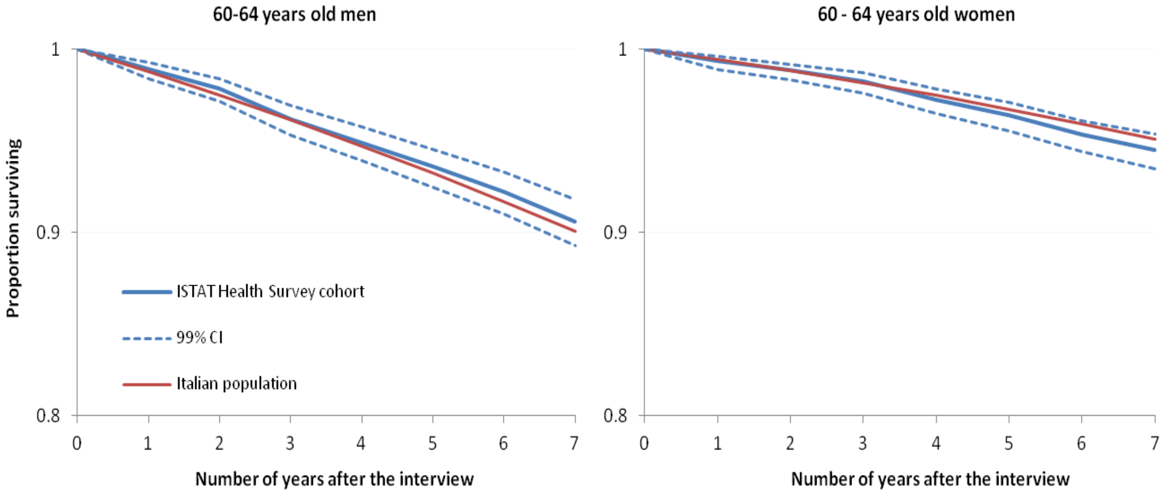
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.4 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 55-59 years old



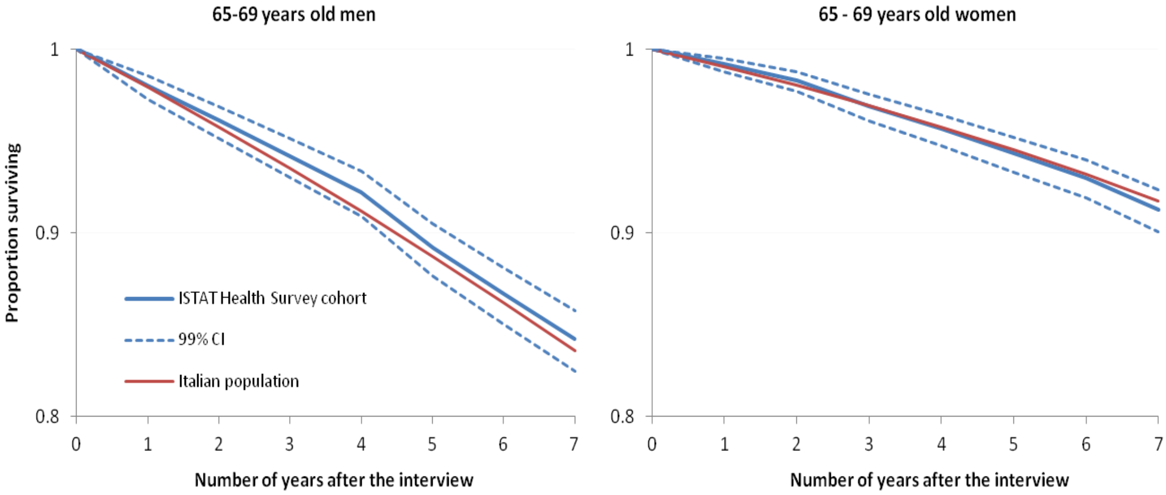
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.5 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 60-64 years old



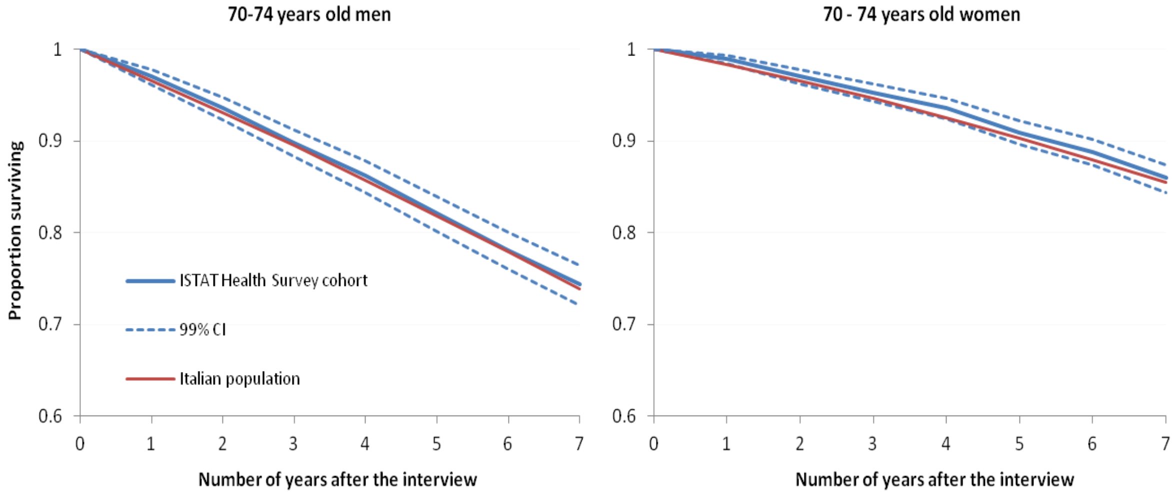
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.6 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 65-69 years old



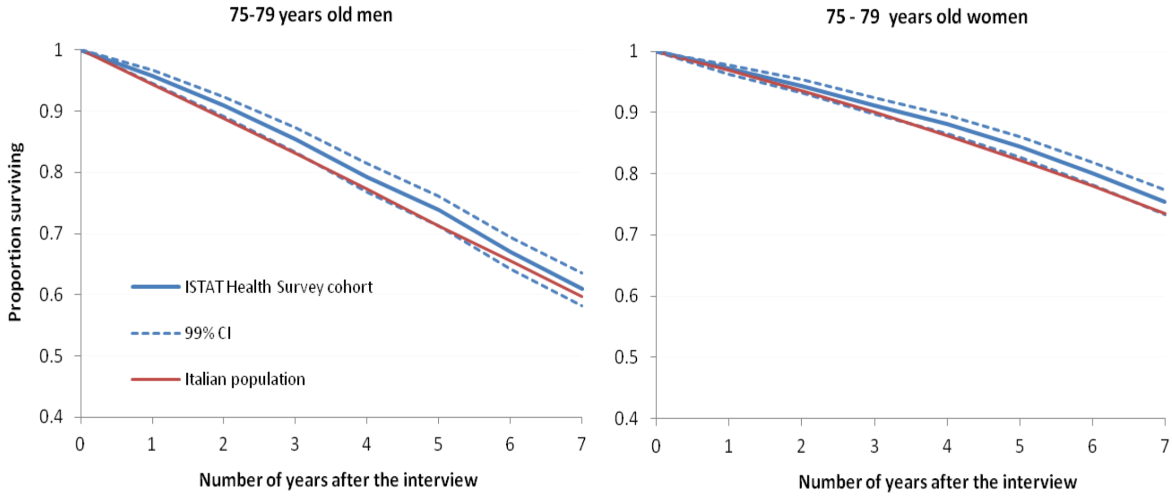
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.7 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 70-74 years old



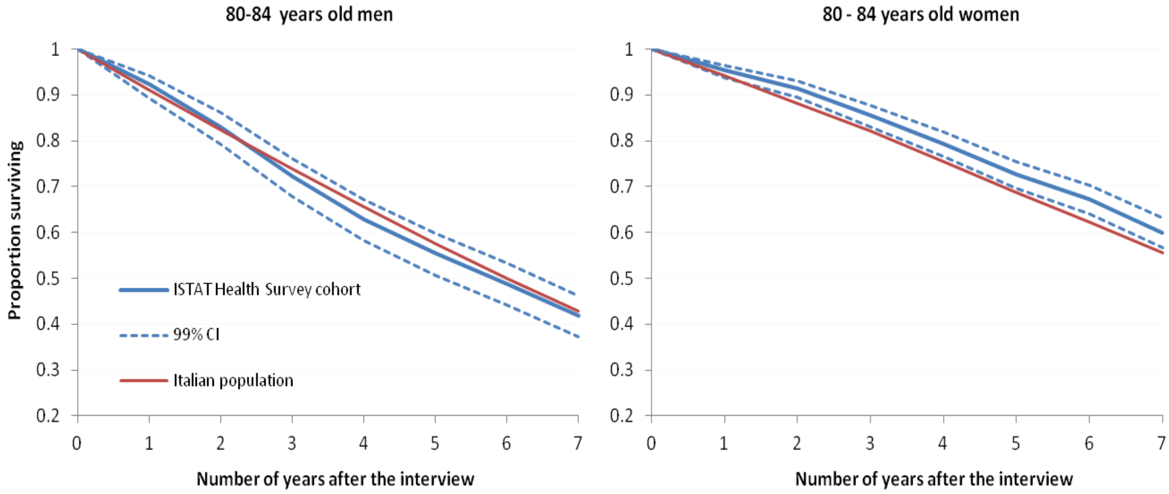
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.8 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 75-79 years old



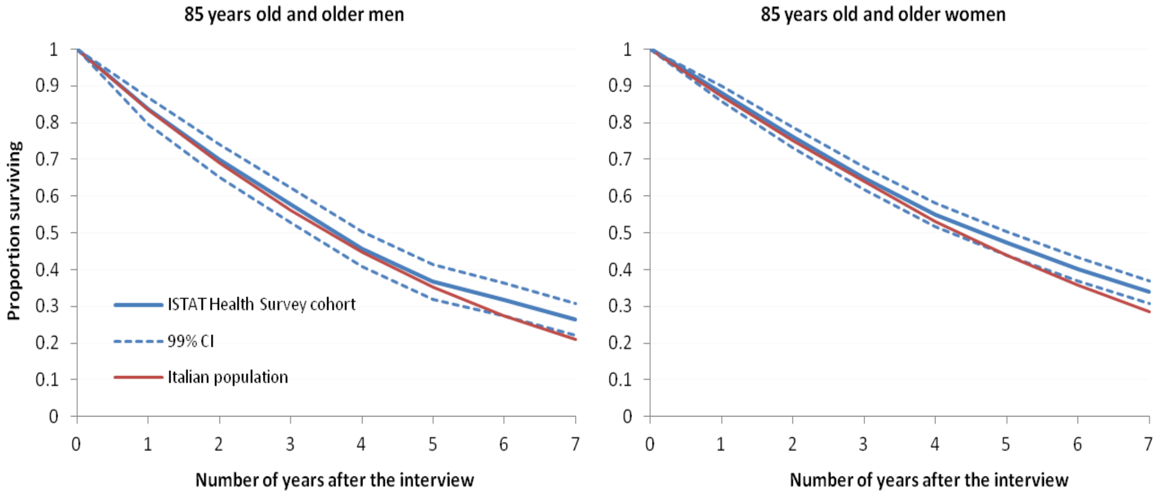
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.9 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 80-84 years old



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 3.10 – Mortality experience during the years of follow-up of the ISTAT 1999/2000 HIS cohort compared to that of the Italian population of the same age, Men and women aged 85 years old and older



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

4. "Looking forward": mortality risks according to health status at interview

4.1 Introduction

The present chapter focuses on the predictive value of poor health for mortality at older ages. It indeed reports the analyses that I have carried out with the aim of assessing the risks of dying associated with different health conditions in the study population. A forward perspective is thus adopted in this part of the thesis, as the main interest is in evaluating how the health conditions that individuals have at a specific point in time (i.e. the date of interview) affect their survival probabilities over the subsequent years. For this purpose, survival analysis clearly appears to be the most appropriate tool.

As a first step, Kaplan-Meier curves are represented to describe the survival experience of interviewees over the seven years of follow-up according to their health status at baseline. For each considered dimension of health - i.e. self-perception, functional status and chronic morbidity - the time spent in different conditions is studied both in the total sample and according to the two most important demographic characteristics: gender and age. In addition, relative survival curves - obtained by dividing the survival probabilities in poor health to the survival probabilities in good health - are represented for each age group in order to isolate the role of poor health in reducing the chances of survival.

Afterwards, the risk of dying associated with poor health status at baseline is quantified analytically by using multivariate Cox regression modelling in order to take into account the survival time of interviewees. This permits to estimate the simultaneous impact of the diverse dimensions of health on mortality risks while controlling for all the socio-demographic covariates included in the study (namely gender, age, marital status and educational level). Such characteristics are known to be important predictors of both health status and death. For this reason, regression models should be adjusted for their potentially confounding effects.

The chapter is divided into two sections: the first (i.e. paragraph 4.2) provides a brief overview of the most important aspects of the methodology used, whereas the second (i.e. paragraph 4.3) reports the results of the analyses.

4.2 Overview of methods

Survival analysis - alternatively called "failure time analysis" to account for all its possible areas of application - comprises a variety of techniques that have been developed to analyse the waiting time until the occurrence of an event of interest. In this work, similarly to epidemiological studies focusing on the survival time with a specific condition (e.g. cancer), the event of interest is death. On the other hand, the survival time is measured by the values of variable *time after interview/proximity to death* expressed in months. To support the interpretation of results, the basic concepts of survival analysis and some specific methodological aspects of the techniques used in this study are presented in the following pages.

4.2.1 Basic concepts of survival analysis

Let us consider a non-negative random variable T that represents the time until the occurrence of death. For $t \in [0, \infty)$, it will be characterised by:

- a probability density function $f(t) = \lim_{\Delta t \to 0} \frac{Pr(t<T\leq t+\Delta t)}{\Delta t}$, that denotes the probability that death occurs in the infinitesimal interval $(t, t + \Delta t]$;
- a cumulative distribution function $F(t) = Pr(T \leq t)$, that denotes the probability that death has occurred within time t;
- a survival function $S(t) = Pr(T > t)$, that denotes the probability that death occurs after time t;
- a hazard function $h(t) = \lim_{\Delta t \to 0} \frac{Pr(t<T\leq t+\Delta t \mid T>t)}{\Delta t}$ that denotes the probability that death occurs in the infinitesimal interval $(t, t + dt]$, conditional to the fact that the individual is alive at time t.

In the case that T is a continuous variable, the cumulative distribution function and the survival function can be respectively defined as

$$F(t) = \int_0^t f(u)du$$

and

$$S(t) = 1 - F(t) = 1 - \int_0^t f(u)du = \int_t^\infty f(u)du$$

From the two expressions above it results that $F(0) = 0$ and $\lim_{t\to\infty} F(t) = 1$, while $S(0) = 1$ and $\lim_{t\to\infty} S(t) = 0$. Moreover, we have that

$$f(t) = F'(t) = [1 - S(t)]' = -S'(t)$$

On the other hand, the hazard function can be defined as

$$h(t) = \lim_{\Delta t\to 0} \frac{Pr(t < T \leq t + \Delta t \mid T > t)}{\Delta t} = \frac{f(t)}{S(t)}$$

and will have a cumulative distribution function equal to

$$H(t) = \int_0^t h(u)du = \int_0^t \frac{f(u)}{S(u)}du = \int_0^t \frac{-S'(u)}{S(u)}du = -\ln \mathrm{S}(t)$$

from which it can be concluded that

$$S(t) = exp\{-H(t)\}$$

If - as in this study - T is a discrete variable assuming values at the time points $t_1 < \cdots < t_i < \cdots < t_k$, then the probability density function and the hazard function can be defined respectively as

$$f(t_i) = \Pr(T = t_i)$$

and

$$S(t) = \Pr(T > t) = \sum_{j:t_j > t} f(t_j)$$

Moreover, the hazard function becomes

$$h(t_i) = \Pr(T = t_i \mid T \geq t_i) = \frac{f(t_i)}{S(t_i^-)}$$

where $S(t_i^-) = \lim_{t \to t_i^-} S(t)$

Finally, the survival function can be alternatively written as

$$S(t) = \prod_{j:t_j \leq t} \Pr\left(1 - h(t_j)\right)$$

4.2.2 Kaplan-Meier estimator of the survival function

Different methods have been developed to estimate the survival function. In general, they can be distinguished in two groups: parametric and nonparametric models. The first assume that data come from a definite type of probability distribution, whereas the second do not assume any particular shape of the distribution of data, but only the following basic requirements are satisfied:

- $S(0) = 1$;
- $S(t)$ is never increasing;
- $\lim_{t \to \infty} S(t) = 0$.

The Kaplan-Meier (KM) estimator of the survival function - also known as the *product limit* estimator - is the most popular nonparametric method that can be used when the exact survival times of individuals are available from data. It works as a step function and is able to take into account the information given by censored individuals, i.e. those for which it is not possible to know the exact time of occurrence of death but only that it happens after a certain point in time. For them, indeed, the KM method hypothesises that the event occurs immediately after the last observation.

Let $t_1 < \cdots < t_j < \cdots < t_k$ be the observed failure time in a sample of size n from a population with an unknown survival function; d_j the number of individuals who experience the event of interest at time t_j; c_j the number of individuals who are censored in the interval $\left[t_j, t_{j+1}\right)$; n_i the number of individuals in the sample who are exposed to the risk of experiencing the event just prior to the time t_j.

An estimate of the hazard function at time t_j can be obtained as

$$\hat{h}\left(t_j\right) = \frac{d_j}{n_j}$$

As a consequence, the KM estimator of the survival function can be defined as

$$\hat{S}(t) = \prod_{j:t_j \leq t} \left(1 - \hat{h}\left(t_j\right)\right) = \prod_{j:t_j \leq t} \left(1 - \frac{d_j}{n_j}\right) = \prod_{j:t_j \leq t} \left(\frac{n_j - d_j}{n_j}\right)$$

It must be specified that censored individuals are accounted for in the calculation of the individual at risk of experiencing the event of interest.

Indeed, if $c_j = 0$ we have that

$$n_{j+1} = n_j - d_j$$

If $c_j > 0$, then we have that

$$n_{j+1} = n_j - d_j - c_j$$

The standard error for the KM estimator of the survival function is usually computed according to the so-called Greenwood's formula:

$$S.E.\left[\hat{S}(t)\right] = \hat{S}(t) \sqrt{\sum_{t_j \leq t} \frac{d_j}{n_j\left(n_j - d_j\right)}}$$

Finally, it is important to note that the KM estimator is a maximum likelihood estimator. Its confidence limits can be thus calculated assuming that it follows a normal distribution with a mean equal to $\hat{S}(t)$ and the variance defined by the formula given above. The 95% confidence intervals for the survival function is thus

$$CI95\%\left[\hat{S}(t)\right] = \hat{S}(t) \pm 1.96 \cdot S.E.\left[\hat{S}(t)\right]$$

Confidence intervals calculated using such formula, however, can include values outside of the interval $[0,1]$, which are impossible for $\hat{S}(t)$. A solution to this problem is to apply the asymptotic normal distribution to a logarithmic transformation of the survival function, for which there is not restricted range of values. In particular, using the delta method - according to which $Var[f(x)] = Var(x)\left(\frac{\partial f(x)}{\partial x}\right)^2$ where f is a generic function of x - we obtain

$$S.E.\left[ln\left(-ln\hat{S}(t)\right)\right] = S.E.\left(ln\hat{S}(t)\right)\frac{1}{ln\hat{S}(t)} = \sqrt{\frac{\sum_{t_j \le t}\frac{d_j}{n_j\left(n_j - d_j\right)}}{\left(\sum_{t_j \le t} ln\left(\frac{n_j - d_j}{d_j}\right)\right)^2}}$$

and

$$IC95\%\left[\hat{S}(t)\right] = \left[\hat{S}(t)\right]^{exp(\pm 1.96)S.E.[ln(-ln\hat{S}(t))]}$$

The confidence limits calculated using the formula above always assume values inside the range [0,1].

4.2.3 Relative survival curves

Relative survival curves are traditionally used in the field of epidemiology to study the survival time of individuals who are affected by different types of cancers. Their peculiarity is that they eliminate the effects on survival of other causes of death and thus isolate the role of cancer in determining the probability of death over a certain period of time (Verdecchia et al., 1995). In other words, they quantify the extra risk of death due to presence of cancer itself.

In epidemiological studies, the relative survival probability at time t is usually defined as

$$R(t) = \frac{S(t)}{S^{*}(t)}$$

where $S(t)$ is the survival probability observed in the sample at time t and $S^{*}(t)$ is the corresponding expected survival probability. The latter is basically the survival probability of the total reference population and can be calculated in different ways based on the survival probabilities of the national life tables for the same years in which the group of individuals under study (i.e. those living with cancer) is followed up for death.

In this work, I adapted the calculation of relative survival probabilities and obtained them by dividing the survival probabilities observed for the groups of individuals in poor health (i.e. those who had moderate or severe limitations in ADLs, those who were affected by 3 or more chronic disease and those who perceived themselves in a bad or very bad general health status) to the survival probabilities of their healthier counterparts (i.e. those who were fully functional, those who had no disease or was affected by a maximum of 2 chronic diseases and those who perceive themselves in a good or very good general health status respectively). In this way, it was indeed possible to quantify the excess mortality associated with poor health in the population in the cohort of participants in the 1999-2000 HIS survey in the years subsequent to the interview by eliminating the effects of all those forces that affect survival independently on the health conditions.

In particular, the estimates of the relative survival probabilities are defined as

$$\hat{R}^{p/g}(t) = \frac{\hat{S}^{p}(t)}{\hat{S}^{g}(t)}$$

where $S^{p}(t)$ and $S^{g}(t)$ are the survival probabilities of people in poor and in good health respectively, both estimated with the Kaplan-Meier method.

Under the hypothesis of independence of the two survival functions, we have that

$$Var\left[\ln\left(\hat{R}^{\frac{p}{g}}(t)\right)\right] = Var\left[ln\frac{\hat{S}^p(t)}{\hat{S}^g(t)}\right] = Var\left[\ln\left(\hat{S}^p(t)\right) - \ln\left(\hat{S}^g(t)\right)\right]$$

$$= Var\left[\ln\left(\hat{S}^p(t)\right)\right] + \mathrm{Var}\left[\ln\left(\hat{S}^g(t)\right)\right]$$

According to the delta method, we then have that

$$Var\left[\ln\left(\hat{R}^{\frac{p}{g}}(t)\right)\right] = Var\left[\hat{S}^p(t)\right]\frac{1}{\left(\hat{S}^p(t)\right)^2} + Var\left[\hat{S}^g(t)\right]\frac{1}{\left(\hat{S}^g(t)\right)^2}$$

from which it obviously results that

$$S.E.\left[\ln\left(\hat{R}^{p/g}(t)\right)\right] = S.E.\left[\hat{S}^p(t)\right]\frac{1}{\hat{S}^p(t)} + S.E.\left[\hat{S}^g(t)\right]\frac{1}{\hat{S}^g(t)}$$

where $S.E.\left[\hat{S}^p(t)\right]$ and $S.E.\left[\hat{S}^g(t)\right]$ are given by the Greenwood's formula. Then, confidence intervals can be calculated as

$$IC95\%\left[\hat{R}^{p/g}(t)\right] = \left[\hat{R}^{p/g}(t)\right] exp\left\{\pm 1.96 * S.E.\left[ln\left(\hat{R}^{p/g}(t)\right)\right]\right\}$$

4.2.4 Cox proportional hazards model

The Cox proportional hazards model is a semi-parametric regression model that allows to estimate the impact of different covariates on the hazard of experiencing an event of interest without making any distributional assumption.

Let $x = (x_1, \dots, x_i, \dots, x_p)$ be a vector of covariates measured at time 0. In the simplest case, the proportional hazards model is specified as

$$h(t|x) = h_0(t)\exp(x\beta)$$

where $h(t|x)$ is the probability of experiencing the event of interest at the time t for an individual who has survived to t and has a set of covariates x, while $h_0(t)$ corresponds to the hazard of an individual for whom $x = 0$. The latter element - which depends only on time - is called *baseline hazard*.

From the above formula, it results that

$$\exp(x\beta) = exp(x_1\beta_1 + \cdots + x_i\beta_i + \cdots + x_p\beta_p) = \frac{h(t|x)}{h_0(t)}$$

is the *relative hazard* or *hazard ratio (HR)*, which quantifies the effect of the covariates on the hazard function through the vector of the regression parameters $\beta = (\beta_1, \dots, \beta_i, \dots, \beta_p)$. It clearly appears that the hazard functions at different values of the covariates are proportional and that the relative risk does not vary over time. Thus, if we consider two individuals A and B who differ by only one covariate i we will have that

$$HR = exp\left(\frac{h(t|x^A)}{h(t|x^B)}\right) = exp\left(\frac{x_1\beta_1 + \cdots + x_i^A\beta_i + \cdots + x_p\beta_p}{x_1\beta_1 + \cdots + x_i^B\beta_i + \cdots + x_p\beta_p}\right) = exp[\beta_i(x_i^A - x_i^B)].$$

After that the model has been specified, the components of β are estimated from the data using the so-called *partial likelihood* method.

If there are no censored observations, the likelihood function for a sample of n individuals can be written as usual, i.e. as

$$L(\beta) = \prod_{i=1}^{n} f_i(t_i)$$

When some observations are censored, however, this formula is not appropriate and the likelihood function should be rather written as

$$L(\beta) = \prod_{i=1}^{k} f_i(t_i) \cdot \prod_{i=k+1}^{n} S_i(t_i)$$

where k is the number of uncensored observations and t_i represents the time of death for uncensored individuals on the one hand, and the time of observation for censored individuals on the other hand.

The partial likelihood, which ignores the information given by the censored observations, can be then defined as

$$L(\beta) = \prod_{i=1}^{k} f_i(t_i)$$

Under the proportional hazard model, this equation becomes equal to

$$L(\beta) = \prod_{i=1}^{k} \frac{\exp(x_i\beta)}{\sum_{l \in R_{t_i}} \exp(x_l\beta)}$$

where R_{t_i} is the set of individuals at risk of experiencing the event of interest just before the time t_i. As usual, by maximising the partial likelihood function it is possible to find a maximum likelihood estimate $\hat{\beta}$ which has the same asymptotic properties as an ordinary maximum likelihood estimator. As a consequence, likelihood ratio tests can be performed based on the partial likelihood function (Kalbfleisch and Prentice, 2002).

4.2.5 Tests of the proportional hazards assumption and extended Cox models

It is not uncommon that the proportionality assumption - on which Cox regression analysis relies - is violated. This means that the effect of one or more covariates on the hazard function is not constant over time, causing the hazards at different values of those covariates to be no longer proportional. In such a case, the model specification described in the previous paragraph cannot be valid because it would produce distorted estimates of the coefficients β_i. More specifically, it would lead to constant estimated values for the regression parameters of the covariates whose effect on the hazard actually changes over time.

To make sure that the proportional hazards model can be applied, it is thus necessary to test the proportionality assumption. Either graphical or analytical tests can be performed. Among the first, the most frequently used are the log-log plot of survival functions, i.e. the $-\ln\{-\ln(\text{survival})\}$ curves at the different categories of a nominal or ordinal covariate. If the plotted lines are parallel, then the hazards are proportional. However, these graphs can be difficult to interpret. For this reason, it is often preferable to perform analytical tests such as that based on scaled Schoenfeld residuals used in this thesis, which is illustrated below.

The ith Schoenfeld residual for the covariate x_j is defined as

$$r_{ij} = \delta_i\left(x_{ij} - a_{ij}(\beta)\right)$$

where $\delta_i = 1$ if the individual i is uncensored and $\delta_i = 0$ if the individual is censored, x_{ij} is the value assumed by the covariate x_j for the individual i and

$$a_{ij}(\beta) = \frac{\sum_{l\in R_{t_i}} x_{lj} \exp(\beta x_l)}{\sum_{l\in R_{t_i}} \exp(\beta x_l)} = E\left[x_{ij}|R_{t_i}\right]$$

From the equation above, it results that $a_{ij}(\beta)$ can be interpreted as the weighted mean of the covariate x_j, conditional to the structure of the set of individuals at risk R_{t_i}. We thus have that

$$a_{ij}(\beta) = E\left[x_{ij}|R_{t_i}\right]$$

By definition, the ith Schoenfeld residual represents the individual contribution to the first derivative of the logarithm of the partial likelihood function (Collet, 2003), which is equal to

$$\frac{\partial L(\beta)}{\partial \beta_j} = \sum_{i=1}^{n} \delta_i \left(x_{ij} - \frac{\sum_{l\in R_{t_i}} x_{lj} \exp(\beta x_l)}{\sum_{l\in R_{t_i}} \exp(\beta x_l)} \right) = \sum_{i=1}^{n} \delta_i \; \left(x_{ij} - E\left[x_{ij}|R_{t_i}\right]\right)$$

By substituting the vector of regression parameters β with its maximum likelihood estimate $\hat{\beta}$, it is then possible to obtain an estimate of the Schoenfeld residuals. Given that $\hat{\beta}$ is such that

$$\frac{\partial L(\beta)}{\partial \beta_j} = 0$$

it results that the estimated Schoenfeld residuals must sum to zero.

In order to test the proportionality assumption, scaled Schoenfeld residuals (Grambsch and Therneau, 1994) are generally computed by multiplying them by their variance. In particular, given a vector $\hat{r}_i = (\hat{r}_{i1}, \dots, \hat{r}_{ij}, \dots, \hat{r}_{ip})$ where $\hat{r}_{ij}$ is the estimate of the residual for the individual i and the covariate x_j, the corresponding vector of scaled residuals will be equal to

$$\hat{r}_i^* = \left[\widehat{Var}(\hat{r}_i)\right]^{-1} \hat{r}_i$$

and can be easily approximated by

$$\hat{r}_i^* = m\left[\widehat{Var}(\hat{\beta})\right] \hat{r}_i$$

It can be shown that, assuming time-varying regression coefficients

$$\beta_j(t) = \beta_j + \gamma_j g_j(t)$$

where $g_j(t)$ is a function of time, then

$$E\left[r_j(t)\right] \cong \gamma_j g_j(t)$$

This means that if $\gamma_j = 0$ - i.e. if β_j does not change over time - then the scaled Schoenfeld residuals should be centred around an average value of 0. A test can thus be run to test the hypothesis that $\gamma_j = 0$. This is generally done using different functions of time because the significance level of the test usually varies considerably according to the considered function (Hosmer and Lemeshov, 2011). If the test is not significant, then one can conclude that β_j is independent on time and, consequently, that the proportional hazards assumption holds true for the covariate x_j.

If the hazards at the different values of a covariate are not proportional it is possible to specify the Cox regression model in such a way to take into account the time-varying effect of that covariate. This can be easily done by allowing the variable in the model to vary over time, which leads to the estimation of a fixed effect of the covariate and of an interaction term that describes its variation during the period of observation. This corresponds to building a so-called “extended Cox model”, which is defined as

$$h\big(t, x(t)\big) = h_0(t) exp(x(t)\beta) = h_0(t) exp\left(\sum_{j=1}^{p_1} \beta_j x_j + \sum_{m=1}^{p_2} \beta_m(t) x_m\right)$$

where p_1 and p_2 are the numbers of covariates which respectively satisfy and do not satisfy the proportionality assumption, β_j are regression parameters for the covariates that have proportional hazards and $\beta_m(t)$ are the coefficients that quantify the time-varying effects of the covariates whose hazards are not proportional (Ata and Sözer, 2007). It finally results that

$$h\big(t, x(t)\big) = h_0(t) exp\left(\sum_{j=1}^{p} \beta_j x_j + \sum_{j=1}^{p} \gamma_j(t) g_j(t) x_j\right)$$

where p is the total number of covariates and $\gamma_j(t) = 0$ for the covariates with proportional hazards.

Another (maybe simpler) solution would be to stratify the model for the categories of the covariate which has non-proportional hazards. However, this is not appropriate in this study as it would not permit to obtain any information on the effect on the hazards of the variables that describe the health status. Indeed, neither ADL disability nor self-perceived health satisfies the proportionality assumption.

4.3 Results

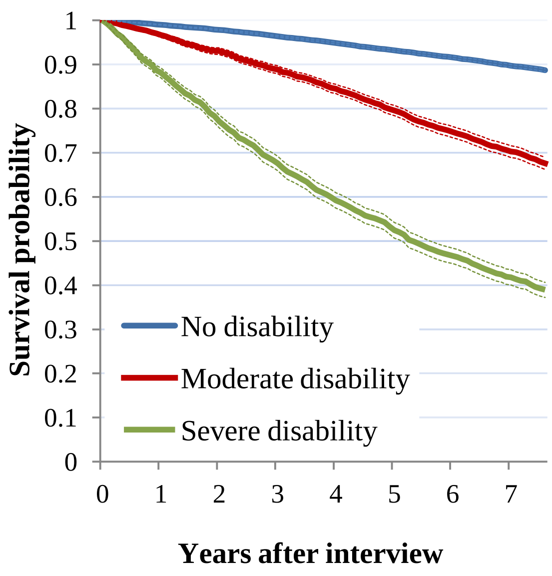
4.3.1 Survival curves by health status at interview

Descriptive results on the implications of ADL disability, multimorbidity and a poor perception of one's general health for survival are reported in this paragraph. The information given by Kaplan-Meier survival curves over the years of follow-up according to health status at baseline interview is also synthesised - for each combination of age, gender and health conditions - by the mean survival times (restricted to the largest time observed in the sample).

Significantly wide mortality gaps emerge between persons who were not functionally impaired and those who, on the contrary, had limitations in at least one usual activity of daily life (Figure 4.1). In fact, 89%, 69% and 41% of individuals who respectively reported to be fully functional, moderately and severely ADL disabled were still alive at the end of follow-up - i.e. 92 months after the interview. These numbers support the hypothesis that ADL disability has a strong predictive power for mortality: indeed, almost all individuals in good functional health survive for quite a long period of time, while considerably higher proportions of people with either moderate or severe limitations in ADLs die each month.

