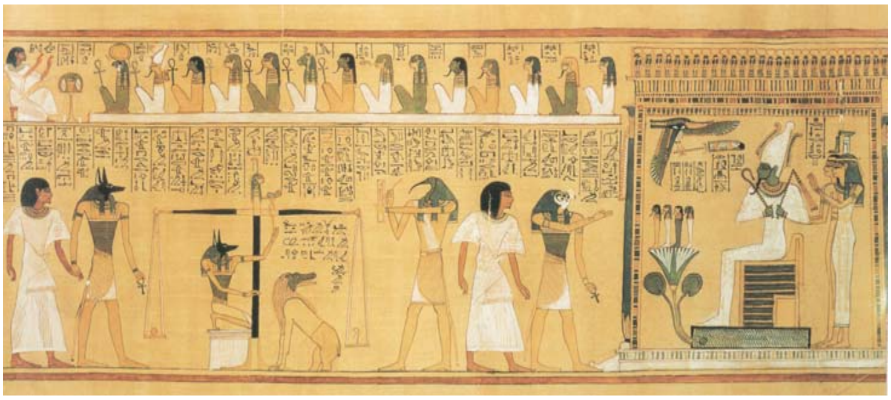
STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH

119

Tiina-Mari Lyyra

Predictors of Mortality in Old Age

Contribution of Self-rated Health, Physical Functions, Life Satisfaction and Social Support on Survival among Older People



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UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2006

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Cover picture: A detail from the Papyrus of Ani, one of the most complete examples of the Chapters of Coming Forth by Day, known also as the Book of Dead,

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"One must wait until evening to see how splendid the day has been"
-Sophocles 496-406 B.C.E.

ABSTRACT

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Length of life is perhaps the best single indicator of the health of a population. The purpose of the present series of studies was to explore the potential predictors of mortality in older people with special emphasis on self-rated health, physical functions, life satisfaction and perceived social support.

The four studies used prospective data drawn from 1) the Evergreen study, where mortality was followed for 10 years in an entire cohort of the 75- and 80-year-old (N=650) residents of the city of Jyväskylä, Finland, 2) the Functional capacity of men born in 1906-10, 1926-30 and 1946-50 research project from which two oldest age cohorts, 257 residents of the city of Jyväskylä, Finland aged 51 to 55 and 71 to 75 years were included and where mortality was followed for 18 years, and 3) The OCTO-twin study, a longitudinal study of intact pairs of Swedish same-sex octogenarian twins, of whom 320 individuals participated in this study. Mortality was followed for 10 years.

The data were collected by interviews and tests in the participant's homes and by examinations at the study centre, which included a health check-up and tests of physical, cognitive and sensory performance. The Cox regression model and its applications were used as statistical methods.

The main findings of these studies imply that psychosocial factors are strong predictors of survival in old age. Perceived social support is important for the health of older women as well as perceived satisfaction with present life in old-old people. Poor results in several performance-based physiological measures feature as strong predictors of mortality in old age. The predictive value of self-rated health could be explained by the occurrence of chronic conditions, but not by different domains of functioning.

A deeper understanding of the predictors of mortality in old age gives information that is useful in identifying risk groups and developing programmes for preventive actions. The results of the present studies suggest that, in addition to improving the physical capacity of older people, it is also essential to promote their perceived social support and psychological well-being in order to improve their quality of life and their health as measured by the most comprehensive indicator of health, survival.

Key words: Mortality, survival, self-rated health, physical functions, life satisfaction, social support, older people

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Jyväskylä, September 20, 2006.
Tiina-Mari Lyyra

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following papers, which will be referred to by their Roman numerals

I Lyyra T-M, Heikkinen E, Lyyra A-L, Jylhä M. 2006. Self-rated health and mortality: Could berformance-based measures of health and functioning explain the association? Archives in Gerontology and