In particular, being in a state of severe ADL disability significantly and importantly reduces the chances of surviving even in the years immediately after the interview: about 10% of people who reported to be severely disabled at baseline died each year and, as a consequence, half of them had already died within slightly more than 5 years. At the same point in time, conversely, approximately 80% of individuals with moderate ADL disability were still alive. This is also reflected by the differences in the mean survival time over the whole period of follow-up: people with severe limitations in ADLs lived 1.5 years and 2.2 years less in comparison to those with no disability and moderate limitations respectively. Indeed, the mean survival time over the period of follow-up is equal to 86.7, 77.5 and 59.9 months (i.e. approximately 7.2, 6.5 and 5.0 years) respectively for people with no, moderate and severe ADL disability (Table 4.1).

Figure 4.1 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by functional status at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

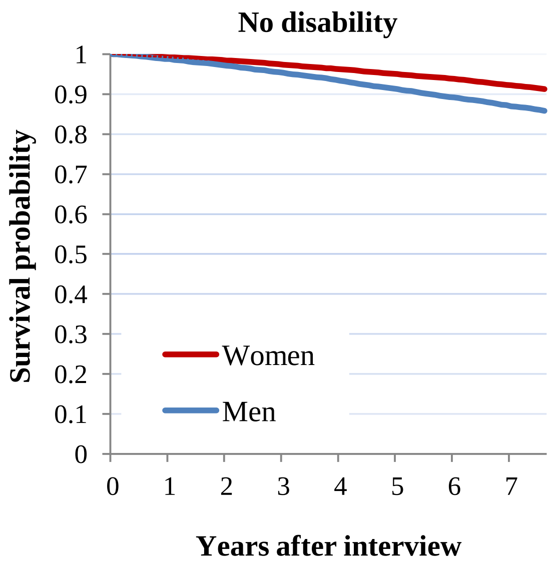
Table 4.1 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to functional status at interview in the population aged 50 years and older.

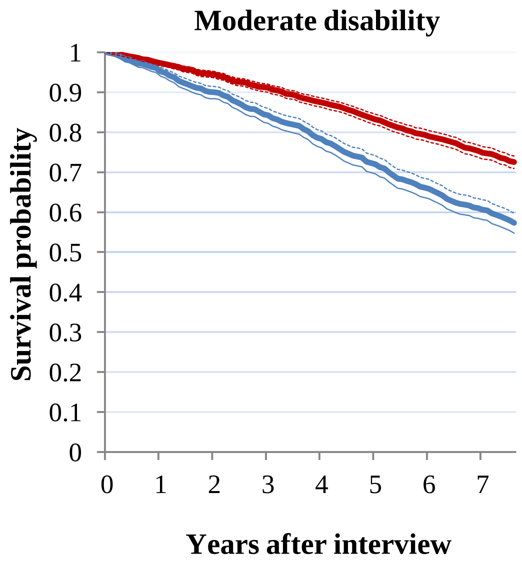
ADL disability	Mean survival time	95% Confidence interval	
		Lb	Ub
No disability	86.7	86.6	86.9
Moderate disability	77.5	76.8	78.2
Severe disability	59.9	58.8	61.0

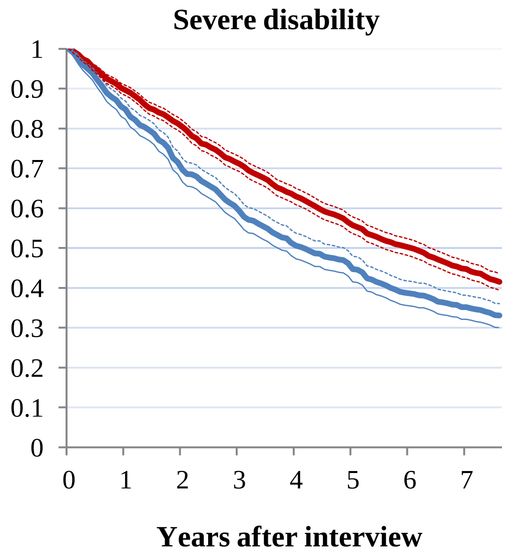
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

With only rare exceptions, survival curves clearly appear to vary significantly between gender and age groups. As expected, women tend to live longer than men: their survival probabilities are constantly higher than those of men over the whole period of follow-up (Figure 4.2). This obviously results in higher proportions of women surviving until the end of the study: 92%, 73% and 43% of women versus 86%, 60% and 36% of men respectively with no, moderate and severe limitations in ADLs were still alive after 91 months of follow-up. Gender differentials, however, are only slightly more pronounced among people with limitations in ADLs (either moderate or severe).

Figure 4.2 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by functional status at interview and gender in the population aged 50 years and over.







Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The mean survival time is always longer among women (despite they have a higher average age), even if the differences are much lower when considering individuals with no or moderate limitations in ADLs (Table 4.2). However, the impact of disability on survival seems to be quite similar between men and women: the reduction in the mean survival time due to the presence of limitations in ADLs differs by approximately 5 months. When considering the median survival time (i.e. the time when half of people is alive), in the group of women with severe limitations in ADLs it is roughly 1.5 years longer as compared to that observed among men with the same level of disability: they are indeed equal to 76 (approximately 6.3 years) and 57 months (approximately 4.8 years) respectively (data not shown in the table).

All these findings are in line with the well-known "health-survival paradox", according to which women usually experience greater survival despite the abundant evidence that they are more subject to poor health.

Table 4.2 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to functional status at interview and gender in the population aged 50 years and over.

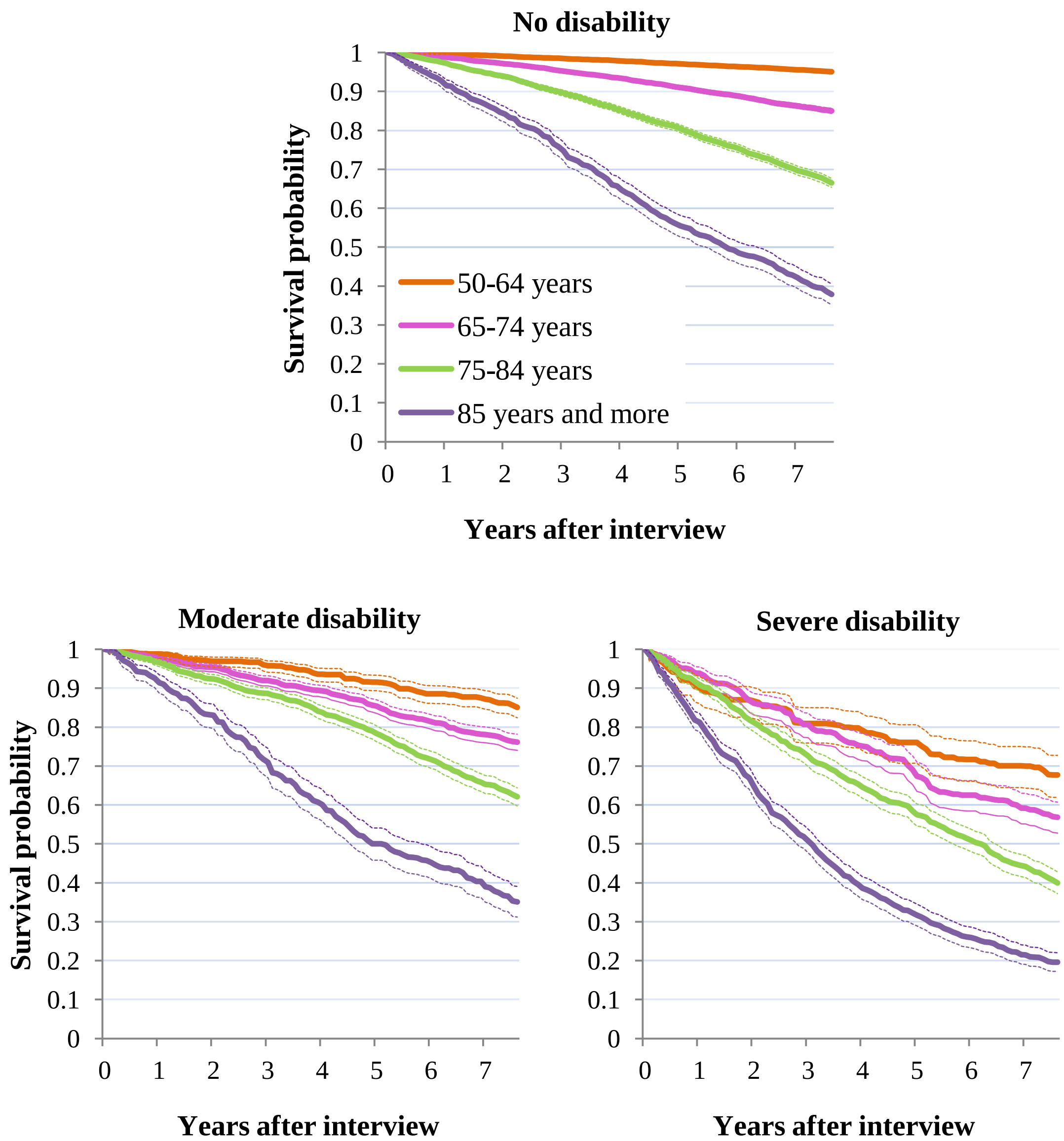
ADL disability	Mean survival time	95% Confidence interval	
		Lb	Ub
Men			
No disability	85.5	85.3	85.7
Moderate disability	72.9	71.5	74.2
Severe disability	54.8	52.8	56.8
Women			
No disability	87.9	87.6	88.0
Moderate disability	79.8	79.0	80.6
Severe disability	62.5	61.1	63.8

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The survival probabilities, obviously, are lower in older age groups over the whole period of follow-up, independently on the presence or severity of functional limitations (Figure 4.3). Overall, age differences appear to be smaller in the first years of follow-up and widen afterwards. Furthermore, the gaps between the three younger age groups (50-64, 65-74 and 75-84 years) are much narrower than that observed between individuals aged 75-84 and 85 years or more.

From the youngest to the oldest age group, the mean survival time decreases by 23.4 and 25.3 months (i.e. approximately 2 years) respectively among people with no or moderate limitations in ADLs, and by 30.3 months (i.e. 2.5 years) among people with severe limitations in ADLs (Table 4.3). The differences in the mean survival times between people with no disability and those with severe functional limitations, on the other hand, increase with age and reach a maximum of 20 months among individuals aged 85 years and older at interview.

Figure 4.3 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by functional status and age group at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

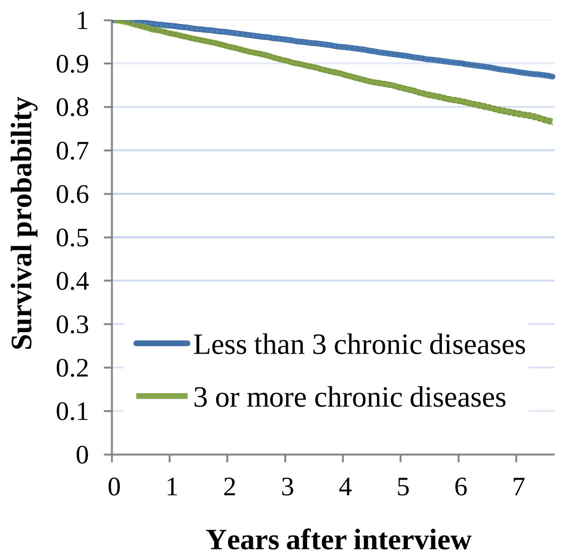
Table 4.3 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to functional status and age group at interview in the population aged 50 years and over.

50 - 64 years			
ADL disability	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
No disability	89.3	89.1	89.4
Moderate disability	85.2	84.0	86.4
Severe disability	76.3	73.3	79.4
65 - 74 years			
ADL disability	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
No disability	85.6	85.3	85.9
Moderate disability	81.4	80.4	82.5
Severe disability	69.3	66.9	71.7
75 - 84 years			
ADL disability	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
No disability	78.9	78.2	79.6
Moderate disability	75.5	74.3	76.7
Severe disability	63.1	61.3	64.8
85 years and more			
ADL disability	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
No disability	65.9	63.7	68.1
Moderate disability	59.9	57.4	62.4
Severe disability	46.0	44.1	47.9

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The effects of multimorbidity on the risk of dying are not as strong as those of ADL disability. Indeed, 87% of people with 0 to 2 chronic disease and 78% of those affected by at least three chronic diseases were still alive at the end of follow-up (Figure 4.4). Data thus seem to support the idea that chronic morbidity - even when it involves more than two diseases - does not reduce by considerable amounts of years the time to be lived at middle and older ages. In other words, people are actually able to live for long periods of time even with multiple diseases. The mean survival time confirms this idea, as people living with 3 or more chronic diseases live only 5 months less than their healthier counterparts (Table 4.4).

Figure 4.4 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by number of chronic diseases at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.4 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to the number of chronic diseases and age group at interview in the population aged 50 years and over.

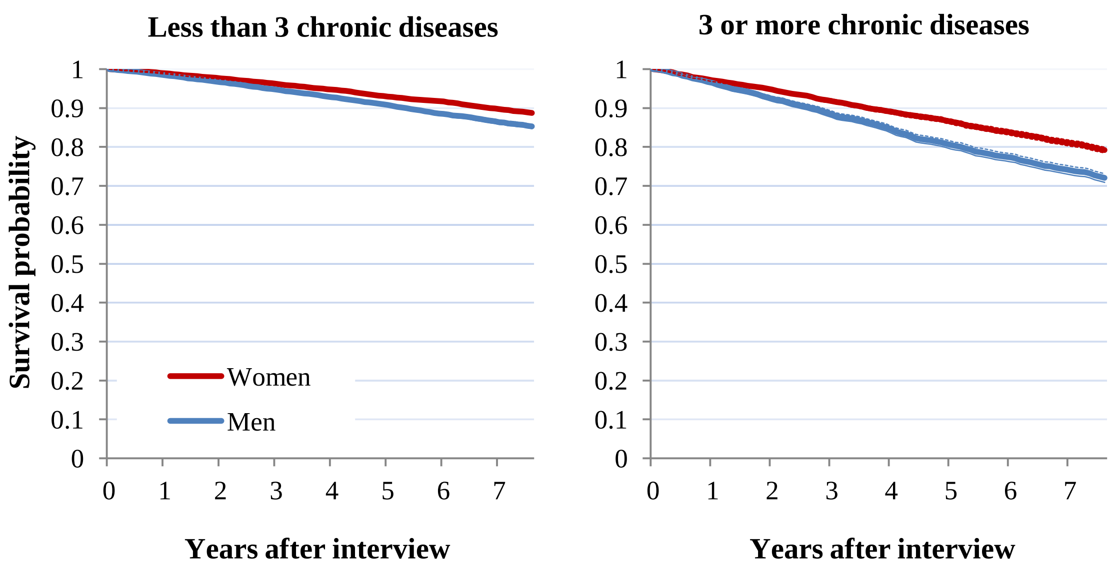
Multimorbidity	Mean survival time	95% Confidence interval	
		Lb	Ub
Less than 3 chronic diseases	85.7	85.6	85.9
3 or more chronic diseases	80.8	80.5	81.2

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Also in the case of multimorbidity, different survival patterns exist between the two genders (Figure 4.5). In particular, 89% of women with no or up to two chronic conditions survived to follow-up, against the 86% of men. On the other hand, 81% of women with multimorbidity survived for the whole period, against the 72% of men. This happens despite the average age among women is higher than among men. The reduction in the mean survival time due to the presence of chronic diseases is only slightly higher among men in respect to women - 6 and 4 months respectively (Table 4.5).

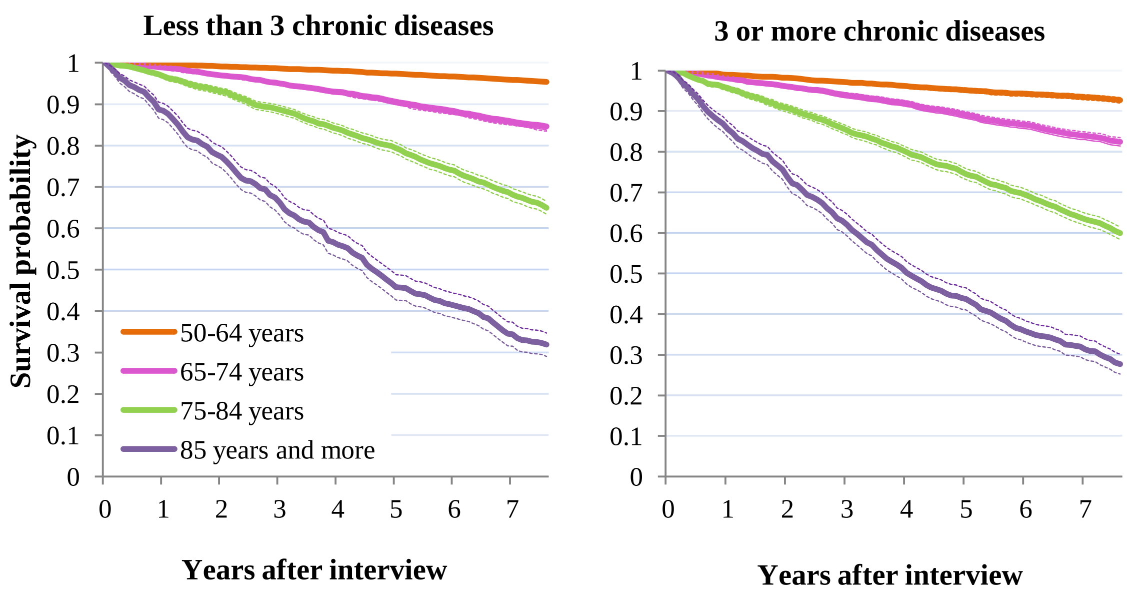
As expected, survival curves vary considerably across age. The oldest age group differs the most from the others, but gaps are clearly visible even between the younger groups (Figure 4.6). However, these differences do not seem to depend on the presence of chronic conditions as they can be observed in both groups of people with 0 to 2 and 3 or more diseases. The differences in the mean survival time according to the number of chronic diseases, indeed, are low even in the oldest age group (Table 4.5).

Figure 4.5 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by number of chronic diseases at interview and gender in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 4.6 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by number of chronic diseases and age group at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.5 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to the presence of chronic diseases at interview and gender in the population aged 50 years and over.

Men			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	85.0	84.8	85.3
3 or more chronic diseases	78.2	77.6	78.8
Women			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	86.5	86.2	86.7
3 or more chronic diseases	82.4	82.0	82.8

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.6 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to the presence of chronic diseases and age group at interview in the population aged 50 years and over.

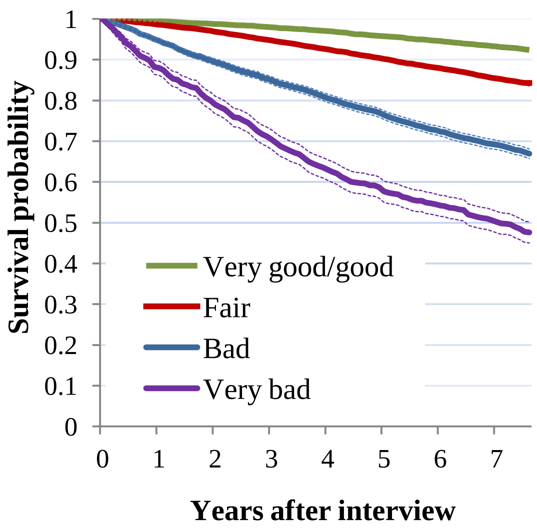
50 - 64 years			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	89.3	89.1	89.4
3 or more chronic diseases	88.0	87.7	88.3
65 - 74 years			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	85.0	84.6	85.4
3 or more chronic diseases	83.4	82.9	83.9
75 - 84 years			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	77.0	76.1	77.8
3 or more chronic diseases	74.2	73.4	75.1
85 years and more			
Multimorbidity	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Less than 3 chronic diseases	57.0	55.1	59.0
3 or more chronic diseases	53.7	51.9	55.4

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Survival curves according to self-rated health at interview have been first explored considering separately each of the five possible categories: very good, good, fair, bad or very bad health. However, those who rate their health as good or very good have nearly identical survival curves. For this reason, they have been grouped together and labelled as people in very good or good health. The same finding has been previously reported for Italy by Egidi and Spizzichino (2006).

The probabilities of surviving decrease considerably along with worsening self-rated health (Figure 4.7): 85%, 68% and 49% of people in fair, bad and very bad self-rated health respectively were still alive at the end of follow-up, against 93% of those who rated their health as good or very good. Perceiving oneself in bad or very bad health thus seems to have a particularly strong impact on mortality, which is almost as strong as that of ADL disability.

Figure 4.7 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by self-rated health at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The mean survival time is equal to 63.3 months (i.e. slightly more than 5 years) for people who felt in very bad health and 75.4 months (i.e. slightly more than 6 years) for those who felt in bad health. This means that being in a very poor or poor general health status reduces the survival time by 2 years and 1 year respectively, as the mean survival time is close to the number of months of follow-up for both people in very good or good and fair health status (i.e. 88.3 and 84.8 months respectively out of 92).

Table 4.7 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to self-rated health and age group at interview in the population aged 50 years and over.

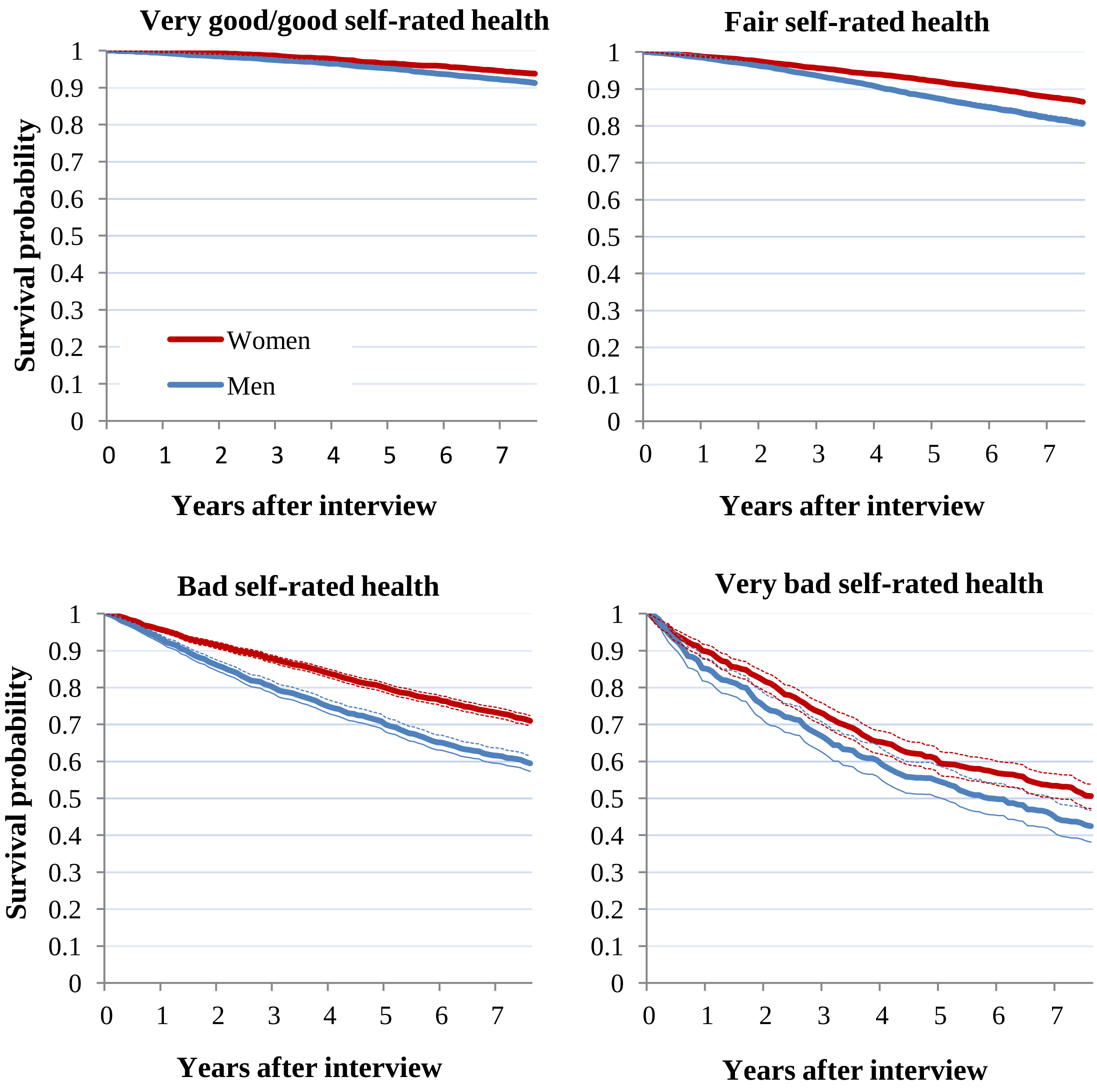
SRH	Mean survival time	95% Confidence interval	
		Lb	Ub
Very good or good	88.3	88.1	88.5
Fair	84.8	84.6	85.0
Bad	75.4	74.7	76.1
Very bad	63.3	61.5	65.0

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Gender gaps - in favour of women - are visible across all possible self-ratings of health, but are generally much wider among people in poor health and narrower between men and women in good health (Figure 4.8). Only in the case of very bad self-rated health the differences between men and women seem to be not significant. However, this could be due to the smaller sample size: fewer interviewees indeed tend to give such an extreme answer when they are asked how they feel about their general health conditions. Differences in the mean survival times between men and women increase only slightly from the highest to the lowest level of self-rated health, reaching a maximum of 6 months among individuals who rated their health as very bad (Table 4.8). The gap between very good or good health and very bad health also differ by some months between men and women: it is more than 2 years (i.e. approximately 28 months) among men and less than 2 years (i.e. approximately 23 months) among women.

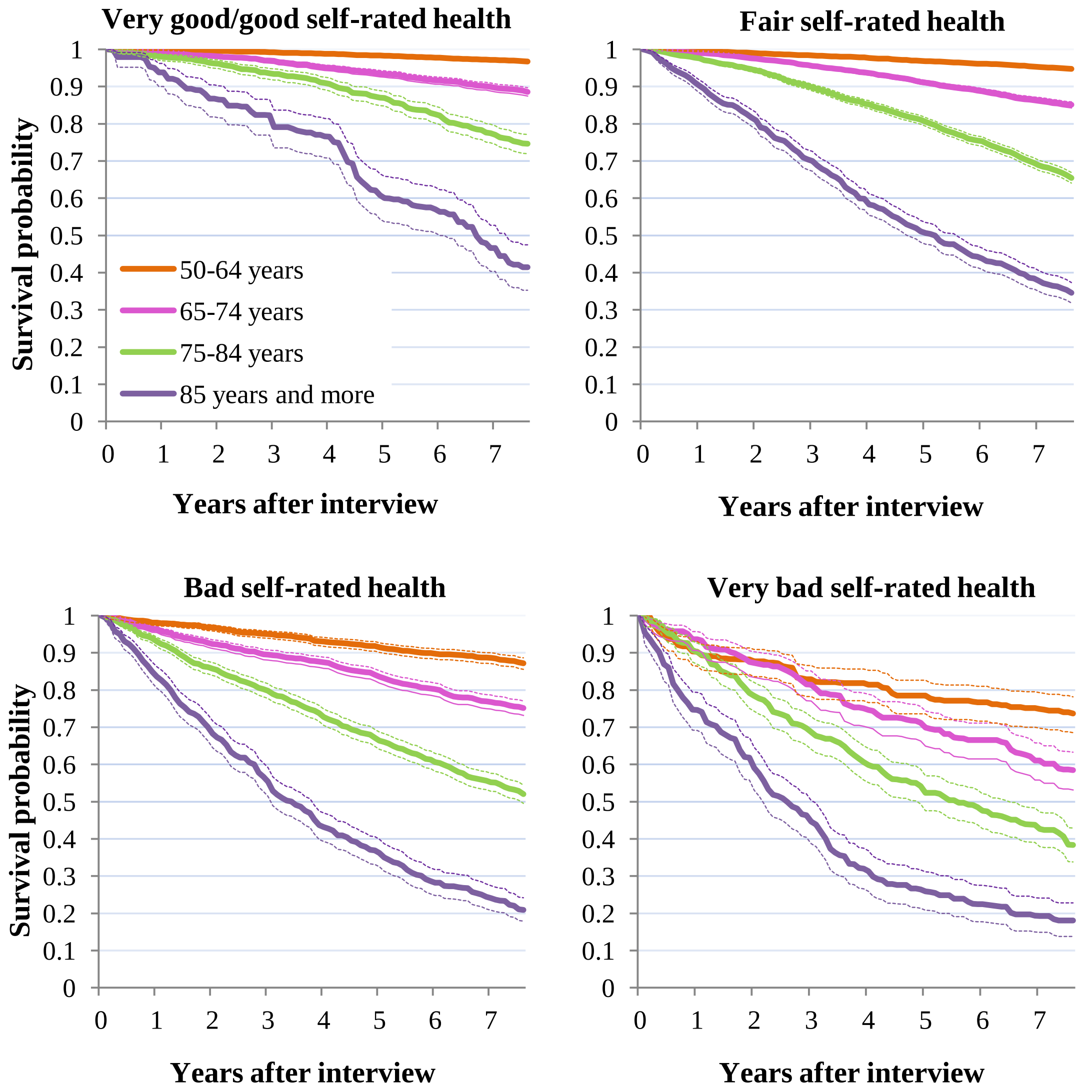
Again, marked differences by age also emerge (Figure 4.9). Smaller differences between the younger age groups are observed among people in good and fair perceived health, while the impact of age on survival seems to be stronger among those declaring a poor health status. As in the case of disability and multimorbidity, being 85 years and older significantly accelerates the occurrence of death: half of the individuals in the oldest age group had already died within slightly more than three years (i.e. 41 months) after having rated their health as bad and slightly less than three years (i.e. 30 months) after having rated their health as very bad. As a consequence, the mean survival times decrease with age, whereas the difference in the mean survival times between the highest and the lowest level of self-rated health increases with increasing age and reach a maximum of 2 years among people aged 85 years and over at interview (Table 4.9).

Figure 4.8 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by self-rated health at interview and gender in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 4.9 - Kaplan-Maier survival curves and 95% confidence intervals over the period of follow-up by self-rated health and age group at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.8 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to self-rated health at interview and gender in the population aged 50 years and over.

Men			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	87.7	87.5	88.0
Fair	83.4	83.1	83.8
Bad	71.1	69.9	72.4
Very bad	59.5	56.6	62.3
Women			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	88.9	88.7	89.2
Fair	85.9	85.7	86.2
Bad	77.8	77.0	78.6
Very bad	65.8	63.7	68.0

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.9 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to self-rated health and age group at interview in the population aged 50 years and over [*to be continued in the next page*].

50 - 64 years			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	89.8	89.7	90.0
Fair	89.1	88.9	89.2
Bad	85.5	84.7	86.3
Very bad	78.0	75.1	81.0
65 - 74 years			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	86.8	86.3	87.4
Fair	85.4	85.0	85.7
Bad	79.5	78.5	80.6
Very bad	69.0	65.9	72.1

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.9 - Mean survival time (in months) over the period of follow-up and 95% confidence intervals according to self-rated health and age group at interview in the population aged 50 years and over [*continued from the previous page*].

75 - 84 years			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	81.8	80.6	83.0
Fair	78.1	77.4	78.9
Bad	68.3	66.8	69.8
Very bad	61.5	58.5	64.5
85 years and more			
SRH	**Mean survival time**	**95% Confidence interval**	
		Lb	**Ub**
Very good or good	67.2	63.7	70.8
Fair	59.6	57.8	61.4
Bad	49.3	46.9	51.7
Very bad	41.3	37.5	45.1

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

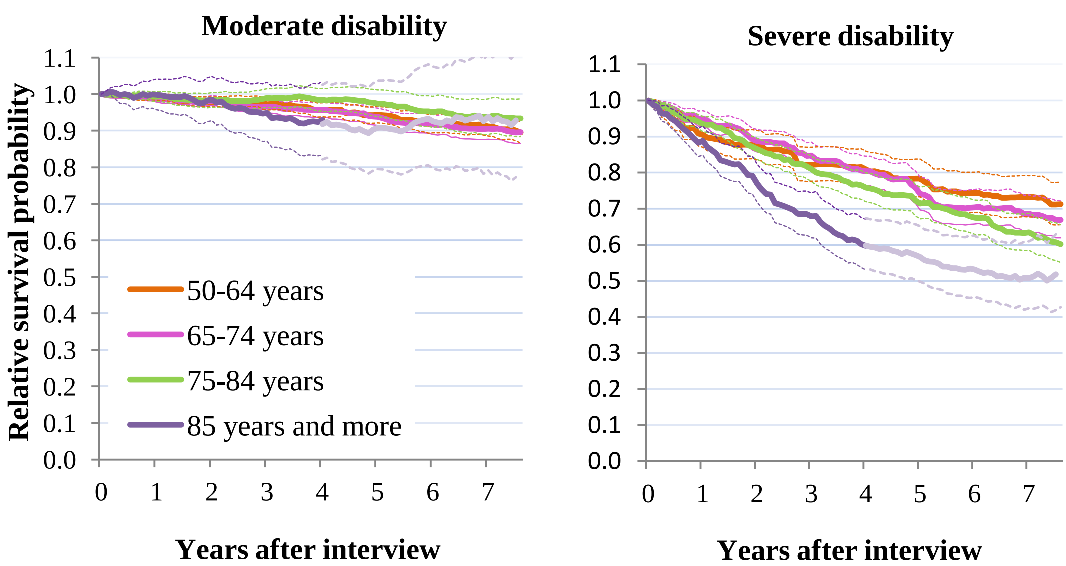
4.3.2 Relative survival curves by health status at interview

Whatever definition of health is adopted, mortality patterns in the period of follow-up according to gender and age group appear to be quite similar between people living in good and poor health. Indeed, gender and age - as well as other characteristics that cannot be easily controlled for in a descriptive analysis - have important effects on mortality independently on the presence of considerable health problems. The calculation of relative survival probabilities allows to isolate the effect on mortality of poor health itself and thus to better unravel the differences in its role in reducing the survival chances of individuals with different basic demographic characteristics. Through relative survival probabilities, indeed, it is possible to quantify the excess mortality due to poor health in the population.

I only included in this paragraph three figures which show relative survival curves according to age at interview for each of the considered dimensions of health: these indeed give the most interesting information. It is important to note that - due to the small size of the group of people aged 85 years and older in both good and poor health status - relative survival curves in this age group are considered to be less informative after 4 years of follow-up. For this reason, survival probabilities and 95% confidence intervals are shown in lighter colours after this period of time. Figures which show relative survival curves in the total, male and female population - are reported in Appendix C.

In the total population aged 50 years and older, the extra risk of dying due to ADL disability - in respect to people with no disability - increase up to approximately 23% and 55% after seven years of follow-up among people with moderate and severe limitations respectively (Figure C.1 in Appendix C). Gender gaps reflect those observed between traditional survival curves, meaning that women have a lower excess mortality due to disability and thus live longer than men even when they have severe limitations in ADLs (Figure C.2 in Appendix C). Moreover, relative survival probabilities are quite similar across age groups during the whole period (Figure 4.10). This is especially true for people with moderate levels of disability but also for those affected by severe disability, whose survival patterns do not significantly diverge by age with the only exception of the oldest group. The finding that the excess mortality due to disability does not change considerably with age is compatible with the idea that the duration of functional limitations before death is similar for people in different stages of their life.

Figure 4.10 - Relative survival curves and 95% confidence intervals over the period of follow-up for moderate and severe disability according to age group at interview in the population aged 50 years and over.

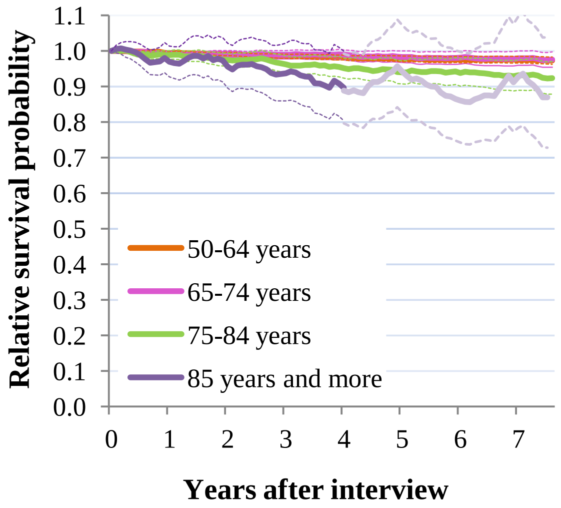


Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Relative survival probabilities for people with multimorbidity confirm the much lower impact of chronic diseases on survival probabilities in comparison with ADL disability:

the overall excess mortality of all individuals aged 50 years and older affected by multimorbidity increases only up to slightly more than 10% after seven years of follow-up (Figure C.3 in Appendix C). Again, the relative survival curve of women is above that of men suggesting that women live for longer periods of time with multiple chronic conditions, with a difference of 12% (Figure C.4 in Appendix C). Also in this case, moreover, age differences appear to be relatively narrow (Figure 4.11). The length of life with chronic morbidities can be thus expected to be similar independently of the age at onset of diseases.

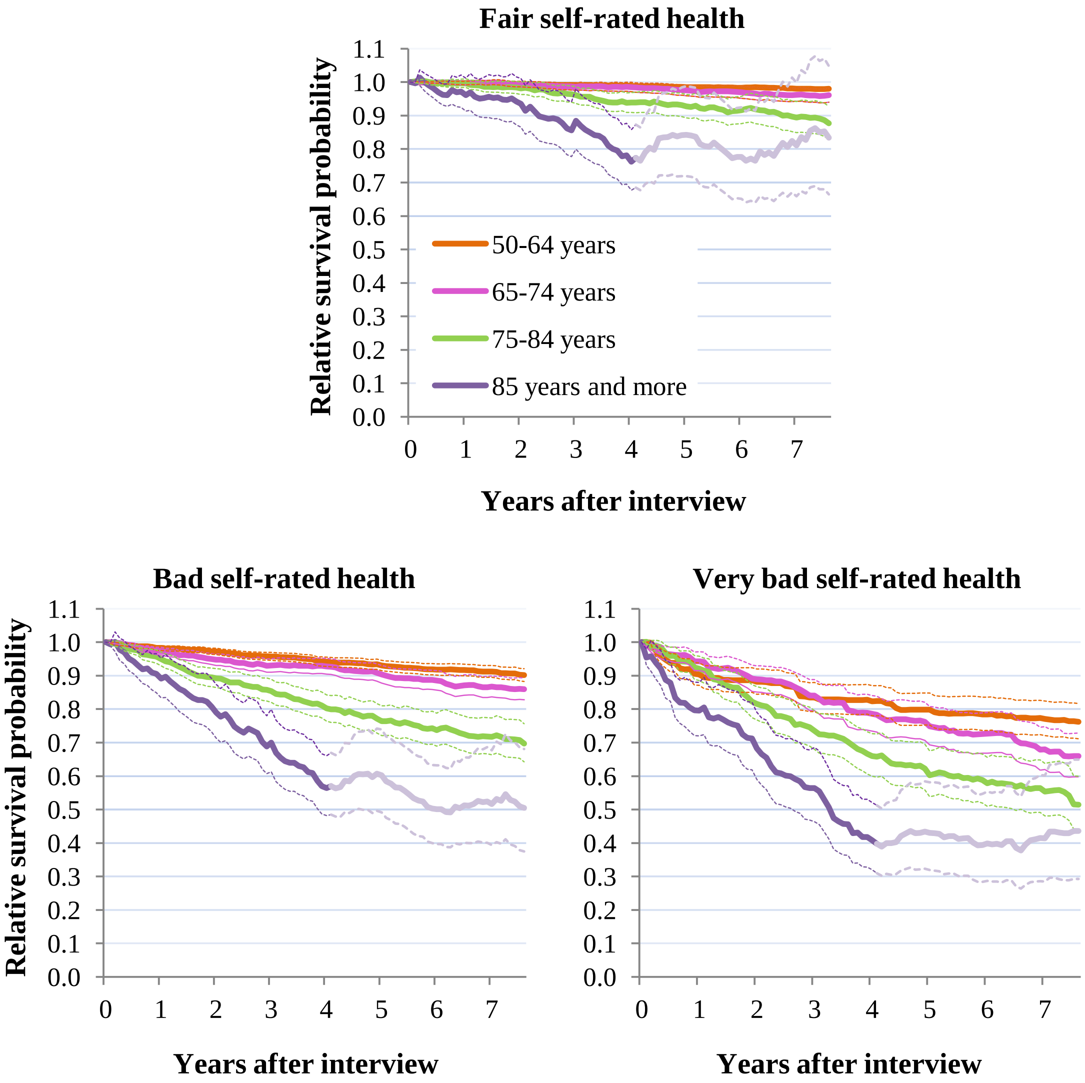
Figure 4.11 - Relative survival curves and 95% confidence intervals over the period of follow-up for multimorbidity according to age group at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Finally, individuals aged 50 years and older declaring to perceive themselves in a fair, poor and very poor health status have mortality risks approximately 9%, 27% and 51% higher than those of people in good health over the period of follow-up (Figure C.5 in Appendix C). Once again, it is shown that women in poor health live longer than men in the same conditions, but a different situation - in respect to what has been said for the other two dimension of health - emerges from the analysis by age (Figure C.6 in Appendix C). Wider differences are indeed observed for different age groups in the levels of excess mortality associated with a poor self-perceived health status (Figure 4.12).

Figure 4.12 - Relative survival curves and 95% confidence intervals over the period of follow-up for fair, bad and very bad self-rated health according to age group at interview in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

4.3.3 Multivariate analysis

Kaplan-Meier and relative survival curves according to health status at interview show that the three considered dimensions of poor health have different impacts on mortality in the subsequent years. In particular, multimorbidity does not seem to play an important role as a determinant of mortality as compared to ADL disability and very poor and poor self-rated health, which considerably reduces survival over the 7 years of follow-up. The next pages report the results of a multivariate analysis which confirm this finding.

Cox regression analysis indeed proves that the effect of multimorbidity on 7-years survival in the total population is not statistically significant when all indicators of poor health - as well as social and demographic characteristics other than gender and age - are controlled for. On the contrary, both ADL disability and poor levels of self-rated health act as strong independent predictors of mortality. Their effects, however, are not constant over the years of follow-up: the proportionality assumption is violated for both these variables, meaning that the hazards at their different values are not proportional. Estimates of the regression parameters of an extended Cox model - including interactions of functional and perceived health with time - lead to decreasing hazard ratios of severe ADL disability and fair, bad and very bad self-rated health actually decrease over the period of follow-up. This proves that the strength of the association between poor health and mortality in the population decreases over the period of follow-up. All other covariates - with the only exception of age - satisfy the proportionality assumption.

The estimated coefficients and hazard ratios from the traditional Cox model - with no interactions with time - are reported in Table 4.10. The effects of socio-demographic variables on mortality immediately appear to be in accordance with the existing literature. The negative coefficient for women indicates that, as expected, they have lower mortality risks in respect to men. More precisely, the female gender corresponds to a 50% reduction in the risk of dying [HR=0.50].

Advancing age - obviously - also strongly and positively affects the risk of dying: hazard ratios indeed always more than double from one age group to the next [HR=2.81 for ages 65-74; HR=5.96 for ages 75-84; HR=11.94 for ages 85 years and more]. However, these can be considered as average effects of age on mortality for the period of follow-up: as it will be demonstrated by the results of the extended Cox model, hazard ratios for the different age groups actually changes over the years of follow-up.

Even if geographical differences in mortality appear to be low, northern Italy is the most disadvantaged area of the country in terms of survival. Indeed, living in the central and southern areas of Italy involves a reduction of 11% [HR=0.89] and 8% [HR=0.92] respectively in the risk of death compared to living in the North. On the other hand, the reduction in the risk of death observed for the Centre does not significantly differ from that observed for the South of Italy.

Marital status has an important impact on mortality: living outside marriage is associated with a 25% increase in mortality risks in comparison with being married. Socioeconomic differences are also evident: having a low educational level involves a 16% higher risk of dying compared to individuals who have at least a high school diploma. However, there are no significant differences between people with high and medium education and between people with low and medium education.

As far as health status is concerned, results show that people with moderate ADL disability can be expected to have a 40% higher risk of death compared to individuals with no limitations in ADLs. Moreover, the risk of dying in 7 years among people with severe ADL disability is estimated to be more than double in respect to that of people without limitations in ADLs [HR=2.22]. Similarly, individuals declaring to perceive themselves in a fair, bad or very bad self-perceived health status respectively have a 45% higher [HR=1.45], more than double [HR=2.22] and almost triple [HR=2.82] risk of dying comparing to people with good or very good self-rated health. As in the case of age, however, it must be considered that the hazard ratios for severe ADL disability and all levels of self-rated change over time.

As anticipated at the beginning of the paragraph - the hazard ratio of multimorbidity is not statistically significant, meaning that having multiple chronic conditions does not reduce survival.

Table 4.10 - Coefficients and hazard ratios with 95% confidence intervals estimated from the traditional Cox regression model in the population aged 50 years and over.

Covariate	Coeff.		95% CI Lb	95% CI Ub	HR		95% CI Lb	95% CI Ub
Sex								
Men (ref.)	0.00				1.00			
Women	-0.69	***	-0.76	-0.65	0.50	***	0.47	0.52
Age								
50-64 (ref.)	0.00				1.00			
65-74	1.03	***	0.96	1.11	2.81	***	2.61	3.02
75-84	1.79	***	1.71	1.86	5.96	***	5.53	6.42
85+	2.48	***	2.39	2.57	11.94	***	10.91	13.05
Educational level								
High (ref.)	0.00				1.00			
Medium	0.09		-0.02	0.19	1.09		0.98	1.21
Low	0.15	***	0.06	0.23	1.16	***	1.06	1.26
Area of residence								
North (ref.)	0.00				1.00			
Centre	-0.12	***	-0.19	-0.06	0.89	***	0.83	0.94
South and islands	-0.08	***	-0.14	-0.04	0.92	***	0.87	0.96
Marital status								
Married (ref.)	0.00				1.00			
Not married	0.22	***	0.17	0.27	1.25	***	1.18	1.31
ADL disability								
No disability (ref.)	0.00				1.00			
Moderate disability	0.34	***	0.27	0.40	1.40	***	1.31	1.49
Severe disability	0.80	***	0.72	0.87	2.22	***	2.06	2.39
Multichronicity								
Less than 3 chronic diseases (ref.)	0.00				1.00			
3 or more chronic diseases	-0.03		-0.07	0.02	0.97		0.93	1.02
Self-rated health								
Good or very good (ref.)	0.00				1.00			
Fair	0.37	***	0.30	0.44	1.45	***	1.35	1.56
Bad	0.80	***	0.71	0.88	2.22	***	2.03	2.42
Very bad	0.99	***	0.88	1.10	2.69	***	2.41	3.00

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 4.11 reports, for each category of the variables, the slope of the regression line of scaled Schoenfeld residuals versus time and the logarithm of time (which is one of the most used transformations in the available literature), together with the p-value of the test of the null hypothesis that the slope is different from zero. This table provides evidence that the proportionality assumption may be violated for age, severe ADL disability and all levels of self-rated health: it is shown that the corresponding p-values are generally lower than the conventional significance threshold of 0.05 and often even lower than 0.001, meaning that the proportionality assumption cannot be assumed as true. For all other covariates, the slopes are never significantly different from zero and it is thus not necessary to include their interactions with time in the extended Cox model[12].

Table 4.11 - Test of the proportionality assumption: slope of the regression line of scaled Schoenfeld residuals versus time and the logarithm of time (γ) and corresponding p-values

Covariate	**t**		**log(t)**	
	γ	**p value**	**γ**	**p value**
Sex: Men	0.009	0.427	0.006	0.614
Age: 65-74	0.018	0.109	0.023	**0.041**
Age: 75-84	0.050	**0.000**	0.055	**0.000**
Age: 85+	0.021	0.052	0.033	**0.003**
Educational level: Medium	0.021	0.068	0.010	0.382
Educational level: Low	0.014	0.202	0.006	0.593
Area of residence: Centre	0.017	0.141	0.021	0.071
Area of residence: South and Islands	0.024	**0.036**	0.020	0.085
Marital Status: Not married	0.014	0.217	0.010	0.362
ADL disability: Moderate	0.000	0.974	-0.006	0.599
ADL disability: Severe	-0.032	**0.004**	-0.039	**0.000**
Multichronicity: 3 or more diseases	0.006	0.616	0.017	0.127
Self-rated health: fair	-0.029	**0.011**	-0.023	**0.046**
Self-rated health: bad	-0.070	**0.000**	-0.070	**0.000**
Self-rated health: very bad	-0.081	**0.000**	-0.091	**0.000**

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

[12] The proportionality test actually indicates that the slope of the regression line of scaled Schoenfeld residuals versus time is significantly different from zero for the category *South and Islands* of the variable *Area of residence*. However, when included in an extended Cox model as a time-varying covariate, this variable did not have a significant interaction with time. I thus treated it as a variable with proportional hazards.

In order to account for possible nonproportionality I allowed age, ADL disability and self-rated health to vary over time by including interactions between these covariates and the variable *time after interview* in the extended version of the Cox regression model. Two coefficients are thus estimated from the model for each considered covariate: one is independent on time and can be referred to as the "main effect" of a variable, whereas the second measures its variation over time. Results are reported in Table 4.12[13].

As expected, the main effects of all variables are statistically significant and reveal a strong positive influence of age and health status on mortality.

For what concerns age, moreover, a positive significant interaction with time is observed for the groups 75-84 and 85 years and over. This means that the hazard ratios estimated for individuals of these ages increase over time, and thus that the effect of age on mortality becomes stronger year after year. This was somehow expected and can be interpreted as an ageing effect, because the age groups are large (10-15 years) and the follow-up period long enough for the average age of individuals in the cohorts to increase.

Interactions with time are also significant for severe ADL disability and all levels of self-rated health. However, the direction of change is opposite in respect to what observed for age. The interaction terms are indeed negative for both dimensions of health, showing that the strength of the association of severe limitations in ADLs and fair, bad and very bad self-rated perceived health with mortality is highest in the first years of follow-up and then diminishes over time. The values of the coefficients demonstrate that the greatest variation over time is observed for bad [β= -0.011] and very bad [β= -0.016] self-rated health, while a similar pattern of variation is observed for fair self-perceived health and severe ADL disability [β= -0.003 and β= -0.004 respectively].

[13] It is worth noting that all the covariates included in the traditional model are also controlled for in the extended model. However, their coefficients remain equal to those reported in Table 4.10 and, for this reason, they are not included again in Table 4.12.

Table 4.12 - Coefficients and 95% confidence intervals from the extended Cox regression model quantifying the main effect and its variation over time for the covariates age, disability and self-rated health in the population aged 50 years and over*.

Main effects				
Covariate	**Coeff.**		**95% CI Lb**	**95% CI Ub**
Age				
50-64 (ref.)	0.00			
65-74	0.91	***	0.75	1.06
75-84	1.42	***	1.26	1.58
85+	2.26	***	2.08	2.44
ADL disability				
No disability (ref.)	0.00			
Moderate disability	0.33	***	0.19	0.47
Severe disability	0.96	***	0.81	1.10
Self-rated health				
Good or very good (ref.)	0.00			
Fair	0.56	***	0.39	0.72
Bad	1.31	***	1.12	1.5
Very bad	1.69	***	1.47	1.91
Interactions with time				
Covariate	**Coeff.**		**95% CI Lb**	**95% CI Ub**
Age				
50-64 (ref.)	0.000			
65-74	0.002		0.000	0.005
75-84	0.007	***	0.004	0.010
85+	0.004	*	0.001	0.007
ADL disability				
No disability (ref.)	0.000			
Moderate disability	0.003		0.000	0.005
Severe disability	-0.004	***	-0.006	-0.001
Self-rated health				
Good or very good (ref.)	0.000			
Fair	-0.003	***	-0.007	-0.002
Bad	-0.011	***	-0.014	-0.007
Very bad	-0.016	***	-0.020	-0.011

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05

* All the other covariates (i.e. gender, educational level, geographical area of residence, marital status and multimorbidity) are also included in the models, but the values of their coefficients are not reported here because they are equal to those reported in Table 4.10

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Time-varying hazard ratios for covariates with nonproportional effects on the outcome can be calculated using the parameters estimated by an extended Cox proportional hazard model as $\exp(\beta + \beta_t \cdot t)$, where β is the main effect of a variable, β_t is the coefficient representing the variation of the main effect over time and t is the variable for time (Schemper, 1992). In this study, I estimated nonproportional hazard ratios and 95% confidence intervals at different years of follow-up for severe ADL disability and fair, bad or very bad self-perception of the general health status.

Table 4.13 presents the results for severe ADL disability. It emerges that immediately after the interview people with severe limitations in ADLs have a risk of dying that is 2.64 times higher in respect to individuals who have no difficulties in the main activities of their daily life. However, the annual decrease in hazard ratio is such that after seven years the increase in the risk of death associated with being disabled is much lower, as the hazard ratio at this moment in time is equal 1.88.

Table 4.13 - Time-varying Hazard ratios and 95% confidence intervals from the extended Cox regression model for severe disability in the population aged 50 years and over.

Covariate	Years after interview	HR	95% CI	
			Lb	Ub
Severe ADL disability	0	2.64	2.27	3.03
	1	2.51	2.23	2.82
	2	2.39	2.18	2.62
	3	2.28	2.11	2.46
	4	2.17	2.02	2.34
	5	2.07	1.90	2.26
	6	1.98	1.78	2.20
	7	1.88	1.65	2.15

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The situation is slightly different as far as self-rated health is concerned (Table 4.14). The effect on mortality of the considered categories of this variable varies over time in different ways. The decrease in the hazard ratio associated with a fair self-perceived health status - as expected based on the interactions with time estimated by the extended Cox model - is similar to that observed for severe disability. In seven years, the hazard ratio decreases linearly from a starting value of 1.86 to reach a value of 1.30. On the contrary, the decrease in the additional risk of dying associated with bad or very bad SRH is much stronger and shows a more exponential rather than linear pattern. In particular, the hazard ratio decreases in seven years from 3.74 to 1.51 for bad SRH and from 5.47 to 1.57 for very bad SRH.

Table 4.14 - Time-varying Hazard ratios and 95% confidence intervals estimated from the extended Cox regression model for fair, bad and very bad self-rated health in the population aged 50 years and over.

Covariate	Years after interview	HR	95% CI	
			Lb	Ub
Fair SRH	0	1.86	1.58	2.18
	1	1.76	1.55	2.01
	2	1.68	1.51	1.86
	3	1.59	1.46	1.73
	4	1.51	1.41	1.62
	5	1.44	1.34	1.54
	6	1.37	1.25	1.49
	7	1.30	1.16	1.45
Bad SRH	0	3.74	3.16	4.53
	1	3.32	2.86	3.85
	2	2.91	2.58	3.28
	3	2.55	2.31	2.81
	4	2.24	2.05	2.44
	5	1.96	1.79	2.15
	6	1.72	1.54	1.93
	7	1.51	1.31	1.74
Very bad SRH	0	5.47	4.44	6.82
	1	4.60	3.85	5.46
	2	3.84	3.34	4.41
	3	3.21	2.86	3.61
	4	2.69	2.40	3.00
	5	2.25	1.97	2.56
	6	1.88	1.59	2.21
	7	1.57	1.28	1.92

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

To evaluate and compare the goodness of fit of the two models (the traditional model which does not include interactions with time and the extended model which includes interactions with time), the log likelihood statistic is presented in Table 4.15 together with the values of the likelihood ratio test and the corresponding p-values. As it is possible to see, all indicators suggest that the extended model has a better fit in comparison to the traditional proportional hazard model that do not include any interaction term to allow for the association of covariates with time. Data thus confirm that the extended Cox regression model should be preferred in this case in order to obtain correct estimates of the impact of ADL disability and low levels of self-rated health on mortality.

Table 4.15 - Goodness of fit statistics for the traditional and extended Cox regression models

Goodness of fit	**Traditional model**	**Extended model**
Degrees of freedom	15	23
Log likelihood	-75975.7	-75896.5
Likelihood Ratio Test (p value)	10165.8 (0.000)	10324.3 (0.000)

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

When considering men and women separately, some differences emerge (Table 4.16). In particular, the effect of a low or medium educational level on mortality is only significant among men. Moreover, estimated differences in the risk of death between people living in the South and in the North of Italy appear to be not statistically significant among women.

For what concerns health status, the main differences between men and women is that the strengths of the association between severe ADL disability and mortality risks declines over the years of follow-up only among men. For women - as it is proved by the results of the proportionality tests - the impact on survival of severe limitations over time is actually constant over time [HR=2.39]. The effects of perceiving oneself in a fair, bad or very bad health are similar for the two genders and decrease over time among both men and women. Multimorbidity does not reduce the survival chances in the period of follow-up neither among men nor women.

Table 4.16 - Coefficients and 95% confidence intervals from the extended Cox regression model including interaction terms between time and the covariates age, ADL disability and self-rated health among men and women aged 50 years and over.

	Men				Women			
Covariate	**Coeff.**		**95% CI Lb**	**95% CI Ub**	**Coeff.**		**95% CI Lb**	**95% CI Ub**
Main effects								
Age								
50-64 (ref.)	0.00				0.00			
65-74	0.95	***	0.75	1.15	0.82	***	0.56	1.08
75-84	1.45	***	1.25	1.66	1.39	***	1.13	1.64
85+	2.07	***	1.83	2.32	2.40	***	2.12	2.67
Educational level								
High (ref.)	0.00				0.00			
Medium	0.11		-0.01	0.23	0.003		-0.18	0.18
Low	0.20	***	0.09	0.30	0.050		-0.10	0.19
Area of residence								
North (ref.)	0.00				0.00			
Centre	-0.24	*	-0.42	-0.05	-0.11	*	-0.20	-0.02
South and islands	-0.31	***	-0.46	-0.16	-0.06		-0.14	0.01
Marital status								
Married (ref.)	0.00				0.00			
Not married	0.22	***	0.14	0.29	0.21	***	0.13	0.29
ADL disability								
No disability (ref.)	0.00				0.00			
Moderate disability	0.34	***	0.14	0.54	0.37	***	0.17	0.58
Severe disability	1.06	***	0.85	1.27	0.92	***	0.72	1.14
Multichronicity								
Less than 3 chronic diseases (ref.)	0.00				0.00			
3 or more chronic diseases	0.04		-0.02	0.11	-0.09	**	-0.17	-0.03
Self-rated health								
Good or very good (ref.)	0.00				0.00			
Fair	0.55	***	0.34	0.76	0.58	***	0.31	0.85
Bad	1.43	***	1.18	1.67	1.23	***	0.94	1.52
Very bad	1.67	***	1.36	1.98	1.72	***	1.38	2.05
Interactions with time								
Age								
50-64 (ref.)	0.00				0.00			
65-74	0.001		-0.002	0.004	0.004		0.000	0.009
75-84	0.006	***	0.002	0.009	0.009	***	0.004	0.013
85+	0.004		0.000	0.009	0.003		-0.001	0.008
ADL disability								
No disability (ref.)	0.000							
Moderate disability	-0.001		-0.004	0.003	0.001		-0.003	0.004
Severe disability	-0.009	***	-0.013	-0.004	-0.001		-0.005	0.003
Self-rated health								
Good or very good (ref.)	0.000							
Fair	-0.012		-0.007	0.003	-0.004		-0.009	0.000
Bad	-0.012	***	-0.016	-0.007	-0.010	***	-0.015	-0.005
Very bad	-0.015	***	-0.021	-0.009	-0.016	***	-0.022	-0.010

Levels of significance: *** $p<0.001$, ** $p<0.01$, * $p<0.05$

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5. “Looking backward”: the association between poor health and proximity to death

5.1 Introduction

The analysis presented in the previous chapter has been carried out from a “looking forward” perspective, with the aim of understanding how the different dimensions of poor health influence the timing of death. Following this approach, individuals have been grouped according to their health status at the moment of interview in order to estimate and compare their risks of death over the subsequent years. Conversely, the analysis reported in the present chapter has been carried out in a “looking backward” perspective. The main goal was indeed to evaluate the risk of a person to be in poor health, given that he/she is destined to die within a definite amount of time. In this case, thus, individuals have been grouped according to the number of years remaining until death at the moment of interview in order to evaluate and compare their health conditions.

First of all, the results of a descriptive analysis are reported to provide information on the prevalence of the three considered dimensions of poor health (i.e. ADL disability, multimorbidity and bad or very bad self-rated health) according to proximity to death among older adults and older people. In particular, the proportion in poor health is first calculated among decedents (i.e. all those individuals who died within seven years from the 1999-2000 HIS interview) and among survivors (i.e. all the others). Then, the prevalence of poor health is studied more in depth among decedents according to the number of years remaining until death in order to assess its increase from the group most distant from death to the group closest to death. In this descriptive part of the study, only two demographic variables are considered: gender and age.

Afterwards, the strength of the association between health status, age and proximity to death is investigated analytically using multivariate logistic regression analysis. In particular, separate models with each measure of poor health as the outcome variable are presented. The effects of the interactions of proximity to death with age and gender are also investigated in order to identify potential differences between men and women or between age groups.

Similarly to the previous chapter, a brief overview of methods is first given in paragraph 5.2 before the presentation of the results, to which paragraphs 5.3 and 5.4 are entirely dedicated.

5.2 Overview of methods

As anticipated in the introduction, the multivariate analysis has been conducted using logistic regression methods. Depending on the number of categories of the variable of health status included as the outcome, binary or multinomial logistic regression models have been estimated in order to investigate the impact of age and proximity to death on the risk of being in poor health at the moment of interview.

In particular, the effects of the covariates on multimorbidity are analysed in simple logistic models, as this variable has only two possible categories (3 or more VS 0 to 2 chronic diseases). On the other hand, the effects of the covariates on ADL disability and self-rated health are investigated using multinomial logistic regression models. Both these variables have indeed more than two possible categories.

5.2.1 Binary logistic regression models

Logistic regression analysis assumes that the logarithm of the odds of the probability that the outcome occurs in the target population can be expressed as a linear combination of k explanatory variables as in the following equation:

$$logit(\pi) = ln\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_i x_i + \cdots + \beta_k x_k$$

The odds of π are defined as the ratios of the probability that the outcome occurs to the probability that the outcome does not occur and can assume values in the range $(0, +\infty)$. As a consequence, their logarithmic transformations have an unlimited range of possible values. The regression parameters $\beta_i, 1 \leq i \leq k$ give an estimate of the impact of the different covariates on the logit of the probability π. By taking the exponential of the β coefficients it is possible to obtain the so-called Odds Ratios (ORs), which measure the strength of the association of the covariates with the dependent variable.

Let us consider a categorical covariate x_i which can only assume two values (the simplest case possible): for instance, 1 and 2. Then, π_1 and π_2 are the probabilities that individuals for whom $x_i = 1$ and $x_i = 2$ respectively experience the outcome of interest, while $Odds_1$ and $Odds_2$ are the corresponding odds. The OR is thus defined as

$$OR = \frac{Odds_1}{Odds_2} = \frac{\pi_1}{1 - \pi_1} \cdot \frac{1 - \pi_2}{\pi_2}$$

and quantifies the difference between the odds of the probability to experience the outcome of interest estimated in the group of individuals for whom $x_i = 1$ and that estimated in the group of individuals for whom $x_i = 2$.

The OR calculated according to the formula above can assume values between 0 and $+\infty$, with a value of 1 meaning that the odds of experiencing the outcome does not change between the different categories of the covariate, and thus that no association exists between the covariate and the outcome variable. On the contrary, an OR higher than 1 indicates that the odds of experiencing the outcome is higher among individuals for whom $x_i = 1$ as compared to individuals for whom $x_i = 2$. In such a case, a positive association emerges between the covariate and the outcome. An OR lower than 1 indicates that the odds of experiencing the outcome is lower among individuals for whom $x_i = 1$ as compared to individuals for whom $x_i = 2$, meaning that a negative association exists between the covariate and the outcome variable.

5.2.2 Multinomial logistic regression models

The multinomial logistic regression model is a generalisation of the binary logistic model that can be used when the outcome variable has more than 2 categories.

Let us consider a dependent variable Y than can assume one among $1 \leq j \leq J$ values. Then, $\pi_{ij} = Pr\{Y_i = j\}$ is defined as the probability that Y assumes the generic value j for the individual i. Given that the categories of the variable are mutually exclusive and exhaustive, we clearly have that

$$\sum_{j=1}^{J} \pi_{ij} = 1$$

which means that - for each individual or group of individuals with the same characteristics - the probabilities that the outcome variable assumes the different possible values sum to 1.

Multinomial logistic regression is based on the assumption that the logit of the relative risk that the outcome variable assumes a value equal to j as compared with another specific value chosen as the reference category can be expressed in a linear form, as in the following equation:

$$logit(\pi_{ij}) = ln\left(\frac{\pi_{ij}}{\pi_{iJ}}\right) = \alpha_0 + x_i'\beta_j$$

where π_{iJ} is the probability that the outcome variable assumes the last value - i.e. J[14] - for the individual or group i and β_j (with $1 \leq j \leq J-1$) is the vector of regression coefficients. Thus, it appears that the multinomial logistic regression models are completely analogous to binary logistic models, except from the fact that they consist of a total of $J-1$ equations rather than only one.

By taking the exponential of the regression parameters estimated from a multinomial logistic model, we obtain the so-called Relative Risk Ratios (RRR). Let us consider a categorical covariate x_i which can only assume two values: 1 and 2. Then, π_{1j} and π_{2j} are the probabilities that individuals for whom $x_i = 1$ and $x_i = 2$ respectively experience the outcome j. Then, π_{1j}/π_{1J} and π_{2j}/π_{2J} are the corresponding relative risks and the RRR can be defined as follows:

$$RRR = \frac{\pi_{1j}}{\pi_{1J}} \cdot \frac{\pi_{2J}}{\pi_{2j}}$$

Similarly to the ORs estimated through binary logistic regression analysis, RRRs measure the strength of the association between a covariate and the outcome variable and can assume values in the range $[0, +\infty]$. In particular, a RRR equal to 1 indicates that no

[14] It should be noted that each of the possible values of the dependent variable can be taken as the reference category.

significant association exists, meaning that the relative risk of experiencing the outcome j rather than the outcome J is the same independently on the value of the covariate x_i. A RRR higher than 1 is indicative of a positive association, meaning that the relative risk estimated among individuals for whom $x_i = 1$ is higher than that estimated among individuals for whom $x_i = 2$. Finally, a RRR lower than 1 is indicative of a negative association, meaning that the relative risk estimated among individuals for whom $x_i = 1$ is lower than that estimated among individuals for whom $x_i = 2$.

5.2.3 Goodness of fit statistics

The method of maximum likelihood is used to estimate the model parameters in logistic regression analysis. Thus, the goodness of fit of the model can be evaluated through the Likelihood Ratio Test (LRT).

In particular, the LRT test is used to compare two nested models in order and identify the one which better fits the data. The models to be compared could be either the *null model* (i.e. the model with no covariates) and the *alternative model* (i.e. the model with all the covariates the analyst wishes to include), or any pair of nested models that have in common a number of covariates and differ in that one of them includes at least one additional covariate in respect to the other.

Let us consider the case in which the LRT is used to compare the null with the alternative model. If these models have maximum likelihood estimates respectively equal to $\hat{L}_0$ and $\hat{L}_1$, then their ratio can be defined as

$$L = \frac{\hat{L}_0}{\hat{L}_1}$$

and the LRT as

$$LRT = -2ln(L) = -2ln\left(\frac{\hat{L}_0}{\hat{L}_1}\right) = -2\left(ln\hat{L}_0 - ln\hat{L}_1\right)$$

Under the hypothesis that the null model has the same goodness of fit as the alternative model, we have that

$$-2ln(L) \sim \chi_p^2$$

i.e. that the LRT has a χ^2 distribution with p degrees of freedom, where p is the difference in the number of regression parameters between the null and the alternative models. For what concerns its interpretation, the higher the LRT the more the alternative model appears to better fit the data in comparison to the null model.

The LRT for the difference between the log likelihoods of two nested models m_1 and m_2 will be thus $LRT = -2\left(ln\hat{L}_{m_1} - ln\hat{L}_{m_2}\right) \sim \chi_p^2$, where p is the difference in the number of regression parameters between the two models.

5.3 Descriptive results: prevalence of poor health over the last years of life

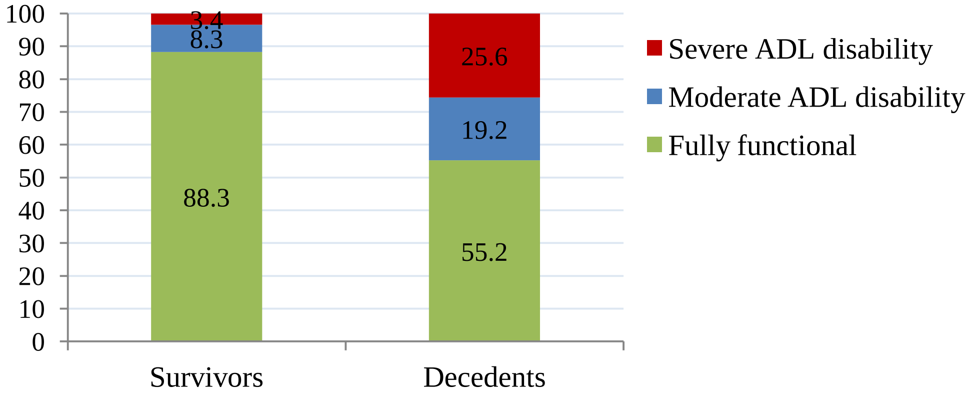
5.3.1 ADL disability

From the preliminary descriptive analysis, it appears that - among all considered measures of health - ADL disability is the most strongly related to proximity to death.

Some clues come from Figure 5.1. This shows that the proportion of individuals who were fully functional at the moment of interview (i.e. those who did not have any limitations in ADLs) is much higher among survivors rather than among decedents: it is indeed equal to 88.3% [95% CI = 88.0-88.6] and 55.2% [95% CI = 53.4-56.3] respectively. The opposite can be said for the share of individuals who had either moderate or severe difficulties in performing at least one ADL: 19.2% of decedents and 8.3% of survivors had moderate limitations in ADLs at interview, while 25.6% of decedents and 3.4% of survivors had severe limitations and were thus not able to perform at least one ADL without help.

Figure 5.1 not only shows that - as expected - the groups of decedents and survivors differ considerably in terms of the prevalence of ADL disability (and especially severe disability, whose prevalence is almost 8 times higher among decedents than survivors). Most importantly, it shows that the prevalence of ADL disability in the group of survivors above 50 years of age is quite low and that - at the same time - even more than half of decedents were in good functional health.

Figure 5.1 - Proportion of fully functional, moderately and severely ADL disabled individuals at the moment of interview among decedents and survivors aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.1 shows how the prevalence of ADL disability varies according to gender and age in both groups of decedents and survivors.

In accordance with the abundant literature on gender differences in health status, an important advantage emerges in favour of men. Indeed, women generally have ADL limitations almost twice as often as men (a smaller gap is only observed between female and male decedents living in a state of moderate ADL disability). When looking at the differences between age groups, it is possible to see that the prevalence of moderate ADL disability increases with age more steeply among survivors than among decedents. On the other hand, the prevalence of severe limitations in ADLs increases considerably with age among both decedents and survivors, reaching a particularly high value among decedents aged 85 years and older. When combining information on both gender and age, it emerges that the frequency with which survivors aged 85 years and over - as well as decedents in most age groups - report moderate limitations in ADLs does not differ significantly between men and women. On the contrary, an important gender gap is evident among decedents in the two oldest age groups - i.e. after 75 years of age - as far as the prevalence of severe ADL disability is taken into account.

If decedents and survivors are to be compared, a reduction of the differences between them in terms of the prevalence of ADL disability can be observed along with increasing age. In particular, decedents aged 50-64 years reported to have severe limitations in ADLs at interview more than 7 times more frequently in respect to survivors of the same ages: the proportions are indeed equal to 7.3% and 1.0% respectively. On the other hand, decedents aged 85 year and older reported to have severe limitations in ADLs slightly less than twice as often as survivors in the same age group: the proportions are indeed equal to 54.4% and 31.7% respectively. Finally, it appears that the differences between decedents and survivors in the prevalence of either moderate or severe ADL disability are slightly higher for men rather than for women. Overall, moderate limitations in ADLs are 3 and 2 times more frequent among decedents in respect to survivors respectively for men and women. Moreover, severe limitations in ADLs are 8.8 and 7.8 times more frequent among decedents in respect to survivors respectively for men and women. The decreasing pattern with age, however, can be similarly observed among both men and women.

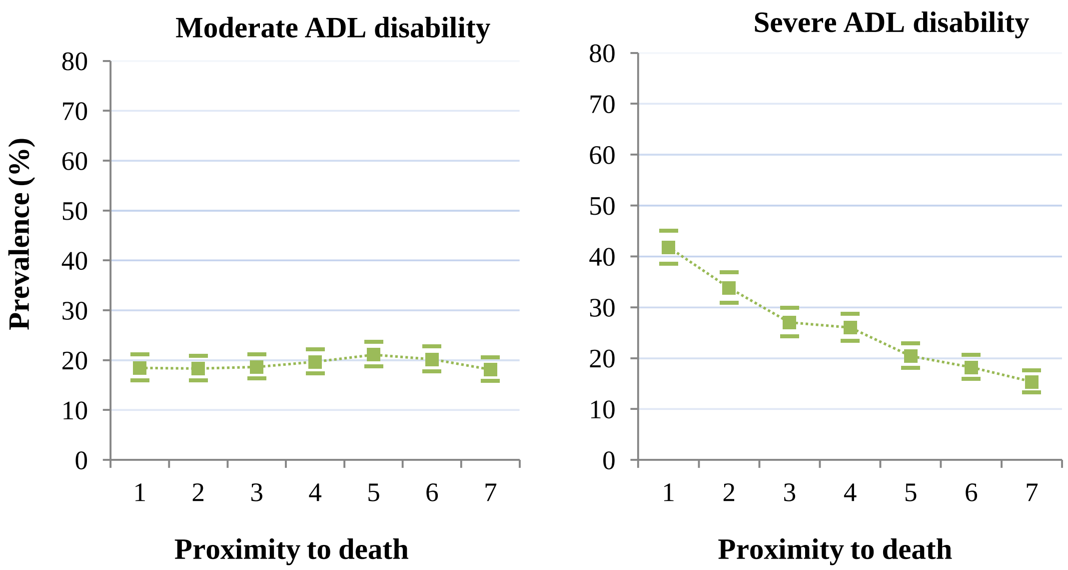
Table 5.1 - Prevalence of moderate and severe ADL disability and 95% confidence intervals among decedents and survivors aged 50 years and over according to age at interview and gender.

Age	Survivors			Decedents		
	Men	Women	All	Men	Women	All
			Moderate ADL disability			
50 - 64	2.3	3.9	3.1	8.1	10.6	8.9
(95% CI)	*(2.0-2.6)*	*(3.6-4.2)*	*(2.9-3.3)*	*(6.3-10.4)*	*(7.9-14.0)*	*(7.4-10.83)*
65 - 74	7.9	14.5	11.6	13.8	22.4	17.2
(95% CI)	*(7.2-8.7)*	*(13.6-15.4)*	*(11.0-12.2)*	*(12.0-15.9)*	*(19.6-25.5)*	*(15.6-19.0)*
75 - 84	16.3	25.6	22.4	20.8	26.1	23.5
(95% CI)	*(14.6-18.1)*	*(24.1-27.2)*	*(21.21-23.6)*	*(18.6-23.2)*	*(23.7-28.7)*	*(21.8-25.2)*
85+	31.5	27.7	28.8	23.4	22.1	22.6
(95% CI)	*(25.7-37.9)*	*(24.1-31.6)*	*(25.7-32.1)*	*(20.0-27.1)*	*(19.6-24.9)*	*(20.5-24.8)*
All	5.5	10.6	8.3	16.4	22.3	19.2
(95% CI)	*(5.1-5.9)*	*(9.8-10.9)*	*(8.0-8.5)*	*(15.2-17.7)*	*(20.9-23.8)*	*(18.3-20.2)*
			Severe ADL disability			
50 - 64	0.9	1.1	1.0	5.6	10.3	7.3
(95% CI)	*(0.7-1.1)*	*(0.9-1.3)*	*(0.9-1.1)*	*(4.1-7.6)*	*(7.6-13.8)*	*(5.9-9.0)*
65 - 74	2.6	3.8	3.2	11.7	14.9	12.3
(95% CI)	*(2.2-3.0)*	*(3.3-4.3)*	*(2.9-3.6)*	*(10.0-13.7)*	*(12.6-17.6)*	*(11.6-14.5)*
75 - 84	8.0	13.0	11.3	19.1	33.6	26.4
(95% CI)	*(6.8-9.4)*	*(11.9-14.2)*	*(10.4-12.2)*	*(17.0-21.4)*	*(31.0-36.3)*	*(24.7-28.2)*
85+	21.2	35.9	31.7	46.2	59.0	54.4
(95% CI)	*(16.3-27.0)*	*(32.0-40.0)*	*(28.5-35.0)*	*(42.0-50.4)*	*(55.9-62.1)*	*(51.9-57.0)*
All	2.6	4.4	3.4	18.0	33.8	25.6
(95% CI)	*(2.0-2.5)*	*(4.1-4.7)*	*(3.3-3.6)*	*(16.8-19.3)*	*(32.3-35.5)*	*(24.6-26.7)*

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

From the analysis of the functional health status among decedents, it emerges that the prevalence of moderate ADL disability over 50 years of age does not change significantly between groups of people in different years of proximity to death at interview (Figure 5.2). Indeed, it remains generally close to a value of 20%. Conversely, the prevalence of severe limitations in ADLs increases considerably from the group of people in the seventh year before death to the group of people in the last year of life: in fact, it rises from a value of 15.4% [95%CI = 13.3-17.7] to a value of 41.8% [95%CI = 38.6-45.1].

Figure 5.2 - Prevalence of moderate and severe ADL disability and 95% confidence intervals by proximity to death among decedents aged 50 years and over.

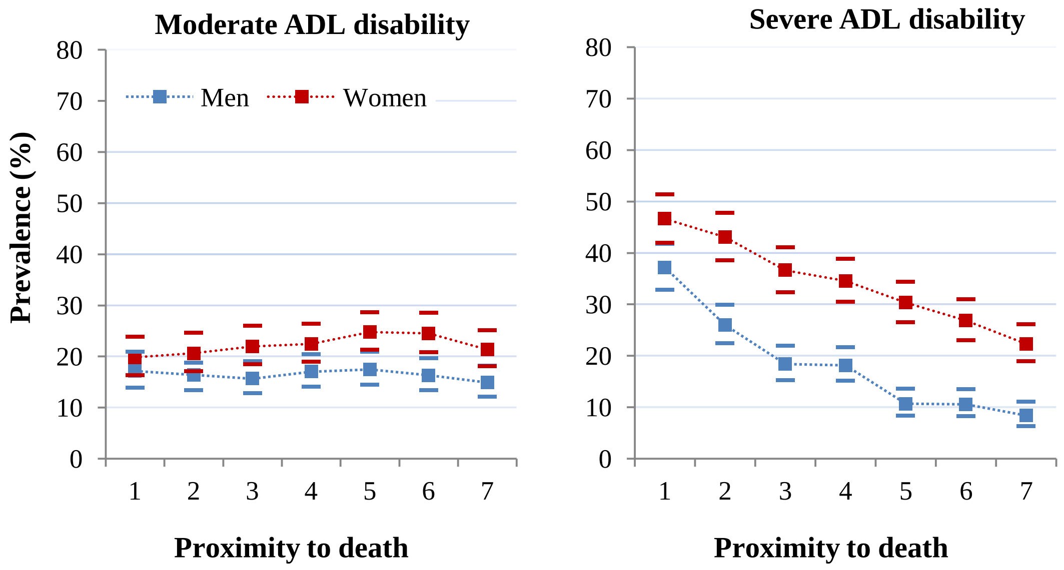


Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Marked gender differences emerge in the prevalence of severe limitations in ADLs, whereas men and women do not differ considerably in the frequency with which they reported to have moderate limitations in ADLs at interview (Figure 5.3). More in details, 8.4% of men [95%CI = 6.3-11.0] and 22.3% of women [95%CI = 19.0-26.0] in the seventh year before death were not able to perform at least one ADL. The corresponding proportions of individuals in the last year of life with severe ADL disability are equal to 37.2% among men [95%CI = 32.8-41.8] and 46.6% among women [95%CI = 41.9-51.4]. These figures not only show that men are usually found to be in better health conditions than women, but also that the magnitude of the increase observed in the prevalence of severe ADL disability from one year of proximity to death to the other is greater among men rather than among women. Indeed, male and female decedents in their last year of life reported to have severe limitations in ADLs respectively about 4.5 and 2 times more frequently than male and female decedents in the seventh year before death. This is compatible with the finding that women generally experience longer survival times in a state of functional impairment in comparison with their male counterparts.

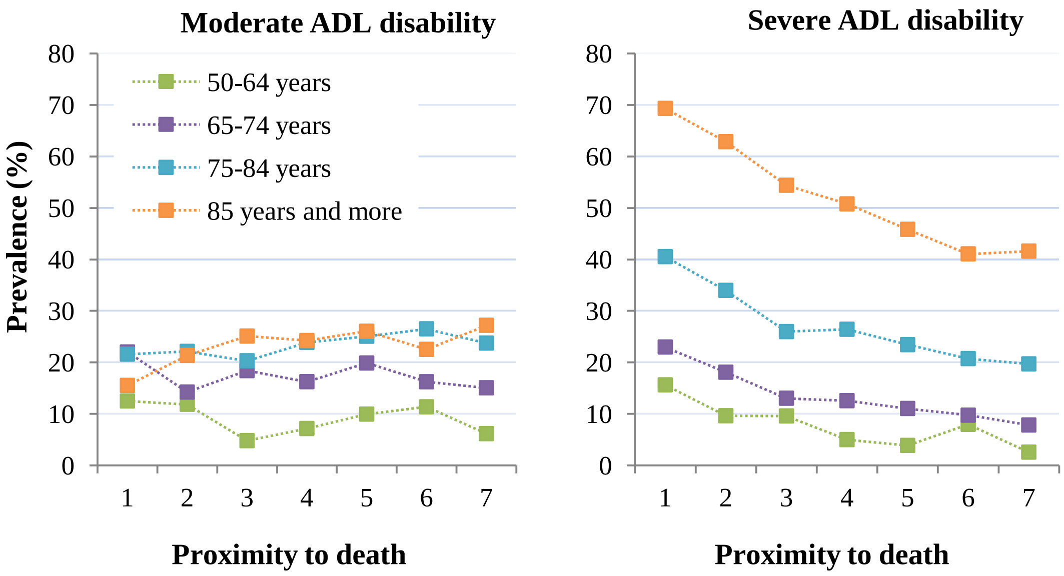
Similarly, age differences in the prevalence of moderate ADL disability are negligible compared to those observed in the prevalence of severe ADL disability (Figure 5.4). In fact, the proportions of individuals with moderate limitations in ADLs at different ages are either close to one another or do not significantly differ (see Table D.1 in Appendix D for 95% confidence intervals, that are not reported here in order to make the graph more readable). On the contrary, wide differences emerge between age groups in the prevalence of severe ADL limitations starting from 75 years (younger groups are quite similar between each other). Moreover, a particularly high prevalence of severe limitations in ADLs is observed at 85 years of age and over in all groups of proximity to death. For what concerns the increase in the prevalence of severe ADL limitations with approaching death, it appears to be steeper at younger ages. From the group of people in their seventh from last year of life to the group of people in their last years of life, indeed, the proportion severely disabled in ADL raises from a value of 2.6% to 15.6% at ages 50-64; from 7.8% to 23.0% at ages 65-74; from 19.7% to 40.5% at ages 75-84; from 41.6% to 69.3% at ages 85 years and over.

Figure 5.3 - Prevalence of moderate and severe ADL disability and 95% confidence intervals by proximity to death and gender among decedents aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 5.4 - Prevalence of moderate and severe ADL disability and 95% confidence intervals by proximity to death and age at interview among decedents aged 50 years and over.



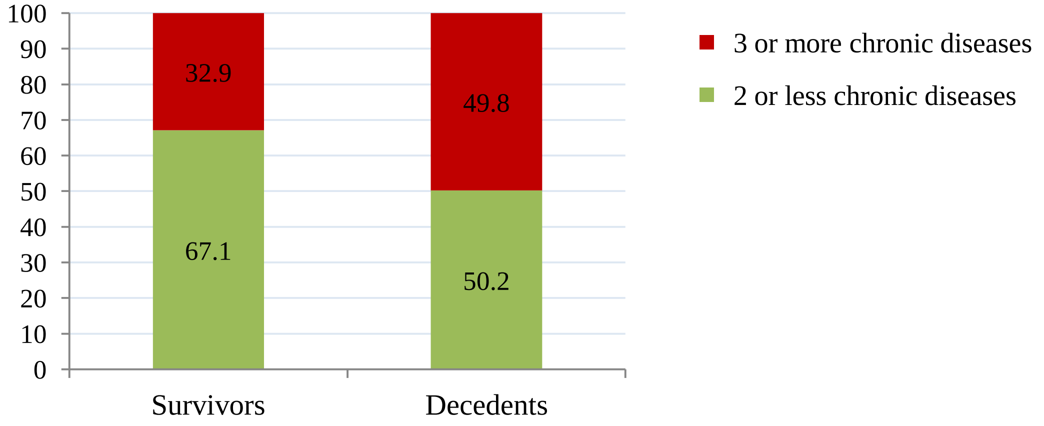
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5.3.2 *Multimorbidity*

What first emerges when looking at the prevalence of multimorbidity in the sample is that - independently on whether decedents or survivors are considered - the simultaneous presence of multiple chronic diseases is a much more frequent condition in respect to ADL disability. Furthermore, it appears that multimorbidity has a much weaker association with proximity to death, as the differences between decedents and survivors in its prevalence are found to be much narrower than the observed differences in the prevalence of ADL disability (either moderate or severe).

In particular, the proportion of individuals affected by 3 or more chronic diseases is about 1.5 times higher among decedents in respect to survivors (Figure 5.5): 49.8% of decedents and 32.9% of survivors respectively reported to have multimorbidity at the moment of interview. On the other hand, the proportion of individuals with less than three chronic diseases is about 30% lower among decedents in comparison with survivors: 50.2% of decedents [95% CI = 49.1-51.4] and 67.1% of survivors [95% CI = 66.7-67.6] reported to have no disease or to be affected by less than 3 chronic diseases at the moment of interview.

Figure 5.5 - Proportion of people with and without multimorbidity among decedents and survivors aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Once again, men are found to be in better health conditions as compared to women in both groups of decedents and survivors: more specifically, respectively 38.7% and 25.8% of female and male survivors as well as 55.5% and 44.5% of female and male decedents reported to have multimorbidity at interview (Table 5.2). Gender gaps, however, considerably reduce with age. For what concerns the differences between age groups - as expected - it results that the prevalence of multimorbidity raises with age but, at the same time, the increase decelerates at the oldest ages. The gap between decedents and survivors appears to be relatively narrow - in comparison with that estimated when analysing ADL disability - especially after 65 years of age. Indeed, an important difference emerges in the age group 50-64 years (where 34.9% of decedents and 24.9% of survivors respectively reported to have multimorbidity at interview), but the magnitude of the difference becomes smaller and smaller with increasing age. A similar pattern can be observed among both men and women.

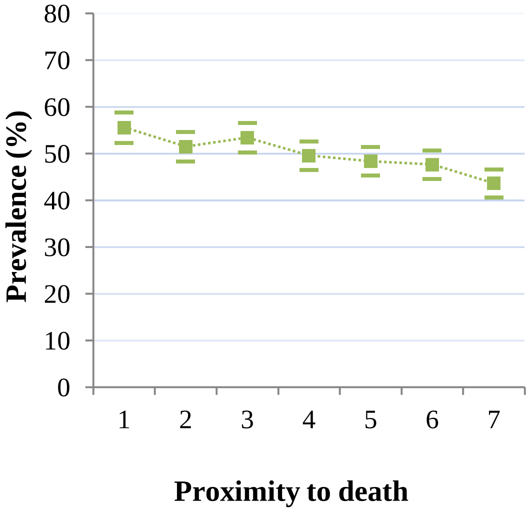
Table 5.2 - Prevalence of multimorbidity and 95% confidence intervals among decedents and survivors aged 50 years and over according to age at interview and gender.

Age	Survivors			Decedents		
	Men	**Women**	**All**	**Men**	**Women**	**All**
50 - 64	19.0	30.3	24.9	30.3	43.3	34.9
(95% CI)	*(18.3-19.7)*	*(29.5-31.1)*	*(24.3-25.4)*	*(27.0-33.8)*	*(38.5-48.3)*	*(32.1-37.7)*
65 - 74	34.2	45.9	40.7	43.7	51.0	46.6
(95% CI)	*(32.9-35.5)*	*(44.6-47.1)*	*(39.8-41.6)*	*(40.8-46.5)*	*(47.5-54.4)*	*(44.3-48.8)*
75 - 84	43.3	54.0	50.3	49.7	60.0	54.8
(95% CI)	*(40.9-45.7)*	*(52.2-55.7)*	*(48.8-51.7)*	*(46.8-52.5)*	*(57.1-62.6)*	*(52.8-56.8)*
85+	48.2	55.1	53.1	53.6	58.5	56.8
(95% CI)	*(41.7-54.8)*	*(50.9-59.2)*	*(49.6-56.6)*	*(49.4-57.8)*	*(55.4-61.6)*	*(54.3-59.3)*
All	25.8	38.7	32.9	44.5	55.5	49.8
(95% CI)	*(25.2-26.4)*	*(38.0-39.3)*	*(32.4-33.3)*	*(42.9-46.1)*	*(53.8-57.1)*	*(48.6-50.9)*

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

When looking at the prevalence of multimorbidity among decedents according to the numbers of years of proximity to death, a moderate increase emerges with approaching death (slightly less than 2 points each year on average). Indeed, 43.6% of decedents in their seventh from last year of life [95%CI = 40.6-46.6] and 55.6% of decedents in their last year of life [95%CI = 52.3-58.8] reported to have more than 3 chronic diseases at interview (Figure 5.6).

Figure 5.6 - Prevalence of multimorbidity and 95% confidence intervals by proximity to death among decedents aged 50 years and over.

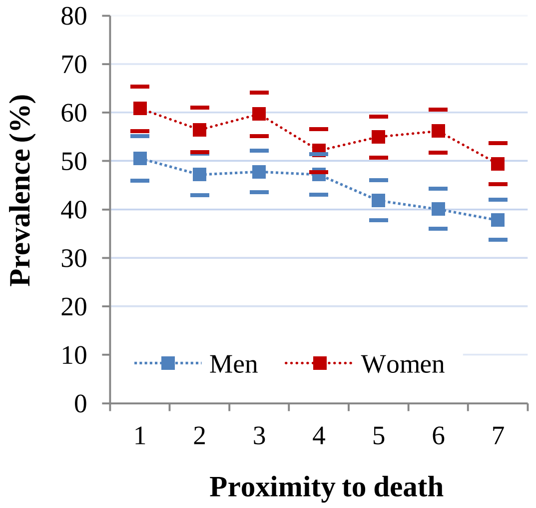


Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Gender differences emerge (Figure 5.7), with women generally reporting to be affected by multiple chronic diseases more frequently than men: an important gap is generally observed all over the last years of life. Moreover, a similar increase can be observed respectively among female and male decedents from the seventh from last to the last year of life.

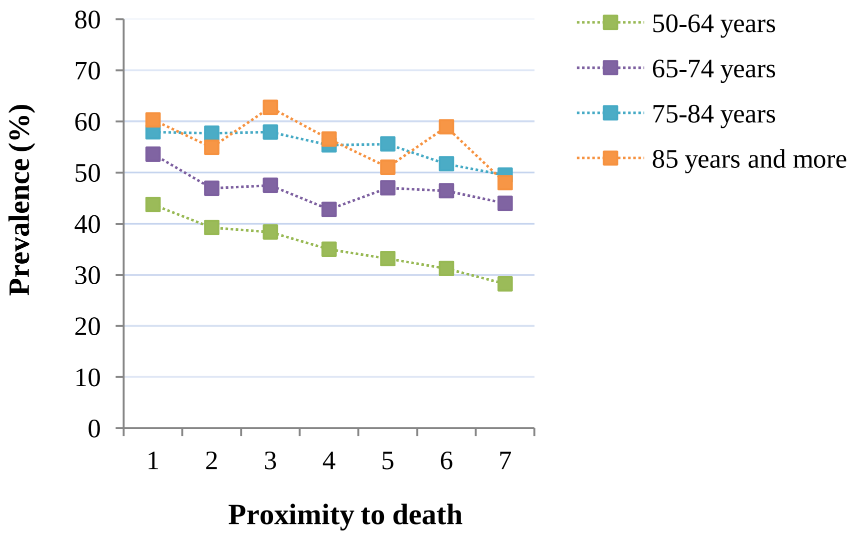
Finally, the prevalence of multiple chronic diseases shows only modest increases with age (Figure 5.8). In particular, the prevalence of multimorbidity stop to increase after 75 years of age, as it is very similar between the two oldest age group (see Table D.2 in Appendix D for 95% confidence intervals). Increases observed from one year of proximity to death to the next are also either very low or not statistically significant.

Figure 5.7 - Prevalence of multimorbidity and 95% confidence intervals by proximity to death and gender among decedents aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 5.8 - Prevalence of multimorbidity and 95% confidence intervals by proximity to death and age at interview among decedents aged 50 years and over.



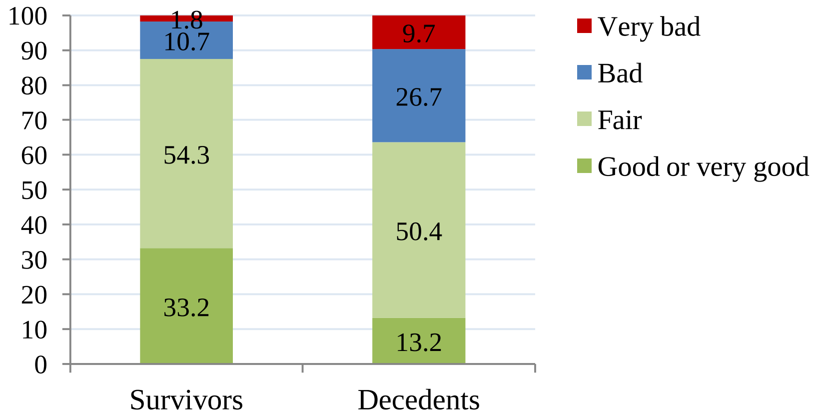
Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5.3.3 Self-rated health

While decedents reported poor health much more frequently than survivors, the differences between groups of decedents at different years of proximity to death seem to be less important.

Figure 5.9 shows that decedents and survivors differ considerably in terms of the proportion of individuals who perceive themselves as being in a bad or very bad general health status: 26.7% of decedents and 10.7% of survivors rated their health as bad, while 9.7% of decedents and 1.8% of survivors rated their health as very bad at the moment of interview. It thus results that individuals who were going to die within seven years from the interview reported to be in bad and very bad health respectively 2.5 and 5.6 times more frequently than those who were destined to live longer. It also emerges that most survivors perceived themselves in good health conditions at the date of interview: 87.5% of them rated their health as very good, good or fair[15]. Despite the fact that decedents are found to perceive their health much more frequently as poor (i.e. bad and very bad) as compared to survivors, their proportions in very good, good and fair perceived health are also very high and sum to 66.3%.

Figure 5.9 - Proportion of people who perceive themselves in good, fair, bad and very bad health among decedents and survivors, in the population aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

[15] It must be reminded that the Italian translation of the term "fair" used in the 1999-2000 HIS questionnaire (i.e. "discretamente") has a positive - rather than neutral - connotation.

Female survivors usually rated their health as poor more often than their male counterparts (Table 5.3). Overall, 13.1% of them are in a bad health status while the corresponding proportion of men is 7.8%. Furthermore, an important gap emerges between men and women of all ages with the only exception of those in the oldest group. On the other hand, it emerges that - in terms of the proportion in bad self-rated health - female and male decedents are more similar to each other: respectively, 30.1% and 23.2% rated their health as bad at interview. For what concerns very bad self-rated health, similar gender differences can be observed among both decedents and survivors. Respectively, 2.1% and 1.4% of female and male survivors rated their health as bad, whereas 11.1% and 8.3% of female and male decedents rated their health as very bad at interview.

The gap between decedents and survivors in the prevalence of both bad and very bad self-rated health is always significant and important among both men and women of all ages. However - as in the case of ADL disability - differences are slightly higher among men in respect to women: overall, male and female decedents rated their health as bad respectively 3 and 2.3 times more frequently than male and female survivors, whereas male and female decedents rated their health as very bad respectively 5.9 and 3.6 times more frequently as compared to male and female survivors. The differences between decedents and survivors, moreover, (once again) reduce along with increasing age.

Finally, the proportion of people who perceived themselves in bad or very bad health increases with age more steeply among survivors rather than among decedents. The highest prevalence of bad self-rated health - equal to 33.9% - is observed among female decedents aged 85 years and older. Female decedents of the same age are also those who most frequently rated their health as very bad at interview: this happens in the 14.2% of cases.

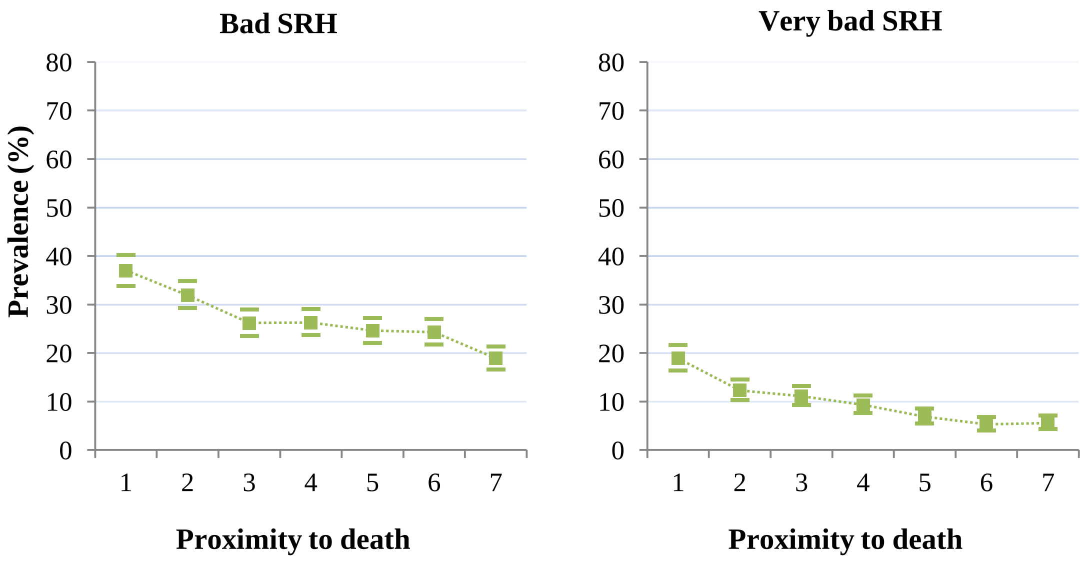
Table 5.3 - Prevalence of bad and very bad self-rated health and relative 95% confidence intervals among decedents and survivors aged 50 years and over according to age at interview and gender.

Age	Survivors			Decedents		
	Men	**Women**	**All**	**Men**	**Women**	**All**
			Bad self-rated health			
50 - 64	5.6	9.0	7.4	16.3	25.3	19.4
(95% CI)	*(5.2-6.1)*	*(8.5-9.5)*	*(7.0-7.7)*	*(13.7-19.2)*	*(21.2-29.8)*	*(17.2-21.9)*
65 - 74	10.4	16.4	13.8	22.8	25.9	24.1
(95% CI)	*(9.6-11.3)*	*(15.5-17.4)*	*(13.1-14.4)*	*(20.5-25.3)*	*(22.9-29.0)*	*(22.2-26.0)*
75 - 84	13.2	20.4	17.9	25.1	32.7	29.0
(95% CI)	*(11.7-14.9)*	*(19.0-21.9)*	*(16.8-19.0)*	*(22.7-27.7)*	*(30.1-35.4)*	*(27.2-30.8)*
85+	18.9	24.1	22.6	28.8	33.9	32.1
(95% CI)	*(14.3-24.6)*	*(20.7-27.8)*	*(19.8-25.7)*	*(25.1-32.8)*	*(31.0-36.9)*	*(29.8-34.5)*
All	7.8	13.1	10.7	23.2	30.1	26.7
(95% CI)	*(7.4-8.2)*	*(12.7-13.6)*	*(10.4-11.0)*	*(21.8-24.6)*	*(29.0-32.2)*	*(25.7-27.8)*
			Very bad self-rated health			
50 - 64	0.9	1.1	1.0	6.2	6.7	6.4
(95% CI)	*(0.8-1.1)*	*(1.0-1.3)*	*(0.9-1.2)*	*(4.6-8.2)*	*(4.6-9.7)*	*(5.1-8.0)*
65 - 74	1.5	2.4	2.0	6.7	9.5	7.8
(95% CI)	*(1.2-1.9)*	*(2.0-2.8)*	*(1.7-2.5)*	*(5.4-8.2)*	*(7.7-11.8)*	*(6.7-9.1)*
75 - 84	3.7	4.3	4.1	8.4	11.0	9.7
(95% CI)	*(2.9-4.8)*	*(3.7-5.1)*	*(3.6-4.7)*	*(6.9-10.1)*	*(9.4-12.9)*	*(8.6-11.0)*
85+	8.1	7.6	7.8	14.8	14.2	14.4
(95% CI)	*(5.2-12.5)*	*(5.7-10.1)*	*(6.1-9.9)*	*(12.0-18.0)*	*(12.2-16.6)*	*(12.7-16.3)*
All	1.4	2.1	1.8	8.3	11.1	9.7
(95% CI)	*(1.3-1.6)*	*(1.9-2.3)*	*(1.7-1.9)*	*(7.5-9.3)*	*(10.1-12.2)*	*(9.0-10.4)*

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

As shown in Figure 5.10, people rate their health as poor or very poor increasingly with approaching death. However, the increase in the prevalence of bad and very bad health is not as important as that observed in the case of ADL disability. In particular, the proportion of individuals who rate their health as bad goes from 18.9% [95% CI = 16.6-21.4] to 37.02% [95% CI = 33.9-40.3] from the seventh to the last to the last year before death, while that of people who rate their health as very bad goes rises 5.5% [95% CI = 4.3-7.1] to 18.9% [95% CI = 16.5-21.6].

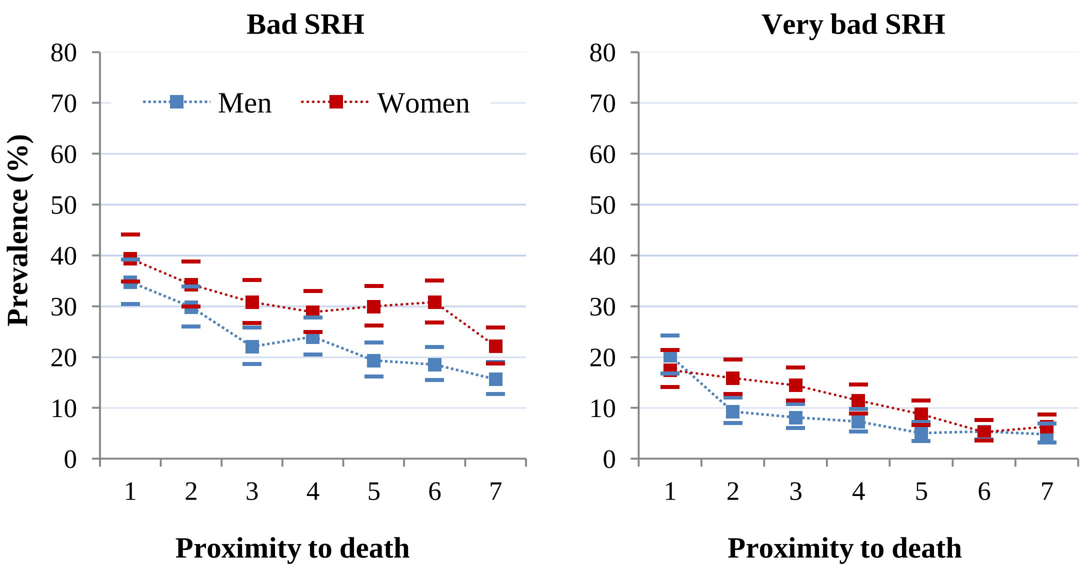
Figure 5.10 - Prevalence of bad and very bad self-rated health and 95% confidence intervals by proximity to death among decedents aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

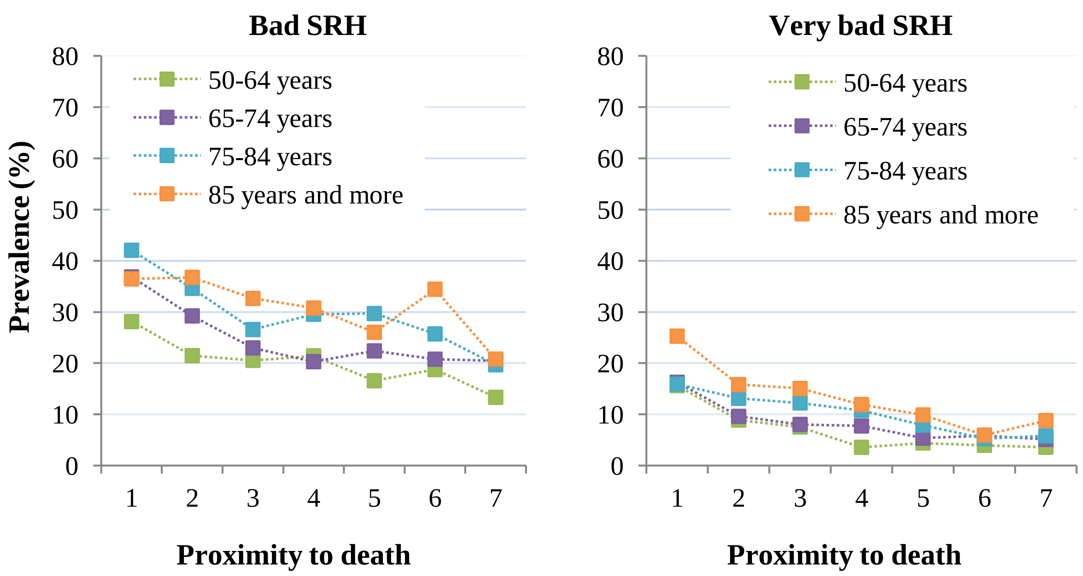
Gender and age over the last seven years before death differentials do not seem to be wide (Figures 5.11 and 5.12 - see Table D.3 in Appendix D for 95% confidence intervals for age groups). Moreover, similar increases in the prevalence of bad or very bad self-rated health can be observed between men and women and across age groups.

Figure 5.11 - Prevalence of bad and very bad self-rated health and 95% confidence intervals by proximity to death and gender among decedents aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure 5.12 - Prevalence of bad and very bad self-rated health and 95% confidence intervals by proximity to death and age at interview among decedents aged 50 years and over.



Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5.4 Multivariate analysis: poor health, age and proximity to death

As anticipated in the introduction to this chapter, the association between proximity to death and the different dimensions of poor health has been analysed through multivariate techniques with the aims of: 1) quantifying more precisely the impact of proximity to death on the risk of poor health while controlling for some basic socio-demographic factors that are known to affect health status other than age and gender; 2) testing if and how the impact of age on health status changes between decedents and survivors.

The results of two nested models are presented for each of the considered measures of poor health as the outcome variable. These two models differ only in the fact that, in addition to other socio-demographic variables - namely age, gender, marital status, educational level and geographical area of residence - one includes proximity to death as a covariate while the other does not. In this way, it is possible to estimate the strength of the association between proximity to death and poor health and, at the same time, to evaluate the predictive power of age for poor health when the number of years remaining before death is controlled for. It should be noted that the effects of socio-demographic variables other than age are always in line with the expectations. For this reason, they will not be discussed here.

Depending on the outcome variable (either ADL disability, multimorbidity or bad and very bad self-rated health), measures of the other dimensions of poor health have been included among the covariates in order to account for their effects. This decision was made based on the current scientific knowledge about the determinants of health. In particular, when ADL disability is the dependent variable, multimorbidity is included as a covariate in logistic regression models. It is indeed well known that chronic diseases often lead to a state of functional impairment (Verbrugge and Jette, 1984). On the other hand, when self-rated health is the dependent variable, both ADL disability and multimorbidity are included in the models as covariates because both functional status and physical conditions have an important direct effect on one's perception of his/her general health (Golini and Egidi, 2015; Shields and Shooshtari, 2001).

Proximity to death is included in the models as a categorical covariate in order to better identify the differences between individuals who were closest to death and those who were farther from death at the moment of interview. In particular, three groups of proximity to death are considered in the analysis: decedents in the last three years of life, decedents between the fourth and seventh from last year of life and survivors.

5.4.1 ADL disability

Table 5.4 reports the results of the two multinomial models built to evaluate the associations of ADL disability with age and proximity to death. In these models, the reference category of the dependent variable is “fully functional”: the output thus consists of the RRRs of having moderate and severe limitations as compared to having no limitations in ADLs at different values of the covariates.

As expected, the results of Model 1 indicate that the RRRs estimated for the different age groups without controlling for the number of years remaining before death are very high, especially in the case of severe ADL disability. The relative risks of having moderate limitations in ADLs are indeed approximately 3, 7 and 16 times higher for individuals aged 65 to 74, 75 to 84 and 85 years and older respectively as compared with those aged 50 to 64 years. Most importantly, the relative risks of having severe limitations in ADLs respectively in the age groups 65-74, 75-84 and 85 years and over are approximately 3, 12.5 and 76.4 times higher than in the age group 50-64 years.

However, it can be shown that the likelihood ratio test for the difference between the log likelihoods of the two models proves that Model 2 fits the data significantly better. Proximity to death should be thus taken into account. From this model, it emerges that the relative risks of severe ADL disability in the age groups 75-84 and 85 years and over are respectively 8 and 34 times higher than in the age group 50-64 years. In the case of moderate ADL disability, on the other hand, the relative risk of having moderate limitations in ADLs is approximately 6 and 12 times higher respectively among people aged 75-84 and 85 years and more than among people aged 50 to 64 years.

As far as proximity to death is concerned, the results of Model 2 show that - as expected - decedents are always found to have both moderate and severe limitations in ADLs more frequently than survivors. Nevertheless, the association between proximity to death and ADL disability can be stronger or weaker according to the severity of limitations. For both groups of decedents in the three last years of life and between the fourth and seventh year before death, indeed, the RRRs of having severe limitations in ADLs are much higher than the RRRs of having moderate limitations.

Furthermore, the values of the RRRs for different groups of proximity to death indicate that the risks of being in a state of severe ADL disability increases considerably with approaching death. In respect to survivors, indeed, the relative risk of having severe limitations in ADLs is more than 6 times higher among decedents in the last three years of life and only 3 times higher among decedents between the fourth and seventh from last year of life. Conversely, statistical tests prove that the differences in the RRRs of having moderate limitations in ADLs between decedents in different groups of proximity to death are also significant, even if much narrower.

Table 5.4 - Relative risk ratios of moderate and severe ADL disability (ref. fully functional) by age at interview and proximity to death and 95% confidence intervals from a multinomial logistic model* estimated on data for the population aged 50 years and over.

	Model 1 Without proximity to death				Model 2 With proximity to death			
Moderate ADL disability								
Covariate	**RRR**		**95% CI Lb**	**95% CI Ub**	**RRR**		**95% CI Lb**	**95% CI Ub**
Age								
50-64 (ref.)	1				1			
65-74	3.16	***	2.88	3.45	2.99	***	2.73	3.27
75-84	7.05	***	6.40	7.77	6.10	***	5.53	6.74
85+	16.21	***	14.05	18.70	12.03	***	10.37	14.00
Proximity to death								
Survivors (ref.)	-				1			
4th to 7th from last year of life	-	-	-	-	1.72	***	1.56	1.90
Last 3 years of life	-	-	-	-	2.01	***	1.79	2.27
Severe ADL disability								
Covariate	**RRR**		**95% CI Lb**	**95% CI Ub**	**RRR**		**95% CI Lb**	**95% CI Ub**
Age								
50-64 (ref.)	1				1			
65-74	2.96	***	2.58	3.42	2.49	***	2.16	2.88
75-84	12.52	***	10.92	14.36	8.22	***	7.13	9.48
85+	76.39	***	64.98	89.80	34.07	***	28.70	40.45
Proximity to death								
Survivors (ref.)	-				1			
4th to 7th from last year of life	-	-	-	-	3.15	***	2.81	3.52
Last 3 years of life	-	-	-	-	6.34	***	5.62	7.16

Goodness of fit statistics	**Model 1**	**Model 2**
Log likelihood	-20465.9	-19953.3
LRT	12219.3	13244
Degrees of freedom	20	24
pvalue	0.000	0.000

* Controlled for gender, marital status, geographical area, educational level and multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Given these results, I performed a more in-depth analysis by building other two models: one included an interaction term between proximity to death and gender, and the other an interaction term between proximity to death and age.

The estimation of the first model allows to evaluate if and how the strength of the association of ADL disability with proximity to death changes between men and women. What emerges is that there are no significant gender differences in the RRRs of having moderate ADL limitations, whereas a significant gap emerges between male and female decedents between the fourth and seventh year before death. For this group of proximity to death, in particular, the RRR is equal to 2.27 and 3.83 respectively among men and women (Table 5.5). This finding could indicate that men experience a faster functional decline at the end of life in respect to women, and is compatible with the common finding that women usually live longer even if their health status is worse.

Table 5.5 - Relative risk ratios of moderate and severe ADL disability (ref. fully functional) and 95% confidence intervals by proximity to death among men and women aged 50 years and over from a multinomial logistic model* including an interaction term between gender and proximity to death.

Proximity to death	Moderate ADL disability				Severe ADL disability			
	RRR		95% CI		RRR		95% CI	
			Lb	Ub			Lb	Ub
Men								
Survivors (ref.)	1				1			
4th to 7th from last year of life	1.72	***	1.49	1.98	2.27	***	1.90	2.73
Last 3 years of life	2.18	***	1.84	2.58	6.20	***	5.20	7.40
Women								
Survivors (ref.)	1				1			
4th to 7th from last year of life	1.78	***	1.56	2.03	3.83	***	3.33	4.42
Last 3 years of life	1.85	***	1.56	2.19	6.08	***	5.17	7.15

Goodness of fit statistics	
Log likelihood	-19940.9
LRT	13269.3
Degrees of freedom	28
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level and multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

The estimation of the second model allows to evaluate if and how the impact of age on ADL disability changes according to the number of years until death and, conversely, the strength of the association of ADL disability with proximity to death changes over age.

First of all, it emerges that the effect of age is much stronger among survivors than among decedents: the RRRs for the age groups above 75 years are indeed much lower in both groups of decedents as compared to survivors (Table 5.6). However, it also appears that there are no significant differences among decedents according to the number of years of proximity to death.

Table 5.6 - Relative risk ratios of moderate and severe ADL disability (ref. fully functional) and 95% confidence intervals by age in different groups of proximity to death from a multinomial logistic model* including an interaction term between age and proximity to death estimated on data for people aged 50 years and over.

Age	Moderate ADL disability				Severe ADL disability			
	RRR		95% CI		RRR		95% CI	
			Lb	Ub			Lb	Ub
Survivors								
50-64 (ref.)	1				1			
65-74	3.11	***	2.82	3.42	2.60	***	2.20	3.08
75-84	6.82	***	6.12	7.60	10.08	***	8.53	11.90
85+	14.45	***	11.84	17.63	46.94	***	37.39	58.92
4th to 7th from last year of life								
50-64 (ref.)	1				1			
65-74	1.93	***	1.41	2.64	2.05	**	1.36	3.08
75-84	3.5	***	2.59	4.73	5.48	***	3.73	8.04
85+	6.01	***	4.27	8.46	19.27	***	12.86	28.87
Last 3 years of life								
50-64 (ref.)	1				1			
65-74	1.97	**	1.33	2.93	1.57	*	1.07	2.28
75-84	2.95	***	2.01	4.32	3.62	***	2.54	5.17
85+	7.53	***	4.96	11.41	18.54	***	12.69	27.09

Goodness of fit statistics	
Log likelihood	-19918.9
LRT	13313.4
Degrees of freedom	36
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level and multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

When interpreting the results in the other way around, it appears that the strength of the association between proximity to death and ADL disability is generally lower after 65 years of age. No clear trends, however, emerge with increasing age as the differences between age groups are often not significant after 65 years (Table 5.7).

Table 5.7 - Relative risk ratios of moderate and severe ADL disability (ref. fully functional) and 95% confidence intervals by proximity to death in different age groups from a multinomial logistic model* including an interaction term between age and proximity to death estimated on data for people aged 50 years and over.

Proximity to death	Moderate ADL disability				Severe ADL disability			
	RRR		95% CI		RRR		95% CI	
			Lb	Ub			Lb	Ub
50-64 years								
Survivors	1				1			
4th to 7th from last year of life	2.94	***	2.22	3.90	5.06	***	3.45	7.40
Last 3 years of life	3.47	***	2.45	4.91	12.97	***	9.19	18.29
65-74 years								
Survivors	1				1			
4th to 7th from last year of life	1.82	***	1.54	2.16	3.99	***	3.20	4.97
Last 3 years of life	2.20	***	1.78	2.71	7.82	***	6.21	9.85
75-84 years								
Survivors	1				1			
4th to 7th from last year of life	1.51	***	1.30	1.75	2.75	***	2.33	3.24
Last 3 years of life	1.50	***	1.24	1.81	4.66	***	3.87	5.61
85 years and more								
Survivors	1				1			
4th to 7th from last year of life	1.22	n.s.	0.93	1.61	2.08	***	1.61	2.68
Last 3 years of life	1.81	***	1.34	2.43	5.12	***	3.91	6.71

Goodness of fit statistics	
Log likelihood	-19918.9
LRT	13313.4
Degrees of freedom	36
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level and multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5.4.2 Multimorbidity

Table 5.8 reports the results of the two binary logistic regression models estimated in order to evaluate the strength of the associations of multimorbidity with age and proximity to death. Also in this case, the likelihood ratio test shows that Model 2 fits the data significantly better, meaning that proximity to death should be taken into account. However, in both cases, the odds ratios of being affected by more than two chronic diseases estimated for the two oldest age groups are not significantly different from each other but are higher than that estimated for the age group 65-74 years.

For what concerns the association of multimorbidity with proximity to death, results confirm the expectation that decedents are more frequently affected by more than 3 chronic diseases as compared to survivors. More in details, ORs of multimorbidity are equal to 1.26 and 1.58 respectively among decedents between the fourth and seventh year before death and among decedents in the last three years of life. These figures indicate that the gap between decedents and survivors in terms of chronic multimorbidity widens with approaching death. At the same time, however, the increase in the ORs of multimorbidity from one group of proximity to death to the other appears to be much lower in comparison to the increase estimated in the analysis on ADL disability.

The analysis of the interactions between proximity to death and gender shows that the association of proximity to death with multimorbidity is stronger among men rather than among women (Table 5.9), as proved by statistical tests of the difference between coefficients. Moreover, the analysis of the interactions between proximity to death and age show that the effect of age changes slightly between decedents and survivors (Table 5.10) and that the odds ratios of multimorbidity for decedents in the last three years of life are generally higher than the corresponding odds ratios for decedents between the fourth and seventh year before death (Table 5.11). This indicates that the prevalence of multimorbidity is generally higher among people who are closest to death. Moreover, odds ratios are usually lower among older people, i.e. after 65 years of age, in comparison with individuals aged 50 to 64 years. These results confirm the findings for ADL disability and lead to conclude that proximity to death apparently has a stronger association with poor functional and physical health at younger ages and among men.

Table 5.8 - Odds ratios of multimorbidity and 95% confidence intervals from a binary logistic model* estimated on data for people aged 50 years and over.

	Model 1 Without proximity to death				Model 2 With proximity to death			
Covariate	**OR**		**95% CI Lb**	**95% CI Ub**	**OR**		**95% CI Lb**	**95% CI Ub**
Age								
50-64 (ref.)	1				1			
65-74	1.93	***	1.85	2.02	1.88	***	1.79	1.97
75-84	2.78	***	2.62	2.95	2.55	***	2.40	2.71
85+	3.07	***	2.80	3.38	2.50	***	2.26	2.76
Proximity to death								
Survivors (ref.)	-				1			
4th to 7th from last year of life	-	-	-	-	1.26	***	1.17	1.35
Last 3 years of life	-	-	-	-	1.58	***	1.45	1.72

Goodness of fit statistics	**Model 1**	**Model 2**
Log likelihood	-29042.1	-28975.3
LRT	3492.0	3625.8
Degrees of freedom	9	11
pvalue	0.000	0.000

* Controlled for gender, marital status, geographical area and educational level

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.9 - Odds ratios of multimorbidity and 95% confidence intervals by proximity to death among men and women aged 50 years and over from a binary logistic model* including an interaction term between gender and proximity to death.

Proximity to death	**Men** OR		**95% CI Lb**	**95% CI Ub**	**Women** OR		**95% CI Lb**	**95% CI Ub**
Survivors (ref.)	1				1			
4th to 7th from last year of life	1.37	***	1.25	1.51	1.15	**	1.04	1.27
Last 3 years of life	1.75	***	1.56	1.95	1.41	***	1.25	1.59

Goodness of fit statistics	
Log likelihood	-28969.1
LRT	3638.2
Degrees of freedom	13
pvalue	0.0

* Controlled for gender, marital status, geographical area and educational level

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.10 - Odds ratios of multimorbidity and 95% confidence intervals by age in different groups of proximity to death from a binary logistic model* including an interaction term between age and proximity to death estimated on data for people aged 50 years and over.

Age	OR		95% CI Lb	95% CI Ub
Survivors				
50-64 (ref.)	1			
65-74	1.90	***	1.81	2.00
75-84	2.65	***	2.47	2.83
85+	2.81	***	2.43	3.27
4th to 7th from last year of life				
50-64 (ref.)	1			
65-74	1.67	***	1.37	2.03
75-84	2.13	***	1.75	2.58
85+	2.04	***	1.64	2.54
Last 3 years of life				
50-64 (ref.)	1			
65-74	1.33	*	1.04	1.70
75-84	1.79	***	1.40	2.27
85+	1.75	***	1.36	2.24

Goodness of fit statistics	
Log likelihood	-28966.3
LRT	3643.7
Degrees of freedom	17
pvalue	0.0

* Controlled for gender, marital status, geographical area and educational level

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.11 - Odds ratios of multimorbidity and 95% confidence intervals by proximity to death in different age groups from a binary logistic model* including an interaction term between age and proximity to death estimated on data for people aged 50 years and over.

Proximity to death	OR		95% CI Lb	95% CI Ub
50-64 years				
Survivors	1			
4th to 7th from last year of life	1.47	***	1.24	1.73
Last 3 years of life	2.17	***	1.78	2.66
65-74 years				
Survivors	1			
4th to 7th from last year of life	1.29	***	1.14	1.45
Last 3 years of life	1.52	***	1.30	1.77
75-84 years				
Survivors	1			
4th to 7th from last year of life	1.18	**	1.05	1.33
Last 3 years of life	1.47	***	1.27	1.70
85 years and more				
Survivors	1			
4th to 7th from last year of life	1.06		0.87	1.30
Last 3 years of life	1.35	**	1.10	1.65

Goodness of fit statistics	
Log likelihood	-28966.3
LRT	3643.7
Degrees of freedom	17
pvalue	0.0

* Controlled for gender, marital status, geographical area and educational level

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

5.4.3 Self-rated health

Table 5.12 reports the results of the two multinomial logistic regression models built to evaluate the strength of the association of bad and very bad self-perceptions of health with both age and proximity to death. In these models, the reference category of the outcome variable comprises very good, good and fair ratings of health. In the following pages, it will be referred to as "good" for the sake of simplicity.

As expected based on the available literature, it appears that age does not considerably increase the chances of perceiving oneself in poor general health conditions, even when proximity to death is not taken into account. Indeed, the results of Model 1 indicate that individuals aged 65-74 and 75-84 years are approximately 23% and 13% respectively more likely - in comparison with those aged 50-64 - to rate their health as bad rather than good. Moreover, the difference between the RRRs estimated by the model for the two age groups mentioned above is not statistically significant. On the other hand, people aged 85 and older do not differ significantly from the younger age groups in their relative risk of perceiving themselves in bad health.

The results of Model 2 - which of self-rated health has a significantly better goodness of fit than Model 1 - indicate that, when controlling for proximity to death, only being in the age group 65-74 is associated with a significant increase in the relative risk of perceiving oneself in bad general health conditions in respect to being 50 to 64 years old. Furthermore, being at least 85 years old significantly reduces by almost 45% the chances of perceiving oneself in bad health as compared to being in the youngest age group considered in this analysis.

Similar results are obtained when estimating the impact of the covariates on very bad self-rated health. In this case, the results of Model 1 indicate that age groups never differ significantly in terms of relative risks of perceiving oneself in very bad general health. The results of Model 2 show that, when controlling for proximity to death, the risk of very bad self-rated health relative to good health is significantly reduced by approximately 40% in the age group 85 years and older as compared to 50-64 years. The RRRs for the age groups 65-74 and 75-84, however, remain statistically not significant.

The results of Model 2 also prove that a strong association exists between both bad and very bad self-rated health and proximity to death. Indeed, the relative risks of perceiving oneself in bad health are 50% higher and more than double among decedents between the fourth and seventh from last year of life and in the last three years of life respectively.

Similarly, the RRRs of perceiving oneself in very bad health are significantly different for decedents in different groups of proximity to death and show an increase with approaching death: their values are equal to 1.77 and 3.76 between the fourth and seventh year before death and in the last three years of life respectively.

The estimation of an additional model including an interaction term between proximity to death and gender does not lead to identify any significant differences between men and women in terms of relative risks of perceiving oneself in a very bad general health status However, a gender difference emerges in the relative risks of perceiving oneself in a bad health status for decedents in different groups of proximity to death, which are generally higher among women rather than among men (Table 5.13).

The results of the additional model including an interaction term between proximity to death and age show that RRRs of bad and very bad health of decedents aged at least 75 years - independently on the number of years remaining before death - are particularly low (Table 5.14). Interpreting the results in the other way around, it appears that the differences between decedents and survivors are lower at higher ages in comparison with the age group 50-64 years. Once again, however, clear trends with increasing age do not emerge (Table 5.15).

Table 5.12 - Relative risk ratios of bad and very bad self-rated health and 95% confidence intervals from a multinomial logistic model* estimated for people aged 50 years and over.

	Model 1 Without proximity to death				Model 2 With proximity to death			
	Bad SRH							
Covariate	**RRR**		**95% CI Lb**	**Ub**	**RRR**		**95% CI Lb**	**Ub**
Age								
50-64 (ref.)	1				1			
65-74	1.23	***	1.14	1.32	1.16	***	1.08	1.25
75-84	1.13	*	1.03	1.24	0.97	n.s.	0.88	1.07
85+	0.93	n.s.	0.81	1.07	0.66	***	0.57	0.76
Proximity to death								
Survivors (ref.)	-				1			
4th to 7th from last year of life	-	-	-	-	1.55	***	1.41	1.71
Last 3 years of life	-	-	-	-	2.43	***	2.18	2.71
	Very bad SRH							
Covariate	**RRR**		**95% CI Lb**	**Ub**	**RRR**		**95% CI Lb**	**Ub**
Age								
50-64 (ref.)	1				1			
65-74	1.14	n.s.	0.96	1.34	1.03	n.s.	0.87	1.22
75-84	1.09	n.s.	0.90	1.31	0.86	n.s.	0.71	1.04
85+	0.96	n.s.	0.76	1.20	0.60	***	0.45	0.72
Proximity to death								
Survivors (ref.)	-				1			
4th to 7th from last year of life	-	-	-	-	1.77	***	1.49	2.09
Last 3 years of life	-	-	-	-	3.76	***	3.18	4.46

Goodness of fit statistics	**Model 1**	**Model 2**
Log likelihood	-18989.7	-18801.8
LRT	10994.9	11370.7
Degrees of freedom	24	28
pvalue	0.000	0.000

* Controlled for gender, marital status, geographical area, educational level, ADL disability, multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.13 - Relative risk ratios of bad and very bad self-rated health (ref. very good, good or fair) and 95% confidence intervals by proximity to death among men and women aged 50 years and over from a multinomial logistic model* including an interaction term between gender and proximity to death.

	Bad SRH				Very bad SRH			
Proximity to death	**RRR**		**95% CI**		**RRR**		**95% CI**	
			Lb	**Ub**			**Lb**	**Ub**
Men								
Survivors (ref.)	1				1			
4th to 7th from last year of life	1.75	***	1.52	2.00	2.03	***	1.58	2.61
Last 3 years of life	2.78	***	2.40	3.23	3.93	***	3.09	4.42
Women								
Survivors (ref.)	1				1			
4th to 7th from last year of life	1.40	***	1.23	1.59	1.57	***	1.27	1.96
Last 3 years of life	2.12	***	1.82	2.47	3.55	***	2.85	4.42

Goodness of fit statistics	
Log likelihood	-18795.9
LRT	11382.7
Degrees of freedom	32
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level, ADL disability, multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.14 - Relative risk ratios of bad and very bad self-rated health (ref. very good, good or fair) and 95% confidence intervals by age in different groups of proximity to death from a multinomial logistic model* including an interaction term between proximity to death and age estimated for people aged 50 years and over.

	Bad SRH				Very bad SRH			
Age	**RRR**		**95% CI**		**RRR**		**95% CI**	
			Lb	**Ub**			**Lb**	**Ub**
Survivors								
50-64 (ref.)	1				1			
65-74	1.20	***	1.10	1.30	1.04	n.s.	0.86	1.28
75-84	1.02	n.s.	0.92	1.14	1.06	n.s.	0.85	1.33
85+	0.83	n.s.	0.67	1.03	0.95	n.s.	0.67	1.35
4th to 7th from last year of life								
50-64 (ref.)	1				1			
65-74	0.81	n.s.	0.62	1.06	0.85	n.s.	0.52	1.40
75-84	0.64	**	0.50	0.83	0.52	**	0.32	0.85
85+	0.44	***	0.33	0.60	0.34	***	0.20	0.56
Last 3 years of life								
50-64 (ref.)	1				1			
65-74	0.91	n.s.	0.66	1.25	0.66	n.s.	0.41	1.06
75-84	0.74	n.s.	0.54	1.02	0.46	**	0.29	0.71
85+	0.45	***	0.32	0.62	0.29	***	0.19	0.46

Goodness of fit statistics	
Log likelihood	-18780.9
LRT	11412.5
Degrees of freedom	40
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level, ADL disability, multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table 5.15 - Relative risk ratios of bad and very bad self-rated health (ref. very good, good or fair) and 95% confidence intervals by proximity to death in different age groups from a multinomial logistic model* including an interaction term between proximity to death and age estimated for people aged 50 years and over.

	Bad SRH				**Very bad SRH**			
Proximity to death	**RRR**		**95% CI**		**RRR**		**95% CI**	
			Lb	**Ub**			**Lb**	**Ub**
50-64 years								
Survivors	1				1			
4th to 7th from last year of life	2.22	***	1.77	2.78	2.80	***	1.80	4.35
Last 3 years of life	3.22	***	2.46	4.20	7.02	***	4.70	10.49
65-74 years								
Survivors	1				1			
4th to 7th from last year of life	1.51	***	1.28	1.78	2.28	***	1.68	3.08
Last 3 years of life	2.45	***	2.01	2.98	4.42	***	3.23	6.05
75-84 years								
Survivors	1				1			
4th to 7th from last year of life	1.40	***	1.19	1.64	1.38	*	1.05	1.81
Last 3 years of life	2.34	***	1.94	2.83	3.02	***	2.28	4.01
85 years and more								
Survivors	1				1			
4th to 7th from last year of life	1.18	n.s.	0.90	1.55	0.99	n.s.	0.66	1.49
Last 3 years of life	1.74	***	1.33	2.26	3.79	***	2.34	6.14

Goodness of fit statistics	
Log likelihood	-18780.9
LRT	11412.5
Degrees of freedom	40
pvalue	0.000

* Controlled for gender, marital status, geographical area, educational level, ADL disability, multimorbidity

Levels of significance: *** p<0.001, ** p<0.01, * p<0.05, n.s. not significant

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

6. Discussion and conclusions

Along with demographic ageing and increasing longevity, researchers in different fields of study - epidemiologists, demographers, and economists above all - have been increasingly focusing on the potential consequences that the presence of a high proportion of older people might have for the sustainability of health and social systems. Indeed, given that age is a very well-known risk factor for poor health, old age is commonly seen as a period of unavoidable physical and mental decline. As a consequence, older people are considered to form the frailest segment of the population. According to this idea, living for a long time after 65 years (i.e. the conventional old-age threshold) simply translates into living for many years in a state of poor health. Such a situation would clearly be unsustainable, especially now that the cohorts of baby boomers are progressively entering old age.

In this context, a particular interest has arisen over the last decades in analysing - from different points of view - the association between health and mortality. Some researchers have been working to unravel the role played by the different dimensions of poor health (i.e. functional limitations, chronic morbidity and self-rated health) in determining the risk of death. Others have been focusing on the differences in terms of health care expenditures, health care service use and health status between people in the last years of life and those who are destined to live longer. Moreover, many studies - mostly in the area of health economics - have been performed with the aim of shedding some light on the roles of age and proximity to death in determining the need for health care in the population and related costs.

The work presented in this thesis contributes to both the above mentioned lines of research. From the "looking forward" perspective, it provides new insights on the average duration of poor health and thus on how poor health affects survival over a period of seven years. From the "looking backward" perspective, it provides estimates of the prevalence of poor health according to both age and proximity to death, making it possible to understand whether poor health is concentrated in the last years of life or not. Different dimensions of health (functional, objective and subjective) are taken into account, as each of them is important in determining the health status of older people. In particular, functional health is measured by the ability to perform basic self-care activities: a person is considered severely disabled if he/she is not able to perform at least one ADL without help, and moderately disabled if he/she has only some difficulty in performing at least one ADL. Objective health is measured by multimorbidity, defined as the presence of three or more chronic diseases among the 29 listed in the HIS questionnaire. Subjective health is measured by self-rated health: those people who rated their health as bad and very bad at interview are considered to be in poor health.

The results of the study give some food for thought about the possible need to - at least in part - revise the expectations on the negative consequences of population ageing.

It is worth noting that only a limited literature is currently available which addresses these issues in the Italian population.

More precisely, a relatively higher number of studies have been performed with the aim of estimating - from a “looking forward” perspective - the predictive value of poor health for the risk of death. However, these studies generally focus on specific groups of individuals, such as those living in delimited geographical areas or those who are affected by a certain condition or disease (Corrao et al., 1991; Menotti et al., 2001; Noale et al., 2003; Landi et al., 2010). In other words, they use more an epidemiologic than demographic approach. Until today, only one study - based on data from the European Community Household Panel - has analysed the impact of poor self-rated health on mortality in the general Italian population (Egidi and Spizzichino, 2006).

To my knowledge, on the other hand, very few studies have been performed - from a “looking backward” perspective - on the last years of life of older Italians. To be more specific, some researchers have analysed the differences in health care expenditures for decedents and survivors (Bartolacci et al., 2001; Raitano et al., 2006; Gabriele et al., 2009) based on data from ad hoc surveys that they have carried out in some specific Italian regions in order to gather the needed information. No studies have analysed the health conditions of individuals or the use of health care services according to the number of years remaining before death.

This thesis fills this gap by providing new evidence on the complex relationship between poor health and mortality in the Italian population based on a representative sample of individuals aged 50 years and older.

6.1 “Looking forward”: health and survival

The main results obtained by analysing the data from a “looking forward” perspective can be classified into two groups:

1. evidence on the average duration of moderate and severe ADL disability, multimorbidity and bad and very bad self-rated health over a period of seven years in the total population aged 50 years and older and in different gender and age groups;
2. evidence on the independent predictive value of each of the above mentioned dimensions of poor health for the risk of dying in seven years.

For what concerns the first point, results obviously show that the survival experience of participants in the 1999-2000 Italian HIS over the seven years of follow-up is much different according to the health status at the moment of interview. The interesting finding is that those individuals who have the most severe health problems - i.e. severe limitations in ADLs as well as bad and very bad perceptions of their own health - tend to die faster than it is often thought: indeed, their survival chances appear to be significantly lower as compared to those of their healthier counterparts even during the first years of follow-up. As a consequence, considerable differences in the average survival time over the period of follow-up can be observed between people who had severe limitations in ADL and those who were fully functional on the one hand, and between people who rated their health as bad and very bad and those who rated their health as good or very good on the other hand. It also emerges, however, that people with moderate ADL disability, those in a state of multimorbidity and those who perceived their health as fair generally experienced longer survival over the seven years of follow-up.

To be more specific, individuals aged 50 years and older who did not have limitations in ADLs and those who perceived their health as good or very good survived on average almost the whole period of follow-up (i.e. 86.7 and 88.3 of the total 92 months respectively). Individuals with severe limitations in ADLs lived on average 26.8 months (i.e. slightly more than 2 years) less than people without limitations. Similarly, individuals who rated their health as bad and very bad lived on average 12.9 and 25 months (i.e. approximately one and two years respectively) less than people in good health. When considering each age group separately, the widest differences are observed among individuals aged 85 years and older: people with severe ADL disability lived on average about 20 months less than people without limitations in ADL, while people in bad and very bad self-rated health lived on average about 18 and 26 months less than people in good or very good self-rated health respectively.

The same differences in the average survival time over the period of follow-up between people in good and poor health are not observed when poor health is defined in terms of moderate ADL disability, fair self-rated health[16] or multimorbidity. Indeed, people in these conditions generally lived on average only between 5 and 6 months less than their healthier counterparts. In general, people with and without multimorbidity at interview survive for most of the period of follow-up, even at older ages. The average survival time is considerably lower only in the group of people aged 85 years and more. The most interesting finding is thus that individuals generally live for much shorter periods of time in the most severe health conditions (i.e. severe ADL disability and poor self-rated health) than with multimorbidity. It is important to note that multimorbidity can be included among the less severe conditions because the list of diseases according to which the measure has been defined includes a variety of conditions that are not always severe and in most cases simply require a pharmacological treatment. This is an important result because severe health problems obviously represent a much heavier burden on the health care system and also because it supports the hypothesis that chronic diseases could have less consequences than expected.

For what concerns the second point, the results of a multivariate analysis performed to estimate the independent predictive value of each dimension of poor health for mortality while controlling for some important socio-demographic characteristics known to affect health[17] generally confirm the expectations based on average survival times discussed above. Indeed, it emerges that severe ADLs as well as bad and very bad self-rated health are important predictors of death in seven years. Moderate limitations in ADLs and fair self-rated health also predict death, even if to a lesser extent. On the contrary, chronic morbidity does not significantly alter the risks of dying, meaning that individuals are not

[16] Once again, it should be stressed that a fair health status cannot be defined as a poor health status because of the positive connotation of the Italian translation of the term used in the 1999-2000 HIS survey.

[17] It should be reminded that these socio-demographic characteristics include age, gender, geographical area of residence, marital status and educational level.

expected to die in a short period of time due exclusively to the presence of (one or many) chronic diseases. These findings are consistent with the available literature, as many studies prove that the impact of multimorbidity on mortality is actually mediated by disability (Marengoni et al., 2009; Landi et al., 2010; St. John et al., 2014; Golini and Egidi 2015).

As illustrated in Chapter 2, the existence of a strong association between functional limitations and mortality has been widely documented in previous studies based on different measures of disability. The latter is often defined as the presence of limitations either in ADLs or in other areas of activity (Scott et al., 1997). When a distinction is made between different types of limitations, however, ADL disability often prove to be the one with the strongest impact on mortality. For instance, van den Brink et al. (2005) have shown that the inability to perform at least one ADL without help is a more important predictor of mortality than the inability to perform either IADLs or mobility-related activities. Such a result could be somehow expected, because experiencing difficulties in basic self-care tasks can be assumed as the highest level of functional impairment.

In view of this consideration, it appears reasonable that not only severe but also moderate ADL disability - even if to a lesser extent - predicts death. Other studies have shown that moderate limitations in ADLs significantly affect survival, but the definitions of severity of functional limitations are highly variable and always different from the one adopted in this study. As an example, in Mor et al. (1994) moderate and severe ADL disability are defined as the inability to perform one to two ADLs and 3 or more ADLs respectively.

Another result is that the effect of severe ADL disability on mortality in the male population shows a decreasing trend over time, and is thus stronger in the first years of follow-up. The same trend is not observed in the female population: this supports the hypothesis that men who have severe limitations in ADLs are more likely to die in a small number of years in respect to women. This finding could be an indication that women - even after controlling for health status - tend to survive for longer periods of time in respect to men and is consistent with the so-called male-female health-mortality paradox. It is indeed widely documented that women usually live longer than men, even if they are in generally worse health conditions (Wingard, 1984; Oksuzyan et al., 2008).

A strong association between poor self-rated health and mortality has also been widely reported in the international literature. In some cases, among other health-related indicators, a poor perception of health even emerges as the strongest determinants of mortality (as in Mossey and Shapiro, 1982). For this specific dimension of health, moreover, a comparison with previous findings for Italy is possible thanks to the work done by Egidi and Spizzichino already mentioned before (2006). The latter shows that perceiving oneself in bad or very bad health was a strong risk factor for 5-year mortality among the Italian participants in the European panel survey on health status.

The results of the analysis presented in this thesis - which controls for the time during follow-up - only partially confirm this finding. It is indeed estimated that either a bad or very bad perceived health status is significantly associated with an increased risk of mortality. However, the strength of this association actually decreases over time. This finding holds true among both men and women. A similar decrease in the importance of the association between poor health and mortality has been previously found in other studies not necessarily referring to the same definition of self-perceived health (Scott et al., 1997; Corrao et al., 1991). Once again, this finding can be interpreted as the effect of a more rapid elimination from the population of people who have worse conditions in respect to others. A consequence is that perceiving oneself in bad and very bad general health has a higher impact than ADL disability on mortality only during the first years of follow-up.

6.2 "Looking backward": poor health, proximity to death and age

The results obtained by analysing the data from a "looking backward" perspective can be classified into three main groups:

1. evidence on the prevalence of moderate and severe ADL disability, multimorbidity and bad and very bad self-rated health among survivors and decedents (both in the whole group and according to the number of years remaining before death) aged 50 years and older and in different gender and age groups;
2. evidence on strength of the association between proximity to death and the above mentioned dimensions of poor health;

3. evidence on the differences between decedents and survivors in the predictive value of age for the different dimensions of poor health.

For what concerns the first point - as it should be expected - decedents generally report more frequently than survivors to be in poor health conditions. What is interesting to note is the extent to which decedents and survivors differ: the observed gaps are often so wide that they seem to support the hypothesis that poor health is mainly concentrated among those individuals who are destined to die within a small number of years. This is the case, in particular, for moderate and severe ADL disability and poor (i.e. bad and very bad) self-rated health. When considering the total population aged 50 years and older, for instance, it emerges that 3.4% and 25.6% of survivors and decedents respectively had severe limitations in ADLs and 8.3% and 19.2% of survivors and decedents respectively had moderate limitations in ADLs at the moment of interview. Similarly, 1.8% and 9.7% of survivors and decedents respectively rated their health as bad, while 10.7% and 26.7% of survivors and decedents respectively rated their health as very bad at interview. Furthermore, as the prevalence of severe ADL disability as well as the proportion of people in bad and very bad health increase considerably over the last seven years of life, the differences with survivors are much larger for those decedents who are closest to death. The highest prevalence is indeed observed in the very last year of life, when 41.8% and 55.9% respectively reported to have severe limitations in ADLs and to perceive themselves in poor health. The same pattern is not observed for moderate ADL disability, whose prevalence remains pretty stable - around a value of 20% - over the last seven years of life.

As far as age differences are concerned, the largest proportion of people with severe limitations in ADLs - more than 50% - is among decedents aged 85 years and older. However, the same proportion is considerably lower at the younger ages: only about 1 out of 4 decedents aged 75 to 84 years had severe ADL disability. When considering survivors, 1 out of 3 of those aged 85 years and older and only of 1 out of 10 of those aged 75 to 85 years had severe limitations in ADL at interview. From these figures, it clearly appears that severe ADL disability is mainly a characteristic of the oldest-old people, especially when they are close to death. The situation is slightly different for poor self-rated health, whose highest prevalence - equal to 46.5% - is also found among decedents aged 85 years and older. In this case, both gender and age differences are much narrower.

It should be noted that the proportion of people in good health - which is particularly high among those individuals who were destined to live more than seven years after the interview - can also be quite high even among decedents. Indeed, more than 50% and 60% of people who died within seven years from the interview respectively reported to be fully functional and to perceive their health as very good, good or fair at interview. This finding indicates that many people are actually able to experience a healthy ageing (i.e. they are able to live in good health conditions until they are relatively close to death) and is particularly important because these individuals do not represent a burden for health care systems at all for the most part of their life during old age. Moreover, the proportion of healthy agers decrease with age but remains considerably high even at older ages: in particular, 23% of people aged 85 years and older was fully functional at the moment of interview, while more than half reported to perceive their health as very good, good or fair. It is worth noting that the proportion of people aged 75 to 84 years who were fully functional at interview is considerably higher than that observed among the oldest-old: it is indeed approximately equal to 66%.

Multimorbidity is a more common condition among both decedents and survivors, and the differences between them are smaller. When considering the total population aged 50 years and older, indeed, it appears that 32.9% and 49.8% of survivors and decedents had three or more chronic conditions at the moment of interview. Moreover, the prevalence of multimorbidity among decedents does not change considerably according to the number of years remaining before death, only increasing from 43.6% to 55% with minor differences between age groups.

As a consequence of the evidence discussed above, a strong association emerges between proximity to death and severe ADL disability as well as bad and very bad self-rated health, whereas the association between proximity to death and moderate ADL disability as well as multimorbidity appears to be weaker.

One of the main findings is that the strength of the association between proximity to death and poor health - independently on whether moderate and severe ADL disability, multimorbidity or bad and very bad self-rated health are being considered - is usually lower in the older groups of individuals. This basically means that the groups of older decedents and survivors are more similar between each other in terms of the prevalence of poor health in comparison with their younger counterparts (especially decedents and survivors aged 50 to 64 years). Such a result could be expected: indeed, the average number of extra years that survivors can expect to live is likely to decrease considerable along with increasing age. As a matter of facts, thus, this finding is not surprising and confirms those of previous studies that similarly found a decrease in the strength of the association of proximity to death with health care expenditures (Lubitz and Riley, 1993), health care service use (Forma et al., 2009), and also ADL disability (Klijis et al., 2010). Moreover, it must be noted that a wide gap is always observed between the youngest age group (i.e. 50-64 years) and all the older groups of individuals but, at the same time, no clear trends emerge with increasing age after 65 years.

For what concerns gender differences, it is found that the association between proximity to death and poor health is generally stronger among men rather than among women. This is also not surprising: indeed, a stronger association indicates a steeper increase in the prevalence of poor health from one group of proximity to death to the next, and it is well established that the duration of poor health is longer among women as compared to men. Exactly the same results have been obtained by Klijis et al. (2010) in their study of the association between proximity to death and disability in the adult population living in the Netherlands. Once again, thus, women prove to have more vulnerable health conditions than men.

For what concerns the third point - besides estimating the extent to which poor health is related to proximity to death - a major aim of analysing the data from a “looking backward” perspective was to unravel whether the predictive value of age for poor health is different among decedents and survivors. Indeed, the concerns arisen over time about the consequences of population ageing and increased longevity on the health status of the population are mainly based on the fact that age is a very strong predictor of poor health. The finding of a decreased importance of age as a determinant of poor health among decedents in respect to survivors could be a positive signal and hence support the need for reconsidering the projections of the burden of poor health in ageing populations. To my knowledge, this particular issue has never been investigated before.

Different results on the predictive value of age can be reported for each of the three considered dimensions of poor health.

First, by looking at ADL disability among decedents and survivors, it can be observed that age does not have the same impact on the functional status of every single individual in the population when proximity to death is controlled for. It rather seems that age plays a fundamental role in determining the risks of having limitations in ADLs especially among survivors. On the other hand, its association with a poor functional health is much weaker among individuals who are destined to die within a small number of years. In other words, age loses a significant part of its importance as a determinant of ADL disability with approaching death. It must be noticed that the predictive value of age for limitations in ADLs - even if considerably reduced - is still high among decedents. This finding could indicate that being old inevitably implies higher levels of frailty that expose individuals to the risk of developing a disability in basic tasks of daily life. Some researchers have indeed provided evidence that frailty - a highly prevalent condition among older people - occurs independently on specific negative health outcomes, and also that disability is not a synonym of frailty but rather one of its consequences (Fried et al., 2001). Nevertheless, the results reported in this thesis prove that the damages due exclusively to the ageing process - albeit important - could be much less important than expected based on data which do not take into account the differences between decedents and survivors.

Secondly, results confirm the expectations about the predictive value of age for multimorbidity. Indeed, this is also lower among decedents rather than among survivors, but at the same time the differences are much narrower as compared with those observed in the case of ADL disability. The positive finding is rather that, among decedents, the risks of being affected by three or more chronic conditions raise with increasing age only up to 75 years. Such a result indicates that the oldest groups of decedents are expected to be found in similar conditions between each other in terms of chronic morbidity.

Thirdly, the relationships between age and self-rated health are far more complex. Even in the total population (i.e. when proximity to death is not taken into account), it indeed appears that age has a peculiar effect on the subjective health status. The differences with the youngest group of individuals in fact decrease with increasing age and completely disappear after 85 years. Such a decline in the strength of the association between poor self-rated health and age has been already observed elsewhere (Idler, 1993; Ferraro, 1998; Golini and Egidi, 2015) and could thus be expected. It can be interpreted as a sort of adaptation of older people to their objective conditions, which leads them to rate their health positively in respect to their own expectations. In other words, people at older ages expect to have a less favourable health conditions compared to when they were younger. They thus adapt their perception of health to a worsening general health status. Supporting this view, it can be demonstrated that the association of poor self-rated health with disability and chronic morbidity is lower in the older population. For instance, Schnittker (2005) has shown the perception of health is more influenced by depressive symptoms rather than by the presence of (potentially fatal) diseases after 74 years of age. What is new, thus, is not the decreasing importance of age in determining one's self-evaluation of health. The interesting fact is that - when including proximity to death in the analysis - decedents aged 75 years and older are considerably less likely to perceive themselves in bad or very bad health as compared to decedents in the youngest age group, whereas the same pattern is not observed among survivors. This finding could be interpreted as a further intensification of the adaptation of older people to their actual health conditions when they are closer to death.

6.3 "Looking forward and backward": is there a chance to re-evaluate the impact of population ageing on health care systems?

Some of the results obtained by analysing the data from the two different perspectives can be combined to draw a more complete picture of the complex relationships between health and mortality in the Italian adult and older population aged 50 years and more. Indeed, on the one hand the "looking forward" perspective gives insights on the average survival time of individuals over a period of seven years according to the baseline health status. On the other hand, the "looking backward" perspective gives insights on how frequently poor health occurs in the population, considering the wide differences between people who are destined to die in some years and those who are destined to live longer. These results have been discussed separately in the two previous paragraphs, and some considerations have been already made that open to the possibility to adjust the expectations on the potential consequences of ageing for the health status of the population and hence for the sustainability of health care systems. When they are considered together, however, it appears even clearer that the impact of population ageing could be less dramatic than currently expected.

Let us first consider ADL disability. The presence of severe limitations in ADLs indicates that an individual is not able to perform basic self-care activities that are essential to live independently on other people. It is clear that those persons who are severely ADL disabled need constant help and are likely to consume a disproportionately high amount of health care services. What emerges from the results, however, is that people with severe limitations in ADLs live on average much shorter periods of time as compared to their healthier counterparts: the mean survival times discussed in paragraph 6.1 tell that an individual with severe ADL disability at the beginning of follow-up lived on average 59.9 out of 92 months, i.e. about 5 out of 7 years. The average survival times, moreover, are obviously lower at older ages. At the same time, it appears that the prevalence of ADL disability is much higher among individuals who are in the years immediately before death rather than among those who will stay in the population for a longer time. Among the latter, 1 out of 3 of those aged 85 years and older had severe ADL disability, with a considerable increase as compared to a prevalence of 1 out of 10 observed in the age group 75-84 years. On the other hand, among all decedents about 1 out of 4 has severe limitations in ADLs. Moreover, slightly less than half of decedents in the last year of life have severe ADL disability and - once again - this proportion is particularly high after 85 years of age. All these findings shed light on the fact that not only severe ADL disability is mainly prevalent among people who are closer to death (especially among the oldest-old), but also that its duration could relatively short. The latter statement is also supported by recent estimates of the life expectancy with functional limitations among Italian men and women (Egidi, 2014). As a consequence, not only smaller proportions of people than expected will be in a state of severe disability at older ages, but also those people are likely to represent a burden for the health care systems for a relatively short period of time.

The results for poor self-rated health are similar to those obtained for severe ADL disability. On the one hand, what emerges is that the average survival times over the period of follow-up are considerably lower for people who rated their health as bad and very bad as compared to those who rated their health as very good, good or fair. On the other hand, the prevalence of poor self-rated health is very low among both survivors and decedents and poor ratings of health are also much more frequent in the very last years of life (and especially in the last year before death). All these findings indicate that: those individuals who are destined to stay in the population for longer periods of time generally perceive their health conditions positively and thus do not have increased needs for health care services; the prevalence of poor self-rated health is quite low and tends to increase with approaching death; those who rate their health as poor usually die in a relatively short period of time. Also in this case, recent estimates of life expectancy in poor health support this finding (Egidi, 2014).

It cannot be ignored that the situation does not appear to be as much favourable when multimorbidity is taken into account. In particular, what emerge is that the average survival time is not affected by the presence of chronic diseases, even if an individual has three or more concomitant conditions. On the other hand, evidence is provided that the prevalence of multimorbidity in the population - as compared to the prevalence of the other dimensions of poor health - show smaller changes between decedents and survivors, among whom it is respectively equal to 49.8% and 32.9%. The proportion of people with at least three chronic diseases tends to be higher at older ages, while the differences between decedents and survivors decrease with increasing age. In particular, more than half of both decedents and survivors aged 85 years and older had multimorbidity at interview. The latter thus appears to be a long-standing condition which can be expected to spread among decedents as well as survivors. As a consequence, it is likely that the proportion of people with multiple chronic diseases will increase considerably along with population ageing. All these findings are consistent with an abundant literature according to which the prevalence of chronic diseases in the population has been approximately constant or has even been showing an increasing trend over the last decades (Christensen et al., 2009). However - as already mentioned before in this chapter - the measure of multimorbidity used in this study includes diseases that require simple pharmacological treatments and are thus not expected to increase considerably the need for health care services. Moreover, one should bear in mind that the results obtained for multimorbidity represent the only negative findings of this study.

The findings described above have a particular importance because they prove the existence of a strong association between poor health and survival that justifies the need to revise the projections of the future burden of poor health due to population ageing. Indeed, forecasts of the burden of poor health are usually made based exclusively on age. However, the work reported in this thesis provides consistent evidence that severe ADL disability and poor self-rated are concentrated among people in the last years of life and have a relatively short duration. As a consequence, in order to predict the future number and proportion of people in poor health, the expected number of people at higher ages should be somehow “weighted” to account for the fact that individuals are more or less close to death. The need to revisit the projections of the burden of poor health based on similar results regarding the associations between disability and proximity to death has been already recognised before (Klijis et al., 2011).

In general, it must be reminded that women always result to be disfavoured in comparison with men. They do not only have a higher prevalence of poor health (either among decedents or survivors), but also usually experience longer illnesses. Particular attention should be thus devoted to them, in the sense that further investigations are needed in order to understand the causes of the gender differences.

To conclude, there are more positive than negative signals for the future health status of the Italian population. The good news, in particular, is that adult and older individuals generally perceive their health quite positively and frequently do not have important limitations in everyday life activities until they reach the last years before death. This happens despite they often have multiple chronic conditions, whose consequences thus appear to be limited. Much should still be done in order to prevent chronic diseases or try to delay their onset to older ages, especially among women.

6.4 Limitations, strengths and further developments

The study presented in this thesis has some limitations - mainly linked to the structure and availability of the data - that need to be discussed.

A first limitation is related to the methodology followed by ISTAT to create the data set used for the analysis. Despite its name, indeed, the "New Italian Longitudinal Study" is not a real longitudinal survey but rather the result of a record linkage between different data sources. As explained in Chapter 3, the information needed to calculate the linkage key - i.e. the fiscal code - was not available for 8% of participants in the 1999-2000 HIS, who were thus excluded from the data set. However, the data set allows to accurately estimate the prevalence of poor health. It has indeed been already illustrated that the proportion of individuals in poor health is approximately the same among both groups of linked and non-linked participants in the 1999-2000 HIS, and does not change significantly when calculated either for the total or the linked sample (see Appendix A). This could be expected because the absence of personal information does not depend on the individual characteristics of respondents. As far as the assessment of mortality in the linked sample is taken into account, moreover, the results of the validation analysis reported in Chapter 3 demonstrate that its quality is generally high. The survival experience of the sample over the period of follow-up is indeed very similar to that of the total Italian population during the same years. The data are thus suitable for the purposes of this thesis and the results of the analysis adequately represent the total Italian population aged 50 years and over.

Another limitation has to do with the characteristics of data from the Italian National HIS. The latter is indeed a cross-sectional survey that gathers information on the health status of participants at one specific point in time. The obvious consequence is that the only information available for each individual included in the 1999-2000 linked mortality data file is about: 1) his/her health conditions at the moment of interview; 2) his/her vital status at the end of follow-up; 3) his/her death - in case he/she died during the reference period of the study. This means that no information is provided about the changes in the health status of each individual over his/her last years of life. It is thus possible not possible to estimate the individual trajectories of poor health at the end of life, which would give more precise information on the duration of illness prior to death. However, the prevalence of poor health in groups of people defined according to proximity to death can be considered as a proxy of what each individual experiences over the last years of his/her life. The same approach has been used in previous studies aimed at estimating the occurrence of disability in the population over a fixed number of years before death (Klijis et al., 2010; Smith et al., 2013).

Finally, another limitation is that there is no possibility to analyse the possible change over time in the association between health and mortality, which is essential to contribute to the open debate on the potential changes in the health status of the population along with increasing longevity. This is because at the present moment - as already mentioned before - the only data set available from the “New Italian Longitudinal Study” is the 1999-2000 linked mortality data file. Thus, one can estimate the strength of the association between health and mortality in the population to understand whether proximity to death has an important and independent influence on poor health and whether the effects of age on poor health are mediated by proximity to death. Nevertheless, the results of such an analysis strictly refer to a specific period of time and nothing can be said - from a dynamic point of view - on whether the association between poor health and mortality is becoming stronger or weaker over time. Hopefully, this limitation will be overcome in future works, as far as the linked mortality data files of more recent editions of the Italian National HIS will be released by ISTAT.

In spite of the limitations described above, this study has also some important strengths that are related to both the data and the approaches used for the analysis.

First of all, it is the first time that information on both health and mortality are available for a large national sample of the general Italian population. This allows to analyse the association between poor health and survival from a more demographic point of view, thus considering the total population and not only those individuals residing in delimited areas or with specific conditions - as in most epidemiologic studies. From the opposite perspective, it allows for the first time to have information on health in the last years of life for a considerable number of deaths occurred in the general population.

Moreover, this study adds new insights on health and mortality among people aged 50 years and older from both the "looking forward" and "looking backward" perspectives.

On the one hand, even if many studies have been performed in order to estimate the predictive value of the different dimension of poor health for mortality, none have focused on the estimation of the differences in the survival time according to the health status with the aim of understanding the effect of poor health for survival over a relatively short period of time. Seven years are indeed less than those that most people at older ages can expect to live, given that the remaining life expectancy at 65 and 75 years is approximately equal to 20 and 12 years in developed countries (Human Mortality Database, 2015).

On the other hand, the work presented in this thesis provides for the first time evidence on the prevalence of the different dimensions of poor health over the last years of life among Italian older adults and on the differences in the predictive value of age for poor health between people who are close to death and those who are destined to live longer has also never been investigated before.

Finally, the combination of the results obtained by analysing the data from both the "looking forward" and the "looking backward" perspective put into evidence particular aspects related to the health status in the older population that should be taken into account to improve the projections on the future burden of poor health in the population. Moreover, results shed light on the ability of people to live without considerable health problems during old age and on which specific actions should be undertaken in order to further promote healthy ageing (i.e. efforts in preventing and delaying the onset of chronic diseases).

There are many possibilities for future research on the association between health and mortality in the older population.

A first direction, already mentioned before, could be to analyse time trends in the association between poor health and mortality (from both the “looking forward” and “looking backward” perspectives). This will be possible as soon as more recent data combining information on health and mortality in the Italian population will be available.

By taking advantage of the only data set currently available, it is possible to examine some aspects that in my opinion deserve some attention. First of all, it would be interesting to estimate whether there are any differences in the association between poor health and mortality according to the cause of death. In this case, however, one should bear in mind that it is not possible to distinguish between many different broad groups of causes. The relatively small number of deaths due to causes other than cancers and cardiovascular diseases indeed allows to consider only up to three groups of causes of death. Alternatively, differences can be investigated between groups of individuals with specific chronic conditions instead of focusing on multimorbidity.

Another direction could be to analyse socio-economic differences in the association between health and survival. As discusses in Chapter 3, it is indeed very well known from the literature that the socio-economic status is an important predictor of both poor health and mortality. This finding is further confirmed by the results of the regression analyses presented in this thesis. It would be thus interesting to investigate the association between poor health and mortality is stronger or weaker according, for instance, to the level of education of individuals.

Finally, another line of research could be to analyse the consumption of hospital services over the last years of life by using the data set containing not only the information on deaths, but also on hospitalisations occurred over the period of follow-up. In this way, it would also be possible to contribute - from a more economic point of view - to the debate on the red herring hypothesis.

6.5 Conclusions

This study was aimed at exploring the association between poor health and mortality in the Italian population aged 50 years and older from two opposing perspectives. While results cannot say anything about the future evolution of health along with increasing longevity - thus leaving unresolved the doubts on the potential compression or expansion of morbidity - they provide important insights into the current health status of older adult and older people residing in Italy which should be taken into account to adjust the expectations on the future burden of poor health.

To sum up, while poor health considerably reduces the chances of surviving over a period of seven years, it is concentrated in the last years before death (in particular during the last three years of life). Evidence is also provided on the presence of a high proportion of healthy agers in the population, even in the oldest age groups. Moreover, the role of age as a predictor of poor health is considerably less important among people who are close to death rather than among those who are destined to live longer. This - together with the fact the poor health is mostly concentrated at the end of life - supports the hypothesis that the consequences of the ageing process for the onset of poor health are less dramatic than currently expected. The only measure of poor health for which these results does not hold is multimorbidity: this is consistent with the idea that chronic diseases are common in the population, but often do not have consequences for the functional and psychological status (Christensen et al., 2009). It thus appears that actions should be undertaken in order to reduce the burden of chronic morbidity by preventing or at least delaying the onset of major diseases, but the overall situation gives quite positive indications about the consequences of population ageing in terms of the burden of poor health.

One of the most interesting findings of this thesis - especially as far as the functional and subjective dimensions of health are concerned - is related to the very high proportion of healthy agers in the population. These are indeed individuals who live in good health conditions until some years before death, and are thus not expected to consume frequently the health care services. Further research is thus needed in social and medical sciences aimed at identifying the factors which makes a healthy ageing possible, especially among those individuals who currently experience longer durations of illnesses and poorer health. For instance, particular attention should be devoted to gender differences in healthy - and more generally successful - ageing, as women often appear to be frailer than men (Grundy, 2006). It is very important to promote healthy lifestyle: some indications already exist, for instance, that a moderate physical activity after 65 years of age is significantly associated with an increase in the probability of surviving to age 80 and then dying without disability (Leveille et al., 1999). Interventions, however, should be targeted not only to older people but also to younger individuals in order to help them to reach old age in good health (Rechel et al., 2013).

To conclude, the findings of this work are in line with a whole field of research that has been proposing over the last decades a new conceptualisation of ageing. According to the latter, the threshold of old age should be defined based on the remaining life expectancy rather than on chronological age (Sanderson and Scherbov, 2007 and 2008; Lutz et al., 2008). The expression “old age” is indeed generally used to describe a period of inexorable decline in physical and cognitive performances. Considering that during the last century the life course has stretched along with increasing life expectancy, it is clear that 65 years cannot be assumed as the threshold of age anymore. The meaning of ages has changed over time and, nowadays, being over 65 years of age does not necessarily mean being in a poor health status. It is undeniable that a person aged 65 years today has considerably better health conditions comparing with a same-age individual who lived 50 years ago, and this is precisely why some researchers have even started distinguishing between a “third age” and a “fourth age” (Baltes and Smith, 1999). In this sense, it appears reasonable to redefine old age according to the number of years remaining before death, especially as it appears that the most severe health problems are actually concentrated at the end of life.

References

Asada Y., Kephart G., Hurley J., Yoshida Y., Smith A., Bornstein S. (2012), “The role of proximity to death in need-based approaches to health care”, *Health Policy*, 106(3): 291-302

Ata N., Sözer M.T. (2007), “Cox regression models with nonproportional hazards applied to lung cancer survival data”, *Hacettepe Journal of Mathematics and Statistics*, 36(2):157-67

Baltes P.B., Smith J. (1999), Multilevel and systemic analyses of old age: Theoretical and empirical evidence for a fourth age, in Bengtson V.L., Schaie K.W. (Eds.), Handbook of theories of aging (pp. 153-173), New York: Springer.

Bartolacci S., Berni R., Forni S., Tediosi F., Cislaghi C. (2001), “Il valore economico dell’ospedalizzazione in funzione del tempo dalla nascita e dalla morte”, *Politiche Sanitarie*, 4-6: 193-203

Benyamini Y., Idler E.L. (1999), Community studies reporting association between self-rated health and mortality, *Research on Aging*, 21(3): 392-401

Bosworth H.B., Schaie K.W., Willis S., Siegler I. (1999), “Age and distance to death in the Seattle Longitudinal Study”, *Research on Aging*, 21(6): 723-38

Breyer F., Felder S. (2006), “Life expectancy and health care expenditures: a new calculation for Germany using the costs of dying”, *Health Policy*, 75(2): 178-86

Brook R.H., Ware J.E. Jr., Davies-Avery A., Stewart A.L., Donals C.A., Rogers W.H., Williams K.N., Johnston S.A. (1979), “Overview of adult health measures fielded in Rand’s health insurance study”, *Medical care*, 17(7 Suppl):iii-x, 1-131

Cai L., Lubitz J. (2007), “Was there compression of disability for older Americans from 1992 to 2003?”, *Demography*, 44(3): 479-95

Caley M., Sidhu K. (2010), “Estimating the future healthcare costs of an aging population in the UK: expansion of morbidity and the need for preventative care”, *Journal of Public Health*, 33(1): 117-22

Cambois E., Clavel A., Romieu I., Robine J.M. (2008), “Trends in disability-free life expectancy at age 65 in France: consistent and diverging patterns according to the underlying disability measure”, European Journal of Ageing, 5(4): 287-98

Carnes B.A., Olshansky S.J., Grahn D. (2003), “Biological evidence for limits to the duration of life”, *Biogerontology*, 4: 31-45

Caselli G., Egidi V. (1979), “La geographie de la mortalite italienne: differences territoriales et milieu”, *Genus*, 35(1/2): 101-53.

Caselli G., Vallin J. (2001), “Demographic trends: beyond the limits?”, *Population: An English Selection*, 13(1): 41-72

Cassel C.K., Rudberg M.A., Olshansky S.J. (1992), “The price of success: health care in an aging society”, *Health Affairs*, 11(2): 87-99

Caughey G.E., Ramsay E.N., Vitry A.I., Gilbert A.L., Luszcz M.A., Ryan P., Roughead E.E. (2010), “Comorbid chronic diseases, discordant impact on mortality in older people: a 14-year longitudinal population study”, Journal of Epidemiology and Community Health, 64(12): 1036-42

Chan L., Beaver S., Maclehose R.F., Jha A., Maciejewski M., Doctor J.N. (2002), “Disability and health care costs in the Medicare population”, *Archives of physical medicine and rehabilitation*, 83(9):1196-201

Christensen K., Doblhammer G., Rau R., Vaupel J.W. (2009), “Ageing populations: the challenges ahead”, *The Lancet*, 34(9696): 1196-208

Cislaghi C., Zocchetti C. (2008), "La distribuzione per età dell'accesso alle prestazioni sanitarie", I quaderni di Monitor, 22(3 Suppl.): 89-97

Collett D. (2003), "Modelling survival data in medical research", Boca Raton: CRC Press

Colvez A., Blanchet M., "Disability trends in the United States population 1966-76: analysis of reported causes", *American Journal of Public Health,* 71(5): 464-71

Corrao G., Russo R., Carle F. Di Orio F. (1991), "Disabilità, salute percepita e rischio di morte in una coorte di anziani", Annali dell'Istituto Superiore di Sanità, 27(2): 297-303

Crimmins E.M., Sánchez H.B. (2010), "Mortality and morbidity trends: is there compression of morbidity?", *Journal of Gerontology: Social Science,* 66B(1): 75-86

Cutler D.M., Lleras-Muney A., Vogl T. (2008), "Socioeconomic Status and Health: Dimensions and Mechanisms", National Bureau of Economic Research, Working Paper 14333. Available at www.nber.org/papers/w14333

Deeg D.J.H., Kriegsman D.M.W. (2003), "Concepts of self-rated health: specifying the gender differences in mortality risk", The gerontologist, 43(3):376-86

DeSalvo, K.B., Bloser N.B., Reynolds K., He J., Muntner P. (2005), "Mortality prediction with a single general self-rated health question. A meta-analysis", *Journal of General Internal Medicine,* 21(3): 267-75

Dickman P.W. (2004), "Estimating and modeling relative survival using SAS". Available at www.pauldickman.com/rsmodel/sas_colon/

Dickman P.W., Slogget A., Hills M., Hakulinen T. (2004), "Regression models for relative survival", *Statistics in Medicine,* 23: 51-64

Doblhammer G., Kytir J. (2001), “Compression or expansion of morbidity? Trends in healthy-life expectancy in the elderly Austrian population between 1978 and 1998”, *Social Science and Medicine*, 52(3): 385-91

Dow W.H., Norton E.C. (2002), “The red herring that eats cake: Heckit versus two-part model redux”, *Triangle Health Economics Working Paper Series,* No. 1, University of North Carolina at Chapel Hill.

Egidi V. (2014), “Invecchiamento, longevità, salute: nuovi bisogni, nuove opportunità”, in Livi Bacci M. (ed.), *Salute, sopravvivenza e sostenibilità dei sistemi sanitari: la sfida dell’invecchiamento demografico*, Neodemos.it

Egidi V., Spizzichino D. (2006), “Perceived health and mortality: a multidimensional analysis of ECHP Italian data”, *Genus*, 62(3/4):135-53

Experton B., Ozminkowski R.J., Branch L.G., Li Z. (1996), “A comparison by payor/provider type of the cost of dying among frail older adults”, *Journal of the American Geriatric Society*, 44(9): 1098-107

Ferraro K.F. (1980), “Self-ratings of health among the old and the old-old”, *Journal of Health and Social Behavior*, 21(4): 377-83

Ferraro K.F. (1996), “Self and age differences in defining health situations. A comparison of measurement strategies”, *Research on Aging*, 18(2): 175-201

Forma L., Rissanen P., Aaltonen M., Raitanen J., Jylhä M. (2011), “Dementia as a determinant of health and social service use in the last two years of life in 1996-2003”, *BMC Geriatrics,* doi: 10.1186/1471-2318-11-14

Forma L., Rissanen P., Aaltonen M., Raitanen J., Jylhä M. (2009), “Age and closeness of death as determinants of health and social care utilization: a case-control study”, *European Journal of Public Health*, 19(3): 313-8

Forma L., Rissanen P., Noro A., Raitanen J., Jylhä M. (2007), "Health and social service use among old people in the last years of life", *European Journal of Ageing*, 4(3):145-54

Freedman V.A., Martin L.G. (1998), "Understanding trends in functional limitations among older Americans", *American Journal of Public Health*, 88(10): 1457-62

Fried L.P., Tangen C.M., Walston J., Newman A.B., Hirsch C., Gottdiener J., Seeman T., Tracy R., Kop W.J., Burke G., McBurnie M.A. for the Cardiovascular Health Study Collaborative Research Group, "Frailty in older adults: evidence for a phenotype", *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 56(3): M146-56

Fries J.F. (1980), "Aging, natural death and the compression of morbidity", *The New England Journal of Medicine*, 303(3): 130-5

Fries J.F. (1983), "The compression of morbidity", *The Milbank Memorial Fund Quarterly: Health and Society*, 61(3): 397-419

Fries J.F. (1984), "The compression of morbidity: miscellaneous comments about a theme", *The Gerontologist*, 24(4): 354-9

Fries J.F. (1989), "The compression of morbidity: near or far?", *The Milbank Memorial Fund Quarterly*, 67(2): 208-32

Fries J.F (2000), "Compression of morbidity in the elderly", *Vaccine*, 18: 1584-9

Fries J.F. (2003), "Measuring and monitoring success in compressing morbidity", *Annals of internal medicine*, 139: 455-59

Fries J.F., Bruce B., Chakravarty E. (2011), "Compression of morbidity 1980-2011: a focused review of paradigms and progress", *Journal of Aging Research*, Article ID 261702, 10 pages

Gabriele S., Raitano M. (2009), “Invecchiamento, salute, spesa sanitaria e di cura in Italia”, *Studi e Note di Economia*, 14(3): 541-69

Goldberg P., Gueguen A., Schmaus A., Nakache J.P., Goldberg M. (2001), “Longitudinal study of associations between perceived health status and self reported diseases in the French Gazel cohort”, *Journal of Epidemiology and Community Health*, 55(4):412-6

Goldman N., Korenman S., Weinstein S. (1995), “Marital status and health among the elderly”, *Social Science & Medicine*, 40(12): 1717-30

Golini N., Egidi V. (2015), “The latent dimensions of poor self-rated health: how chronic diseases, functional and emotional dimensions interact influencing self-rated health in Italian elderly”, *Social Indicators Research*, DOI: 10.1007/s11205-015-1033-3

Gove W.R. (1973), “Sex, marital status and mortality”, *American Journal of Sociology*, 79(1): 45-67

Graham P., Blakely T., Davis P., Sporle A., Pearce N. (2004), “Compression, expansion, or dynamic equilibrium? The evolution of health expectancy in New Zealand”, *Journal of Epidemiology and Community Health*, 58(8): 659-66

Grambsch P.M., Therneau T. M. (1994), “Proportional hazards tests and diagnostics based on weighted residuals”, *Biometrika*, 81(3): 515–26

Gruenberg E.M. (1977), “The failures of success”, *The Milbank Memorial Fund Quarterly*, 83(4): pp. 779-800

Grundy E. (2006), “Gender and healthy ageing”, In: Yi Z., Crimmins E.M., Carriere Y., Robine J.M. (eds.) Longer life and healthy aging. Springer, Dordrecht, The Netherlands, pp. 173-199.

Gudex C., Lafortune G. (2000), “An inventory of health and disability-related surveys in OECD countries”, *OECD Labour Market and Social Policy Occasional Papers*, No. 44, OECD Publishing

Guralnick J.M., LaCroix A.Z., Branch L.G., Kasl S.V., Wallace R.B. (1991), "Morbidity and disability in older persons in the years prior to death", *American Journal of Public Health,* 81(4): 443-7

Hank K. (2011), "How successful do older Europeans age? Findings from SHARE", *Journal of Gerontology: Social Sciences,* 66B(2): 230-6

Hank K., Jürges H. (2010), "The last year of life in Europe: regional variations in functional status and sources of support", *Ageing and Society,* 30(6): 1041-54

Hogan C., Lunney J., Gabel J., Lynn J. (2001), "Medicare beneficiaries' costs of care in the last year of life", *Health Affairs,* 20(4): 188-95

Hoover D.R., Crystal S., Kumar R., Sambamoorthi U., Cantor J.C (2002), "Medical expenditures during the last years of life: findings from the 1992-1996 Medicare Current Beneficiary Survey", *Health Service Research,* 37(6): 1625-42

HosmerD.W., Lemeshov S., May S. (2011), "Applied survival analysis: regression modeling of time-to-death event data", 2nd edition, Hoboken: John Wiley & Sons

Human Mortality Database (2014), University of California, Berkeley (USA) and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de

Idler E.L. (1993), "Age differences in self-assessments of health: age changes, cohort difference, or survivorship?", *Journal of Gerontology,* 48(6): S289-300

Idler E.L., Angel R.J. (1990), "Self-rated health and mortality in the NHANES-I Epidemiologic Follow-up Study", *American Journal of Public Health,* 80(4):446-52

Idler E.L., Benyamini Y. (1997), "Self-rated health and mortality: a review of twenty-seven community studies", Journal of health and social behaviour, 46(2):21-37

Idler E.L., Kasl S.V., Lemke J.H. (1990), "Self-evaluated health and mortality among the elderly in New Haven, Connecticut, and Iowa and Washington Counties, Iowa, 1982-86", *American Journal of Epidemiology*, 131(1): 91-103

Ingram D.D., Lochner K.A., Cox C.S. (2008), "Mortality experience of the 1986-2000 National Health Interview Survey linked mortality files participants", Vital and Health Statistics, Series 2: Data Evaluation and Methods Research, 147: 1-37

ISTAT (2007a), "Condizioni di salute, fattori di rischio e ricorso ai servizi sanitari, anno 2005. Nota metodologica", Statistiche in breve, Rome (Italy). Available at www3.istat.it/salastampa/comunicati/non_calendario/20070302_00/

ISTAT (2007b), "Differenze di mortalità e ospedalizzazione secondo stato di salute, stili di vita e consumo dei servizi sanitari ISTAT Salute 2000", Internal report on the first year of activities within the project *Mortality and hospitalization differences according to different lifestyles, health conditions and health service uses in the sample of the ISTAT health interview survey 1999-2000*

ISTAT (2013), "L'indagine sulle cause di morte. Nuovo piano di controllo e correzione dei dati di mortalità per causa e fasi procedurali", Letture Statistiche - Metodi, Rome (Italy)

ISTAT (2015), "Tavole di mortalità della popolazione residente", Available at http://demo.istat.it

Jagger C. (2000), "Compression or expansion of morbidity – what does the future hold?", *Age and Ageing*, 29: 93-4

Jagger C., Clarke M. (1988), "Mortality risks in the elderly: five-year follow-up of a total population", *International Journal of Epidemiology*, 17(1): 111-4

Jagger C., Gillies C., Cambois E., Van Oyen H., Nusselder W., Robine J.M., and the EHLEIS team (2009), "Trends in disability-free life expectancy at age 65 in the European Union 1995-2001: a comparison in 13 EU countries", EHEMU Technical Report 2009_5.1., Cedex, France: EHEMU

Jagger C., McKee M., Christensen K., Lagiewka K., Nusselder W., Van Oyen H., Cambois E., Jeune B., Robine J.M. (2013), "Mind the gap - reaching the European target of a 2-year increase in healthy life years in the next decade", *European Journal of Public Health*, 23(5): 829-33

Jürges H., Hank K. (2009), "The last year of life in Europe: initial findings from the SHARE Study", MEA Discussion Paper n. 177-09, Available at http://ssrn.com/abstract=1443992

Jylhä M., Guralnik J.M., Balfour J., Fried L.P. (2001), "Walking difficulty, walking speed, and age as predictors of self-rated health: the women's health and aging study", *Journal of Gerontology Series A, Biological Sciences and Medical Sciences,* 56(10): M69-17

Kalbfleisch J.D., Prentice R. (2002), "The statistical analysis of failure time data", 2nd edition, Hoboken: John Wiley & Sons

Kaplan G., Barell V., Lusky A. (1988), "Subjective state of health and survival in elderly adults", *Journal of Gerontology,* 43(4): S114-20

Kaplan G.A., Goldberg D.E., Everson S.A., Cohen R.D., Salonen R., Tuomilehto J., Salonen J. (1996), "Perceived health status and morbidity and mortality: evidence from the Kuopio ischaemic heart disease risk factor study", *International Journal of Epidemiology,* 25(2):259-65

Katz S., Ford A.B., Moskowitz R.W., Jackson B.A., Jaffe M.W. (1963), "Studies of illness in the aged. The index of ADL: a standardized measure of biological and psychosocial function", *Journal of the American Medical Association,* 185:914-9

Klijis B., Mackenbach J.P., Kunst A.E. (2010), "Disability occurrence and proximity to death", *Disability and Rehabilitation,* 32(21): 1733-41

Klijis B., Mackenbach J.P., Kunst A.E. (2011), "Future disability projections could be improved by connecting to the theory of a dynamic equilibrium", *Journal of clinical epidemiology,* 64(4): 436-43

Lafortune G., Balestat G. (2007), “Trends in Severe Disability Among Elderly People: Assessing the Evidence in 12 OECD Countries and the Future Implications”, *OECD Health Working Papers*, No. 26, OECD Publishing

Landi F. Liperoti R., Russo A., Capoluongo E., Barillaro C., Pahor M., Bernabei R., Onder G. (2010), “Disability, more than multimorbidity, was predictive of mortality among older persons aged 80 years and older”, *Journal of Clinical Epidemiology*, 63(7): 752-9

Larsson K., Kåreholt I., Thorslund M. (2008), “Care utilization in the last years of life in relation to age and time to death: results from a Swedish urban population of the oldest old”, *European Journal of Ageing*, 5(4): 349-57

Lee Y. (2000), “The predictive value of self-assessed general, physical, and mental health on functional decline and mortality in older adults”, *Journal of Epidemiology and Community Health*, 54(2): 123-9

Leinonen R., Heikkinen E., Jylhä M. (2002), “Changes in health, functional performance and activity predict changes in self-rated health: a 10-year follow-up in older people”, *Archives of Gerontology and Geriatrics*, 35(1): 79-92

Lentzner H.R., Pamuk E.R., Rhodenhiser E.P., Rothenberg R.,Powell-Griner E. (1992), “The quality of life in the year before death”, *American Journal of Public Health*, 82(8): 1093-8

Leveille S.G., Guralnik J.M., Ferrucci L., Langlois J. (1999), “Aging successfully until death in old age: opportunities for increasing active life expectancy”, *American Journal of Epidemiology*, 149(7): 654-64

Liao Y., McGee D., Cao G., Cooper R.S. (2000), “Quality of the last year of life of older adults: 1986 VS 1993”, *Journal of the American Medical Association*, 283(4): 512-8

Lipsi R.M., Caselli G. (2002), “Evoluzione della geografia della mortalità in Italia. Tavole provinciali e probabilità di morte per causa anni: 1971-1973, 1981-1983, 1991-1993”, Dipartimento di Scienze Demografiche, Università di Roma “La Sapienza”, Fonti e Strumenti 4.

Lubitz J.D., Cai L., Kramarow E., Lentzner H. (2003), “Health, life expectancy, and health care spending among the elderly”, *The New England Journal of Medicine*, 349(11): 1048-55

Lubitz J.D., Riley G.F. (1993), “Trends in Medicare payments in the last year of life”, *New England Journal of Medicine*, 328(15): 1092-6

Lutz, W., Sanderson W., Scherbov S. (2008), “The coming acceleration of global population ageing”, *Nature*, 451: 716-719.

Lyyra T.M., Leskinen E., Jylhä M., Heikkinen E. (2009), “Self-rated health and mortality in older men and women: a time-dependent covariate analysis”, *Archives of Gerontology and Geriatrics*, 48(1):14-8

Mackenbach J.P., Bos V., Andersen O., Cardano M., Costa G., Harding S., Reid A., Hemström Ö., Valkonen T., Kunst A.E. (2003), “Widening socioeconomic inequalities in mortality in six Western European countries”, *International Journal of Epidemiology*, 32(5): 830-7

Marinacci C., Grippo F., Pappagallo M., Sebastiani G., Demaria M., Vittori P., Caranci N., Costa G. (2013), “Social inequalities in total and cause-specific mortality of a sample of the Italian population, from 1999 to 2007”, *European Journal of Public Health*, 23(4): 582-7

Manton, K.G. (1982), “Changing concepts of morbidity and mortality in the elderly population”, *The Milbank Memorial Fund Quarterly*, 60(2): 183-244

Manton K.G., Corder L., Stallard E. (1997), “Chronic disability trends in elderly United States”, *Proceedings of the National Academy of Sciences of the United States of America*, 94(6): 2593-8

Manton K.G. (2008), “Recent declines in chronic disability in the elderly U.S. population: risk factors and future dynamics”, *Annual Review of Public Health,* 29: 91-113

Manton K.G., Gu X., Lamb V. (2006), “Long-term trends in life expectancy and active life expectancy in the United States”, *Population and Development Review,* 32(1): 81-105

Manton K.G., Gu X., Lowrimore G.R. (2008), “Cohort changes in active life expectancy in the U.S. elderly population: experience from the 1982–2004 national long-term care survey”, *Journal of Gerontology: Social Sciences*, 63B(5): S269-81

Mazzuco S. (2009), “Condizioni di salute nelle Regioni Italiane”, in Ongaro F, Salvini S (Eds) Rapporto sulla popolazione - Salute e sopravvivenza, Gruppo di Coordinamento per la Demografia, Il Mulino: Bologna.

Marengoni A., von Strauss E., Rizzuto D., Winblad B., Fratiglioni L. (2009), “The impact of chronic multimorbidity and disability on functinal decline and survival in elderly persons. A community-based, longitudinal study”, *Journal of Internal Medicine,* 265(2): 288-95

McCallum J.,Shadbolt B., Wang D. (1994), “Self-rated health and survival: a 7-year follow-up study of Australian elderly”, American Journal of Public Health, 84(7): 1100-5

Menotti A., Mulder I., Nissinen A., Giampaoli S., Feskens E.J.M., Kromhout D. (2001), “Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortality: the FINE study (Finland, Italy, Netherlands, Elderly)”, *Journal of Clinical Epidemiology,* 54(7): 680-6

Meslé F., Vallin J. (2000), “Transition sanitaire: tendances et perspectives”, *Médecins/Sciences,* 16(11): 1161-71

Ministero della salute (2013), “Rapporto annuale sull’attività di ricovero ospedaliero. Dati SDO 2012”, Direzione Generale della Programmazione Sanitaria, Rome (Italy). Available at www.salute.gov.it/imgs/C_17_pubblicazioni_2094_allegato.pdf

Mor V., Wilcox V., Rakowski W., Hiris J. (1994), "Functional transitions among the elderly: patterns, predictors, and related hospital use", *American Journal of Public Health*, 84(8): 1274-80

Mor V. (2005), "The compression of morbidity hypothesis: a review of research and prospects for the future", *Journal of the American Geriatrics Society*, 53: S308-9

Mossey J.M., Shapiro E. (1982), "Self-rated health: a predictor of mortality among the elderly", *American Journal of Public Health*, 72(8): 800-8

Mulsant B.H., Ganguli M., Seaberg E.C. (1997), "The relationship between self-rated health and depressive symptoms in an epidemiological sample of community-dwelling older adults", *Journal of the American Geriatric Society*, 45(8): 954-8

Murphy M., Martikainen P. (2013), "Use of hospital and long-term institutional care services in relation to proximity to death among older people in Finland", *Social Science & medicine*, 88: 39-47

Noale M., Maggi S., Minicuci N., Marzari C., Destro C., Farchi G., Scafato E., Baldereschi M., Di Carlo A., Crepaldi G. for the ILSA group (2003), "Dementia and disability: impact on mortality", *Dementia and Geriatric Cognitive Disorders*, 16(1): 7-14

Nybo H., Petersen H.C., Gaist D., Jeune B., Andersen K., McGue M., Vaupel J.W., Christensen K. (2003), "Predictors of mortality in 2,249 nonagenarians – The Danish 1905-cohort survey", *Journal of the American Geriatric Society*, 51(10): 1365-73

OECD (1988), "Ageing populations: the social policy implications", OECD, Paris

Oeppen J., Vaupel J. (2002), "Broken limits to life expectancy", *Science*, 296(5570):1029-31

Oksuzyan A., Juel K., Vaupel J.W., Christensen K. (2008), "Men: good health and high mortality. Sex differences in health and aging", *Aging Clinical and Experimental Research*, 20(2): 91-102

Olshansky S.J., Carnes B.A., Cassel C. (1990), “In search of Methuselah: estimating the upper limits to human longevity”, *Science*, 250(4981): 634-40

Olshansky S.J., Rudberg M.A., Carnes B.A., Cassel C.K., Brody J.A., “Trading off longer life for worsening health. The expansion of morbidity hypothesis”, *Journal of Ageing and Health*, 3(2): 194-216

Omran A.R. (1971), “The epidemiologic transition. A theory of the epidemiology of population change”, *The Milbank Memorial Fund Quarterly*, 49(4): 509-538

Payne G., Laporte A.,Deber R., Coyte P.C. (2007), “Counting backward to health care’s future: using time-to-death modeling to identify changes in end-of-life morbidity and the impact of ageing on health care expenditures”, *The Milbank Quarterly*, 85(2): 213-57

Raitano M. (2006), “The impact of death-related costs on health care expenditure: a survey”, ENEPRI Research Report No. 17

Rakowski W., Fleishman J.A., Mor V., Bryant S.A. (1993), “Self-assessment of health and mortality among older persons: do questions other than global self-rated health predict mortality?”, Research on Aging, 15(1): 92-116

Rau R., Soroko E., Jasilionis D., Vaupel J. (2008), “Continued reductions in mortality at advanced ages”, *Population and Development Review*, 34(4): 747-68

Rechel B., Grundy E., Robine J.M., Cylus J., Mackenbach J.P., Knai C., McKee M. (2013), “Ageing in the European Union”, *The Lancet*, 381(9874): 1312-22

Rice D.P., Fineman N. (2004), “Economic implications of increased longevity in the United States”, *Annual Review of Public Health*, 25: 457-73

Riegel K.F., Riegel R.M. (1972), “Development, drop and death”, *Developmental Psychology*, 6(2): 306-19

Riley G.F., Lubitz J.D. (2010), “Long-term trends in Medicare payments in the last year of life”, *Health Services Research*, 45(2): 565-76

Robine J.M., Cambois E. (2013), “Healthy life expectancy in Europe”, *Population & Societies*, No. 499

Robine J.M., Cambois E., Nusselder W., Jeune B., Van Oyen H., Jagger C. and the JA:EHLEIS team (2013), “The joint action on healthy life years (JA:EHLEIS)”, *Archives of Public Health*, 71(2): 1-5

Robine J.M., Michel J.P. (2004), “Looking forward to a general theory of population aging”, *The journals of gerontology. Series A, Biological sciences and medical sciences*, 59(6): M590-7

Salas C., Raftery J.P. (2001), “Econometric issues in testing the age neutrality of health care expenditure”, *Health Economics*, 10(7): 669-71

Sagardui-Villamor J., Guallar-Castillón P., Garcıa-Ferruelo M., Ramón Banegas J., Rodrıguez-ArtalejoF. (2005), “Trends in disability and disability-free life expectancy among elderly people in Spain: 1986–1999”, *Journal of Gerontology: Medical Sciences*, 60A(8): 1028-34

Sanderson, W., Scherbov S. (2007), “A new perspective on population aging”, *Demographic Research*, 16: 27-58

Sanderson, W., Scherbov S. (2008), “Rethinking Age and Ageing”, *Population Bulletin* 63(4)

Schemper M. (1992), “Cox analysis of survival data with non-proportional hazard functions”, *Journal of the Royal Statistical Society*, 41(4): 455-65

Schneider E., Guralnik J.M. (1990), “The aging of America: impact on health care costs”, *Journal of the American Medical Association*, 263(17): 2335-40

Schnittker J. (2005), “When mental health becomes health: age and the shifting meaning of self-evaluations of general health”, *The Milbank Quarterly,* 82(3): 397-423

Scott W.K., Macera C.A., Cornman C.B., Sharpe P.A. (1997), “Functional health status as a predictor of mortality in men and women over 65”, *Journal of Clinical Epidemiology,* 50(3): 291-6

Seshamani M., Gray A. (2002), “The impact of ageing on expenditures in the National Health Service”, *Age and Ageing*, 31(4): 287-94

Seshamani M., Gray A. (2004a), “Ageing and health care expenditure: the red herring argument revisited”, *Health Economics*, 13(4): 303-14

Seshamani M., Gray A. (2004b), “A longitudinal study of the effects of age and time to death on hospital costs”, *Journal of Health Economics*, 23(2):217-35

Shields M., Shooshtari S., (2001). Determinants of self-perceived health, *Health Reports / Statistics Canada,* 13(1): 35-52

Small B.J., Bäckman L. (1999), “Time to death and cognitive performance”, *Current Directions in Psychological Science*, 8(6): 168-72

Small B.J., Fratiglioni L., von Strauss E., Bäckman L. (2003), “Terminal decline and cognitive performance in very old age: does cause of death matter?”, *Psychology and Aging*, 18(2): 193-202

Smith A.K., Walter L.C., Miao Y., Boscardin W.J., Covinsky K.E. (2013), “Disability during the last two years of life”, *Journal of the American Medical Association Internal Medicine,* 173(16): 1506-13

Stearns S.C., Norton E.C. (2004), “Time to include time to death? The future of health care expenditure predictions”, *Health Economics,* 13(4): 315-27

Steinmann L., Telser H., Zweifel P. (2007), “Aging and future health care expenditure: a consistent approach”, *Forum for Health Economics & Policy,* 10(2): 1-30

Stenholm S., Pentti J., Kawachi I., Westerlund H., Kivimaki M., Vahtera J. (2014), "Self-rated health in the last 12 years of life compared to matched surviving controls: the Health and Retirement Study", *PLoS One*, 9(9): 1-6

St John P.D, Tyas S.L., Menec V., Tate R. (2014), "Multimorbidity, disability and mortality in community-dwelling older adults", Canadian Family Physician, 60(5): e272-80

Sullivan D.F. (1971), "A single index of mortality and morbidity", *HSMHA Health Reports*, 86(4): 347-54

United Nations, Department of Economic and Social Affairs, Population Division (2013), World Population Ageing 2013, ST/ESA/SER.A/348.

Vallin J., Meslé F. (2009), "The segmented trend line of highest life expectancies", Population and development review, 35(1): 159-87

van den Brink C.L., Tijihuis M., van den Bos G.A., Giampaoli S., Nissinen A., Kromhout D. (2005), "The contribution of self-rated health and depressive symptoms to disability severity as a predictor of 10-year mortality in European elderly men", *American Journal of Public Health*, 95(11): 2029-34

Vaupel J. (2010), "Biodemography of human ageing", *Nature*, 464(2788): 536-42

Verbrugge L.M. (1985), "Gender and health: un update on hypotheses and evidence", *Journal of Health and Social Behavior*, 26(3): 156-82

Verbrugge L.M. (1984), "Longer life but worsening health? Trends in health and mortality of middle-aged and older persons", *The Milbank Memorial Fund Quarterly*, 63(3): 475-519

Verbrugge L.M., Jette A.M. (1984), "The disablement process", *Social Science & Medicine*, 38(1): 1-14

Verdecchia A., Capocaccia R., Hakulinen T. (1995), "Methods of data analysis" , in Berrino F., Sant M., Verdecchia A., Capocaccia R., Estève J. (eds.), *Survival of cancer patients in Europe. The Eurocare study,* IARC Scientific Publications, n. 132

Ware J.Jr., Kosinski M., Keller S.D. (1996), "A 12-item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity", *Medical Care,* 34(3): 220-33

Weaver F., Stearns S.C., Norton E.C., Spector W. (2009), "Proximity to death and participation in the long-term care market", *Health Economics,* 18:

Werblow A., Felder S., Zweifel P. (2007), "Population ageing and health care expenditures: a school of "red herrings"?", *Health Economics,* 16(10): 1109-26

Westerhout E., Pellikaan F. (2005), "Can we afford to live longer in better health?", ENEPRI Research Reports No. 10, Available at SSRN: http://ssrn.com/abstract=2012308

WHO (1946), Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.

Wingard R.G. (1984), "The sex differential in morbidity, mortality, and lifestyle", *Annual Review of Public Health,* 5: 433-58

Wolinsky F.D., Johnson R.J. (1992), "Perceived health status and mortality among older men and women", *Journal of Gerontology,* 47(6): S304-12

Wolinsky F.D., Callahan C.M., Johnson R.J. (1994), "Subjective health status and mortality in the elderly", in Vellas B.J., Albarede J.L., Garry P.J. (eds.), *"Facts and research in Gerontology 1994",* New York: Springer

Wolinksy F.D., Culler S.D., Callahan C.M., Johnson R.J. (1994b), “Hospital resource consumption among older adults: a prospective analysis of episodes, length of stay, and charges over a seven-year period”, *Journal of Gerontology*, 49(5): S240-52

Wolinsky F.D., Johnson R.L., Stump T.E. (1995), “The risk of mortality among older adults over an eight-year period”, *The Gerontologist*, 35(2): 150-61

Yang Z., Norton E.C., Stearns S.C. (2003), “Longevity an health care expenditures: the real reasons older people spend more”, *Journal of gerontology Series B: Psychological and Social Sciences*, 58(1): S2-10

Zhao J., Barclay S., Farquhar M., Kinmonth A.L., Brayne C., Fleming J., for the Cambridge City over-75s cohort study collaboration (2010), “The oldest old in the last year of life: population-based findings from Cambridge City over-75s Cohort Study participants aged 85 years and older at death”, *Journal of the American Geriatric Society*, 58(1): 1-11

Zweifel P., Felder S., Meiers M. (1999), “Ageing of population and health care expenditure: a red herring?”, Health Economics, 8(6): 485-96

Appendix A

Table A.2 - Proportion of individuals in the 1999-2000 HIS linked* and total sample according to gender and age groups.

LINKED SAMPLE	Men		Women	
Age group	%	95% CI	%	95% CI
0-14	51.6	(50.5-52.7)	48.4	(47.4-49.5)
15-24	50.7	(49.5-51.9)	49.3	(48.2-50.5)
25-34	50.7	(49.7-51.8)	49.3	(48.3-50.3)
35-44	50.0	(49.0-51.1)	50.0	(48.9-51.0)
45-54	49.2	(48.1-50.3)	50.8	(49.6-51.9)
55-64	48.9	(47.7-50.0)	51.1	(49.9-52.3)
65-69	45.0	(43.3-46.7)	55.0	(53.1-56.8)
70-74	44.7	(42.9-46.5)	55.3	(53.3-57.3)
75-79	39.9	(38.0-41.8)	60.1	(57.8-62.4)
>=80	32.4	(30.6-34.2)	67.6	(65.0-70.2)
Total	**48.6**	**(48.2-49.0)**	**51.4**	**(51.0-51.8)**

TOTAL SAMPLE	Men		Women	
Age group	%	95% CI	%	95% CI
0-14	51.6	(50.1-53.0)	48.4	(47.1-49.8)
15-24	50.7	(49.1-52.2)	49.3	(47.8-50.9)
25-34	50.8	(49.4-52.1)	49.2	(47.9-50.6)
35-44	50.0	(48.6-51.3)	50.0	(48,7-51.4)
45-54	49.3	(47.9-50.8)	50.7	(49.2-52.2)
55-64	48.8	(47.2-50.3)	51.2	(49.7-52.8)
65-69	45.2	(43.1-47.3)	54.8	(52.5-57.1)
70-74	44.5	(42.2-46.8)	55.5	(53.0-58.0)
75-79	39.7	(37.4-42.0)	60.3	(57.4-63.2)
>=80	32.6	(30.4-34.8)	67.4	(64.2-70.6)
Total	**48.6**	**(48.1-49.2)**	**51.4**	**(50.8-51.9)**

* The linked sample comprises 128818 for whom the linkage key was available

Source: ISTAT, 2007b

Table A.2 - Proportion of individuals in the 1999-2000 HIS linked* and total sample according to gender, age and self-rated health.

MEN	**LINKED SAMPLE**				**TOTAL SAMPLE**			
Age	**Bad/very bad SRH**		**Good/very good SRH**		**Bad/very bad SRH**		**Good/very good SRH**	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
15-24	1.2	(0.9-1.5)	89.3	(87.1-91.5)	1.3	(0.9-1.6)	89.2	(86.3-92.1)
25-34	1.7	(1.4-2.0)	83.2	(81.3-85.1)	1.7	(1.4-2.1)	83.2	(80.7-85.6)
35-44	2.3	(2.0-2.7)	73.1	(71.3-74.8)	2.4	(2.0-2.8)	72.9	(70.6-75.2)
45-54	4.4	(3.9-4.9)	58.8	(57.1-60.6)	4.4	(3.8-5.0)	58.8	(56.6-61.0)
55-64	8.7	(7.9-9.4)	42.9	(41.3-44.5)	8.8	(7.9-9.7)	43.0	(41.0-45.0)
65-69	13.4	(11.9-14.8)	30.7	(28.5-32.8)	13.6	(12.0-15.3)	30.4	(27.9-33.0)
70-74	15.9	(14.2-17.6)	24.5	(22.4-26.6)	16.5	(14.5-18.4)	24.2	(21.8-26.7)
75-79	20.0	(17.8-22.2)	17.6	(15.5-19.7)	20.8	(18.2-23.3)	17.8	(15.4-20.1)
>=80	32.7	(29.4-35.9)	14.2	(12.0-16.4)	32.6	(28.9-36.4)	14.3	(11.8-16.7)
Total	**6.2**	(5.9-6.4)	**62.1**	(61.1-63.0)	**6.2**	(6.0-6.6)	**62.5**	(61.1-63.0)

WOMEN	**LINKED SAMPLE**				**TOTAL SAMPLE**			
Age	**Bad/very bad SRH**		**Good/very good SRH**		**Bad/very bad SRH**		**Good/very good SRH**	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
15-24	1.2	(0.9-1.5)	83.7	(81.5-85.9)	1.2	(0.9-1.5)	84.0	(81.2-86.8)
25-34	1.8	(1.5-2.1)	75.1	(73.2-76.9)	1.8	(1.4-2.1)	75.1	(72.8-77.5)
35-44	2.9	(2.5-3.3)	64.8	(63.1-66.4)	3.0	(2.5-3.4)	64.8	(62.6-67.0)
45-54	6.7	(6.0-7.3)	47.1	(45.5-48.6)	6.6	(5.9-7.3)	47.1	(45.2-49.1)
55-64	11.8	(10.9-12.6)	32.7	(31.3-34.1)	11.7	(10.7-12.7)	32.9	(31.1-34.6)
65-69	16.6	(15.2-18.1)	22.1	(20.4-23.8)	16.2	(14.5-17.9)	22.8	(20.8-24.8)
70-74	23.2	(21.4-25.0)	17.8	(16.2-19.4)	23.0	(20.9-25.1)	17.7	(15.8-19.5)
75-79	27.9	(25.8-30.0)	14.6	(13.1-16.1)	28.4	(25.9-30.9)	14.5	(12.7-16.2)
>=80	38.3	(35.9-40.7)	9.9	(8.7-11.2)	38.1	(35.2-40.9)	9.9	(8.5-11.4)
Total	**9.7**	(9.3-10.0)	**50.6**	(49.8-51.5)	**9.5**	(9.3-10.0)	**51.2**	(50.0-51.6)

* The linked sample comprises 128818 for whom the linkage key was available

Source: ISTAT, 2007b

Table A.3 - Proportion of individuals in the 1999-2000 HIS linked* and total sample according to gender, age and presence of disability.**

MEN	**LINKED SAMPLE**		**TOTAL SAMPLE**	
Age groups	%	95% CI	%	95% CI
0-14	0.9	(0.7-1.1)	0.9	(0.7-1.2)
15-24	0.8	(0.6-1.0)	0.8	(0.5-1.0)
25-34	0.8	(0.6-1.0)	0.9	(0.6-1.1)
35-44	1.0	(0.7-1.2)	0.9	(0.7-1.2)
45-54	1.5	(1.2-1.8)	1.4	(1.1-1.8)
55-64	3.0	(2.6-3.5)	3.0	(2.5-3.5)
65-69	6.4	(5.4-7.4)	6.3	(5.2-7.4)
70-74	9.7	(8.3-11.0)	9.8	(8.3-11.3)
75-79	13.9	(12.0-15.7)	14.4	(12.3-16.5)
>=80	38.5	(35.0-42.1)	38.7	(34.6-42.7)
Total	**3.2**	**(3.0-3.4)**	**3.2**	**(3.0-3.4)**

WOMEN	**LINKED SAMPLE**		**TOTAL SAMPLE**	
Age groups	%	95% CI	%	95% CI
0-14	1.0	(0.8-1.3)	1.0	(0.7-1.3)
15-24	0.9	(0.6-1.1)	1.0	(0.7-1.2)
25-34	0.9	(0.7-1.1)	0.9	(0.7-1.1)
35-44	1.0	(0.7-1.2)	1.0	(0.7-1.2)
45-54	1.5	(1.2-1.8)	1.6	(1.3-1.9)
55-64	4.1	(3.6-4.7)	4.3	(3.7-4.9)
65-69	7.5	(6.5-8.5)	7.5	(6.4-8.6)
70-74	13.4	(12.0-14.8)	13.2	(11.6-14.8)
75-79	23.0	(21.1-24.9)	23.0	(20.8-25.2)
>=80	52.0	(49.3-54.8)	52.0	(48.7-55.4)
Total	**5.8**	**(5.6-6.1)**	**5.9**	**(5.6-6.1)**

* The linked sample comprises 128818 for whom the linkage key was available

** Disability is defined as having at least one severe limitation in the areas of mobility, ADLs or communication

Source: ISTAT, 2007b

Table A.4 - Proportion of individuals in the 1999-2000 HIS linked* and total sample according to gender, age and presence of at least one severe chronic disease.

MEN	LINKED SAMPLE		TOTAL SAMPLE	
	%	95% CI	%	95% CI
0-14	1.5	(1.2-1.8)	1.4	(1.1-1.7)
15-24	1.5	(1.2-1.8)	1.6	(1.2-1.9)
25-34	2.4	(2.0-2.7)	2.4	(2.0-2.8)
35-44	4.3	(3.8-4.8)	4.4	(3.8-4.9)
45-54	10.2	(9.5-11.0)	10.4	(9.5-11.3)
55-64	23.9	(22.6-25.1)	23.5	(22.1-25.0)
65-69	34.7	(32.4-36.9)	34.5	(31.8-37.2)
70-74	42.1	(39.4-44.8)	41.6	(38.3-44.8)
75-79	48.0	(44.7-51.4)	48.4	(44.4-52.4)
>=80	54.3	(50.2-58.5)	54.7	(48.8-58.5)
Total	**12.1**	**(11.7-12.5)**	**12.1**	**(11.7-12.4)**

WOMEN	LINKED SAMPLE		TOTAL SAMPLE	
	%	95% CI	%	95% CI
0-14	1.2	(0.9-1.4)	1.2	(0.9-1.5)
15-24	1.7	(1.3-2.0)	1.7	(1.3-2.1)
25-34	2.9	(2.5-3.3)	2.8	(2.4-3.3)
35-44	4.1	(3.7-4.6)	4.1	(3.6-4.6)
45-54	9.8	(9.1-10.5)	9.9	(9.0-10.8)
55-64	19.4	(18.3-20.4)	19.4	(18.1-20.7)
65-69	28.8	(26.9-30.6)	28.6	(26.4-30.8)
70-74	35.3	(33.1-37.6)	35.2	(32.5-37.8)
75-79	41.1	(38.6-43.6)	41.8	(38.7-44.8)
>=80	50.4	(47.7-53.2)	50.4	(47.1-53.7)
Total	**12.7**	**(12.3-13.1)**	**12.7**	**(12.3-13.1)**

* The linked sample comprises 128818 for whom the linkage key was available

Source: ISTAT, 2007b

Appendix B

Table B.3 - Observed and expected survival probabilities* of <u>men aged 50-54, 55-59, 60-64 and 65-69 years old</u> at different years of follow-up, and corresponding differences (observed – expected survival probabilities); significant differences at 99% confidence level are marked in bold italic characters.

Age class	Number of years after the interview	Observed survival probability	Expected survival probability	Difference: observed - expected
50 - 54	0	1	1	0
	1	0.9959	0.9954	0.000
	2	0.9938	0.9906	0.003
	3	0.9899	0.9854	0.005
	4	0.9864	0.9798	***0.007***
	5	0.9808	0.9740	***0.007***
	6	0.9743	0.9679	0.006
	7	0.9669	0.9613	0.006
55 - 59	0	1	1	0
	1	0.9915	0.9923	-0.001
	2	0.9819	0.9841	-0.002
	3	0.9735	0.9755	-0.002
	4	0.9643	0.9663	-0.002
	5	0.9558	0.9566	-0.001
	6	0.9447	0.9464	-0.002
	7	0.9338	0.9357	-0.002
60 - 64	0	1	1	0
	1	0.9892	0.9877	0.001
	2	0.9783	0.9748	0.003
	3	0.9619	0.9614	0.001
	4	0.9490	0.9471	0.002
	5	0.9359	0.9322	0.004
	6	0.9222	0.9167	0.005
	7	0.9061	0.9005	0.006
65 - 69	0	1	1	0
	1	0.9802	0.9792	0.001
	2	0.9611	0.9577	0.003
	3	0.9418	0.9353	0.006
	4	0.9222	0.9117	0.010
	5	0.8918	0.8873	0.004
	6	0.8667	0.8620	0.005
	7	0.8421	0.8357	0.006

* Observed and expected survival probabilities equal survival probabilities in the 1999/2000 HIS sample and in the Italian population respectively.

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.4 - Observed and expected survival probabilities* of <u>men aged 70-74, 75-79, 80-84 and 85 and more years old</u> at different years of follow-up, and corresponding differences (observed – expected survival probabilities); significant differences at 99% confidence level are marked in bold italic characters.

Age group	Number of years after the interview	Observed survival probability	Expected survival probability	Difference: observed - expected
70 - 74	0	1	1	0
	1	0.9709	0.9658	0.005
	2	0.9360	0.9309	0.005
	3	0.8984	0.8948	0.004
	4	0.8619	0.8571	0.005
	5	0.8212	0.8184	0.003
	6	0.7806	0.7792	0.001
	7	0.7433	0.7387	0.005
75 - 79	0	1	1	0
	1	0.9579	0.9445	***0.013***
	2	0.9090	0.8883	***0.021***
	3	0.8540	0.8313	***0.023***
	4	0.7922	0.7721	0.020
	5	0.7381	0.7134	0.025
	6	0.6691	0.6559	0.013
	7	0.6094	0.5977	0.012
80 - 84	0	1	1	0
	1	0.9220	0.9111	0.011
	2	0.8296	0.8243	0.005
	3	0.7227	0.7395	-0.017
	4	0.6292	0.6553	-0.026
	5	0.5539	0.5754	-0.021
	6	0.4878	0.5004	-0.013
	7	0.4183	0.4293	-0.011
85 and more	0	1	1	0
	1	0.8362	0.8343	0.002
	2	0.6992	0.6894	0.010
	3	0.5773	0.5617	0.016
	4	0.4568	0.4475	0.009
	5	0.3670	0.3531	0.014
	6	0.3184	0.2751	0.043
	7	0.2640	0.2102	***0.054***

* Observed and expected survival probabilities equal survival probabilities in the 1999/2000 HIS sample and in the Italian population respectively.

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.5 - Observed and expected survival probabilities* of <u>women aged 50-54, 55-59, 60-64 and 65-69 years old</u> at different years of follow-up, and corresponding differences (observed – expected survival probabilities); significant differences at 99% confidence level are marked in bold italic characters.

Age group	Number of years after the interview	Observed survival probability	Expected survival probability	Difference: observed - expected
50 - 54	0	1	1	0
	1	0.9988	0.9976	0.001
	2	0.9955	0.9950	0.001
	3	0.9915	0.9922	-0.001
	4	0.988	0.9892	-0.001
	5	0.9843	0.9861	-0.002
	6	0.9827	0.9829	0.000
	7	0.9811	0.9794	0.002
55 - 59	0	1	1	0
	1	0.9939	0.9963	-0.002
	2	0.9904	0.9924	-0.002
	3	0.9875	0.9881	-0.001
	4	0.9834	0.9836	0.000
	5	0.9753	0.9788	-0.004
	6	0.9705	0.9738	-0.003
	7	0.9636	0.9685	-0.005
60 - 64	0	1	1	0
	1	0.9933	0.9943	-0.001
	2	0.9883	0.9882	0.000
	3	0.9823	0.9817	0.001
	4	0.9722	0.9747	-0.002
	5	0.9639	0.9673	-0.003
	6	0.9534	0.9594	-0.006
	7	0.9449	0.9510	-0.006
65 - 69	0	1	1	0
	1	0.9921	0.9904	0.002
	2	0.9832	0.9802	0.003
	3	0.9691	0.9693	0.000
	4	0.9569	0.9576	-0.001
	5	0.9431	0.9450	-0.002
	6	0.9301	0.9318	-0.002
	7	0.9129	0.9174	-0.005

* Observed and expected survival probabilities equal survival probabilities in the 1999/2000 HIS sample and in the Italian population respectively.

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.6 - Observed and expected survival probabilities* of <u>women aged 70-74, 75-79, 80-84 and 85 and more years old</u> at different years of follow-up, and corresponding differences (observed – expected survival probabilities); significant differences at 99% confidence level are marked in bold italic characters.

Age group	Number of years after the interview	Observed survival probability	Expected survival probability	Difference: observed - expected
70 - 74	0	1	1	0
	1	0.9897	0.9833	***0.006***
	2	0.9706	0.9656	0.005
	3	0.9531	0.9465	0.007
	4	0.9363	0.9254	0.011
	5	0.9094	0.9032	0.006
	6	0.8882	0.8798	0.008
	7	0.8598	0.8543	0.005
75 - 79	0	1	1	0
	1	0.9709	0.9688	0.002
	2	0.9438	0.9357	0.008
	3	0.9116	0.9005	0.011
	4	0.8816	0.8621	***0.020***
	5	0.8437	0.8215	***0.022***
	6	0.8004	0.7797	***0.021***
	7	0.7543	0.7348	0.020
80 - 84	0	1	1	0
	1	0.9531	0.9415	0.012
	2	0.9151	0.8819	***0.033***
	3	0.8558	0.8203	***0.036***
	4	0.7945	0.7541	***0.040***
	5	0.7272	0.6877	***0.040***
	6	0.6723	0.6225	***0.050***
	7	0.5998	0.5560	***0.044***
85 and more	0	1	1	0
	1	0.8804	0.8716	0.009
	2	0.7622	0.7522	0.010
	3	0.6501	0.6398	0.010
	4	0.5497	0.5321	0.018
	5	0.4728	0.4388	**0.034**
	6	0.4011	0.3573	**0.044**
	7	0.3395	0.2849	**0.055**

* Observed and expected survival probabilities equal survival probabilities in the 1999/2000 HIS sample and in the Italian population respectively.

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.7 - Observed survival probabilities* of men aged 50-54, 55-59, 60-64 and 65-69 years old at different years of follow-up, and corresponding 99% confidence limits

Age group	Number of years after the interview	Observed survival probability	Lower 99% confidence limit	Upper 99% confidence limit
50 - 54	0	1	-	-
	1	0.9959	0.9925	0.9978
	2	0.9938	0.9899	0.9962
	3	0.9899	0.9852	0.9932
	4	0.9864	0.9810	0.9902
	5	0.9808	0.9747	0.9855
	6	0.9743	0.9673	0.9798
	7	0.9669	0.9591	0.9732
55 - 59	0	1	-	-
	1	0.9915	0.9867	0.9946
	2	0.9819	0.9755	0.9867
	3	0.9735	0.9659	0.9794
	4	0.9643	0.9557	0.9712
	5	0.9558	0.9464	0.9635
	6	0.9447	0.9343	0.9534
	7	0.9338	0.9227	0.9434
60 - 64	0	1	-	-
	1	0.9892	0.9838	0.9928
	2	0.9783	0.9713	0.9837
	3	0.9619	0.9529	0.9692
	4	0.9490	0.9389	0.9575
	5	0.9359	0.9247	0.9455
	6	0.9222	0.9101	0.9328
	7	0.9061	0.8930	0.9177
65 - 69	0	1	-	-
	1	0.9802	0.9727	0.9856
	2	0.9611	0.9513	0.9690
	3	0.9418	0.9302	0.9516
	4	0.9222	0.9091	0.9335
	5	0.8918	0.8768	0.9051
	6	0.8667	0.8504	0.8813
	7	0.8421	0.8247	0.8579

* Observed survival probabilities equal survival probabilities in the 1999/2000 HIS sample

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.8 - Observed survival probabilities* of men aged 70-74, 75-79, 80-84 and 85 and more years old at different years of follow-up, and corresponding 99% confidence limits

Age group	Number of years after the interview	Observed survival probability	Lower 99% confidence limit	Upper 99% confidence limit
70 - 74	0	1	-	-
	1	0.9709	0.9614	0.9781
	2	0.9360	0.9228	0.9470
	3	0.8984	0.8826	0.9123
	4	0.8619	0.8440	0.8779
	5	0.8212	0.8015	0.8392
	6	0.7806	0.7595	0.8002
	7	0.7433	0.7211	0.7640
75 - 79	0	1	-	-
	1	0.9579	0.9449	0.9679
	2	0.9090	0.8913	0.9240
	3	0.8540	0.8328	0.8728
	4	0.7922	0.7682	0.8141
	5	0.7381	0.7123	0.7620
	6	0.6691	0.6418	0.6950
	7	0.6094	0.5812	0.6363
80 - 84	0	1	-	-
	1	0.9220	0.8936	0.9430
	2	0.8296	0.7922	0.8609
	3	0.7227	0.6796	0.7611
	4	0.6292	0.5834	0.6713
	5	0.5539	0.5075	0.5979
	6	0.4878	0.4416	0.5324
	7	0.4183	0.3731	0.4627
85 and more	0	1	-	-
	1	0.8362	0.7966	0.8686
	2	0.6992	0.6523	0.7411
	3	0.5773	0.5279	0.6235
	4	0.4568	0.4080	0.5042
	5	0.3670	0.3204	0.4135
	6	0.3184	0.2739	0.3638
	7	0.2640	0.2223	0.3074

* Observed survival probabilities equal survival probabilities in the 1999/2000 HIS sample

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.9 - Observed survival probabilities* of women aged 50-54, 55-59, 60-64 and 65-69 years old at different years of follow-up, and corresponding 99% confidence limits

Age group	Number of years after the interview	Observed survival probability	Lower 99% confidence limit	Upper 99% confidence limit
50 - 54	0	1	-	-
	1	0.9988	0.9964	0.9996
	2	0.9955	0.9921	0.9975
	3	0.9915	0.9872	0.9944
	4	0.988	0.9830	0.9915
	5	0.9843	0.9787	0.9884
	6	0.9827	0.9770	0.9870
	7	0.9811	0.9752	0.9857
55 - 59	0	1	-	-
	1	0.9939	0.9897	0.9964
	2	0.9904	0.9854	0.9937
	3	0.9875	0.9820	0.9914
	4	0.9834	0.9773	0.9880
	5	0.9753	0.9681	0.9810
	6	0.9705	0.9626	0.9767
	7	0.9636	0.9551	0.9706
60 - 64	0	1	-	-
	1	0.9933	0.9891	0.9959
	2	0.9883	0.9830	0.9919
	3	0.9823	0.9760	0.9869
	4	0.9722	0.9646	0.9781
	5	0.9639	0.9555	0.9708
	6	0.9534	0.9440	0.9612
	7	0.9449	0.9348	0.9534
65 - 69	0	1	-	-
	1	0.9921	0.9875	0.9950
	2	0.9832	0.9770	0.9878
	3	0.9691	0.9612	0.9755
	4	0.9569	0.9477	0.9645
	5	0.9431	0.9328	0.9519
	6	0.9301	0.9188	0.9399
	7	0.9129	0.9005	0.9238

* Observed survival probabilities equal survival probabilities in the 1999/2000 HIS sample

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table B.10 - Observed survival probabilities* of women aged 70-74, 75-79, 80-84 and 85 and more years old at different years of follow-up, and corresponding 99% confidence limits

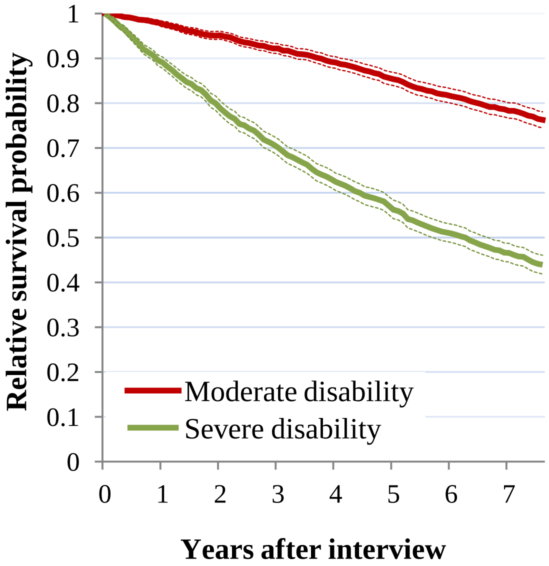
Age group	Number of years after the interview	Observed survival probability	Lower 99% confidence limit	Upper 99% confidence limit
70 - 74	0	1	-	-
	1	0.9897	0.9842	0.9933
	2	0.9706	0.9621	0.9772
	3	0.9531	0.9428	0.9616
	4	0.9363	0.9246	0.9462
	5	0.9094	0.8959	0.9213
	6	0.8882	0.8735	0.9013
	7	0.8598	0.8437	0.8744
75 - 79	0	1	-	-
	1	0.9709	0.9621	0.9777
	2	0.9438	0.9321	0.9535
	3	0.9116	0.8976	0.9238
	4	0.8816	0.8658	0.8956
	5	0.8437	0.8261	0.8596
	6	0.8004	0.7813	0.8181
	7	0.7543	0.7339	0.7735
80 - 84	0	1	-	-
	1	0.9531	0.9370	0.9651
	2	0.9151	0.8949	0.9317
	3	0.8558	0.8310	0.8773
	4	0.7945	0.7665	0.8196
	5	0.7272	0.6967	0.7552
	6	0.6723	0.6405	0.7021
	7	0.5998	0.5668	0.6311
85 and more	0	1	-	-
	1	0.8804	0.8577	0.8996
	2	0.7622	0.7334	0.7883
	3	0.6501	0.6184	0.6798
	4	0.5497	0.5170	0.5811
	5	0.4728	0.4404	0.5046
	6	0.4011	0.3695	0.4325
	7	0.3395	0.3091	0.3700

* Observed survival probabilities equal survival probabilities in the 1999/2000 HIS sample

Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

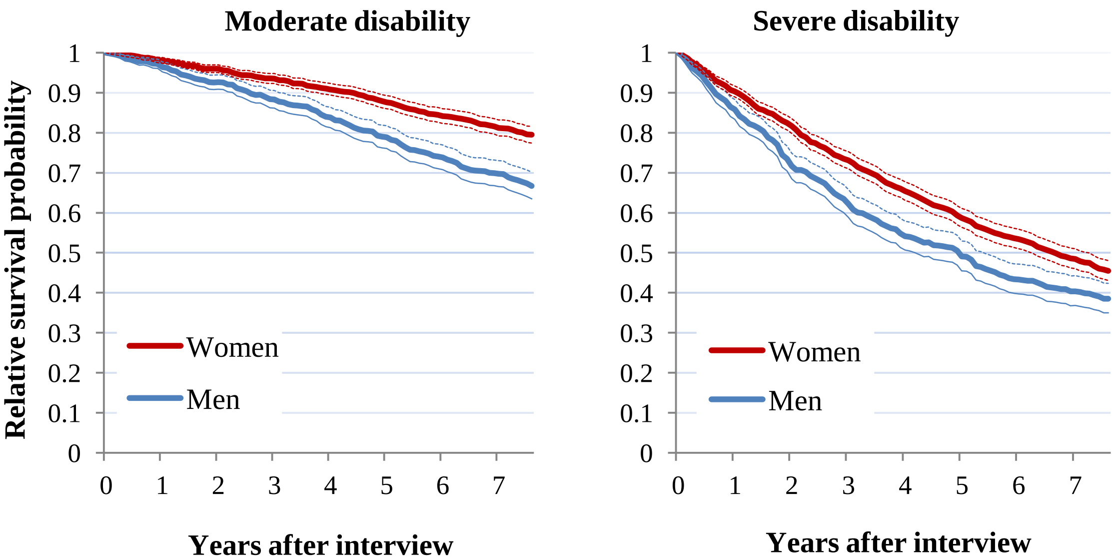
Appendix C

Figure C.11 - Relative survival curves and 95% confidence intervals over the period of follow-up for people with moderate and severe ADL disability at interview in the total population aged 50 years and over.



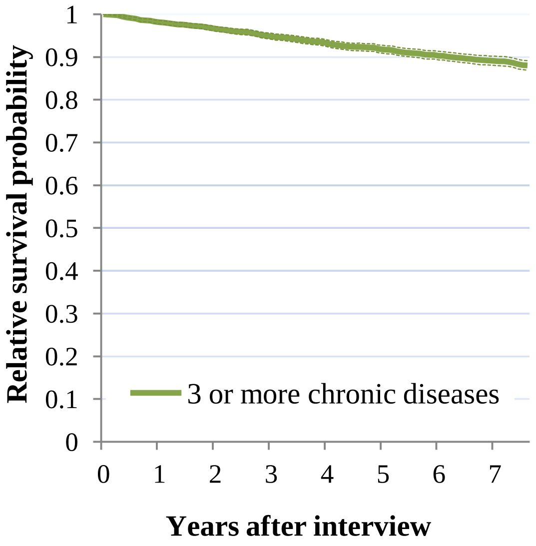
Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure C.2 - Relative survival curves and 95% confidence intervals over the period of follow-up for people with moderate and severe ADL disability at interview among men and women aged 50 years and over.



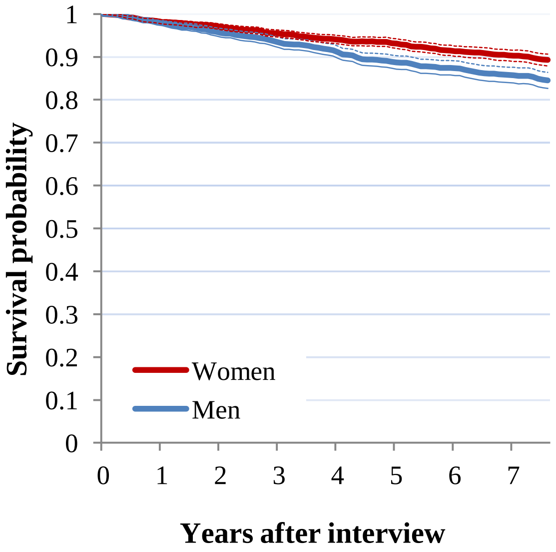
Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure C.3 - Relative survival curves and 95% confidence intervals over the period of follow-up for people with multimorbidity at interview in the total population aged 50 years and over.



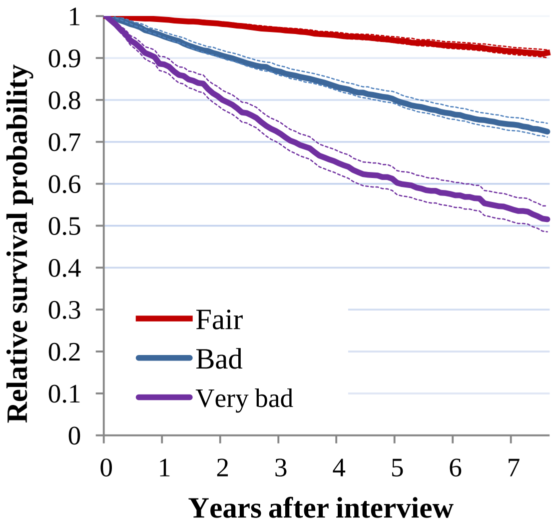
Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure C.4 - Relative survival curves and 95% confidence intervals over the period of follow-up for people with multimorbidity at interview among men and women aged 50 years and over.



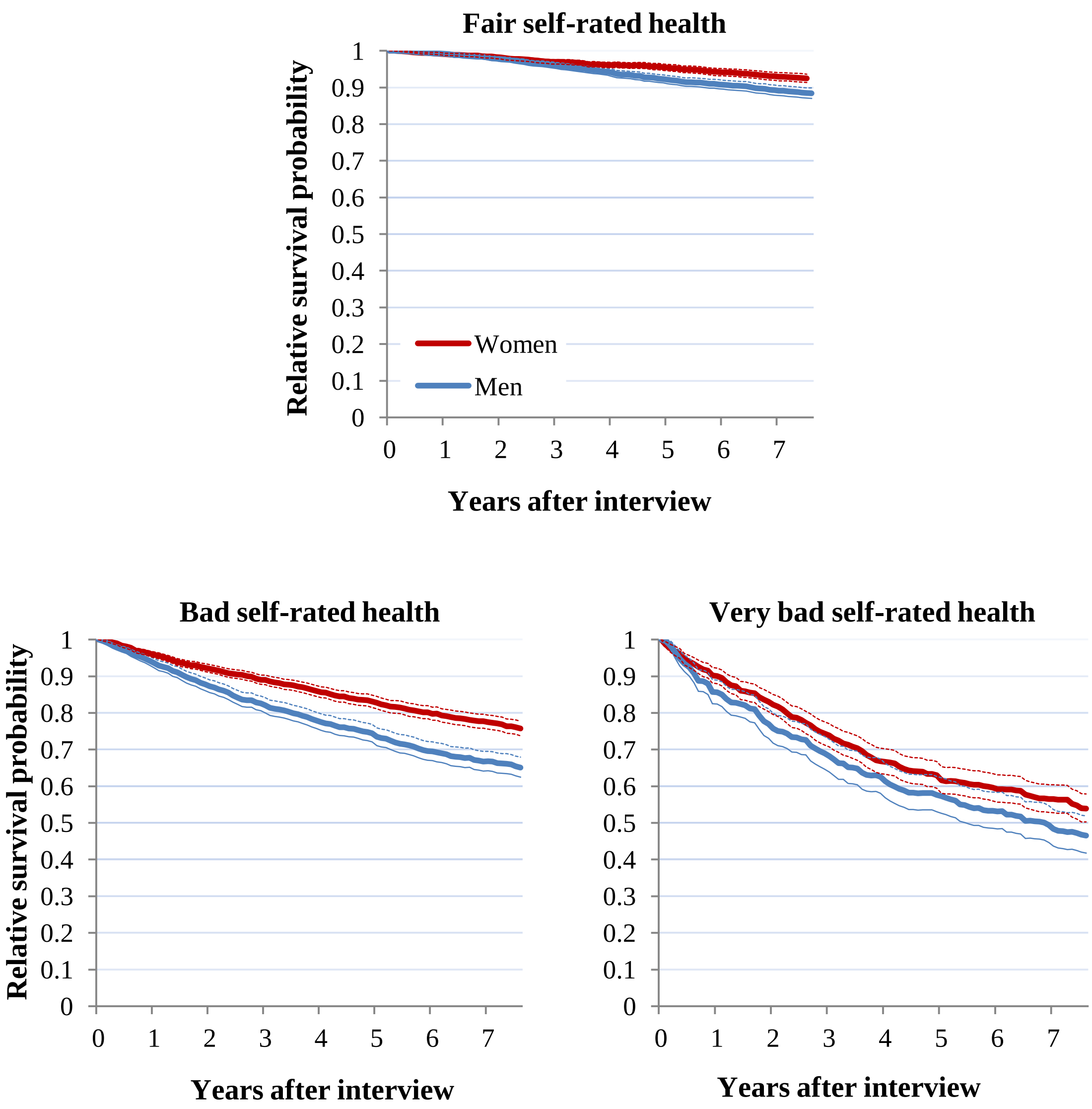
Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure C.5 - Relative survival curves and 95% confidence intervals over the period of follow-up for people in fair, bad and very bad health general health at interview in the total population aged 50 years and over.



Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Figure C.6 - Relative survival curves and 95% confidence intervals over the period of follow-up for people in fair, bad and very bad health general health at interview among men and women aged 50 years and over.



Source: calculations on the ISTAT 1999/2000 HIS linked mortality data file

Appendix D

Table D.1 - Prevalence of moderate and severe ADL disability and 95% confidence intervals among decedents aged 50 years and over according to age and proximity to death

Age	Proximity to death						
	1	2	3	4	5	6	7
Moderate ADL disability							
50-64	12.5	11.85	4.795	7.143	9.945	11.36	6.154
95% CI	*(7.8 - 19.4)*	*(7.4 - 18.5)*	*(2.3 - 9.7)*	*(3.9 - 12.8)*	*(6.4 - 15.2)*	*(7.4 - 17.0)*	*(3.5 - 10.5)*
65-74	22.0	14.2	18.4	16.2	19.9	16.2	15.1
95% CI	*(16.9 - 28.1)*	*(10.5 - 19.0)*	*(14.2 - 23.6)*	*(12.3 - 21.2)*	*(15.8 - 24.6)*	*(12.5 - 20.8)*	*(11.6 - 19.3)*
75-84	21.6	22.1	20.3	23.9	25.1	26.5	23.7
95% CI	*(17.0 - 27.0)*	*(17.9 - 27.1)*	*(16.3 - 25.0)*	*(19.7 - 28.6)*	*(20.9 - 29.8)*	*(22.3 - 31.2)*	*(19.8 - 28.2)*
85+	15.5	21.3	25.1	24.2	26.0	22.5	27.2
95% CI	*(11.7 - 20.3)*	*(16.7 - 26.8)*	*(20.0 - 31.0)*	*(19.4 -29.8)*	*(20.3 - 32.7)*	*(16.5 - 29.9)*	*(20.1 - 35.6)*
Severe ADL disability							
50-64	15.6	9.6	9.6	5.0	3.9	8.0	2.6
95% CI	(10.3 - 23.0)	(5.7 - 15.9)	(5.8 - 15.5)	(2.4 - 10.1)	(1.9 - 7.9)	(4.8 - 13.0)	(1.1 - 6.0)
65-74	23.0	18.1	13.0	12.6	11.0	9.7	7.8
95% CI	(17.8 - 29.1)	(13.9 - 23.2)	(9.5 - 17.7)	(9.1 - 17.1)	(8.0 - 15.0)	(6.9 - 13.6)	(5.4 - 11.3)
75-84	40.5	34.0	26.0	26.4	23.4	20.7	19.7
95% CI	(34.8 - 46.6)	(28.9 - 39.4)	(21.6 - 30.9)	(22.1 - 31.3)	(19.4 - 28.0)	(17.0 - 25.1)	(16.1 - 23.9)
85+	69.3	62.9	54.4	50.8	45.8	41.1	41.6
95% CI	(63.6 - 74.5)	(56.7 - 68.6)	(48.0 - 60.6)	(44.7 - 56.8)	(38.9 - 52.9)	(33.5 - 49.1)	(33.3 - 50.4)

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table D.2 - Prevalence of multimorbidity and 95% confidence intervals among decedents aged 50 years and over according to age and proximity to death

Age	Proximity to death						
	1	2	3	4	5	6	7
50-64	43.8	39.3	38.4	35.0	33.2	31.3	28.2
95% CI	*(35.4 -52.5)*	*(31.4 -47.7)*	*(30.8 -46.5)*	*(27.6 - 43.3)*	*(26.7 - 40.3)*	*(24.8 - 38.5)*	*(22.3 - 34.9)*
65-74	53.6	46.9	47.5	42.8	47.0	46.4	44.0
95% CI	*(46.8 - 60.2)*	*(40.9 - 53.0)*	*(41.5 - 53.6)*	*(37.1 - 48.8)*	*(41.6 - 52.5)*	*(40.9 - 52.0)*	*(38.7 - 49.4)*
75-84	58.0	57.7	57.9	55.4	55.6	51.7	49.5
95% CI	*(51.9 - 63.8)*	*(52.1 - 63.1)*	*(52.6 - 63.1)*	*(50.2 -60.5)*	*(50.5 - 60.6)*	*(46.7 -56.7)*	*(44.6 - 54.4)*
85+	60.3	54.9	62.8	56.5	51.0	58.9	48.0
95% CI	*(54.4 -65.9)*	*(48.8 -61.0)*	*(56.5 -68.7)*	*(50.5 -62.4)*	*(44.0 - 58.0)*	*(50.9 -66.5)*	*(39.4 - 56.7)*

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file

Table D.3 - Prevalence of bad and very bad self-rated health and 95% confidence intervals among decedents aged 50 years and over according to age and proximity to death

Age	Proximity to death						
	1	2	3	4	5	6	7
Bad SRH							
50-64	28.1	21.5	20.6	21.4	16.6	18.8	13.3
95% CI	*(21.0 - 36.5)*	*(15.4 - 29.2)*	*(14.8 - 27.9)*	*(15.4 - 29.0)*	*(11.8 - 22.7)*	*(13.7 -25.2)*	*(8.4 - 18.9)*
65-74	36.8	29.2	23.0	20.3	22.4	20.8	20.5
95% CI	*(30.6 - 43.6)*	*(24.0 - 35.1)*	*(18.3 - 28.5)*	*(15.9 - 25.5)*	*(18.1 - 27.3)*	*(16.6 - 25.7)*	*(16.5 - 25.2)*
75-84	42.1	34.6	26.6	29.6	29.7	25.7	19.7
95% CI	*(36.2 - 48.1)*	*(29.5 - 40.1)*	*(22.1 - 31.6)*	*(25.0 - 34.5)*	*(25.3 - 34.6)*	*(21.6 - 30.4)*	*(16.1 - 23.9)*
85+	36.5	36.8	32.6	30.8	26.0	34.4	20.8
95% CI	*(34.1 - 42.3)*	*(31.0 - 42.9)*	*(27.0 - 38.8)*	*(25.5 - 36.6)*	*(20.3 - 32.7)*	*(27.3 - 42.4)*	*(14.6 - 28.8)*
Very bad SRH							
50-64	15.6	8.9	7.5	3.6	4.4	4.0	3.6
95% CI	*(10.3 - 23.0)*	*(5.1 - 15.0)*	*(4.2 - 13.1)*	*(1.5 - 8.3)*	*(2.2 - 8.6)*	*(1.9 - 8.1)*	*(1.7 - 7.3)*
65-74	16.3	9.6	8.0	7.7	5.4	5.8	5.1
95% CI	*(11.9 - 21.9)*	*(6.6 - 13.8)*	*(5.3 - 12.0)*	*(5.1 - 11.6)*	*(3.4 - 8.5)*	*(3.7 - 9.1)*	*(3.2 - 8.1)*
75-84	15.9	13.1	12.2	10.8	7.9	5.2	5.8
95% CI	*(12.0 - 20.8)*	*(9.8 - 17.4)*	*(9.1 - 16.2)*	*(8.0 - 14.5)*	*(5.5 - 11.1)*	*(3.4 - 8.0)*	*(3.9 - 8.6)*
85+	25.3	15.8	15.1	11.9	9.9	6.0	8.8
95% CI	*(20.5 - 30.7)*	*(11.8 - 20.8)*	*(11.1 - 20.2)*	*(8.5 - 16.5)*	*(6.4 - 15.0)*	*(3.1 - 11.1)*	*(4.9 - 15.2)*

Source: own calculations on the ISTAT 1999/2000 HIS linked mortality data file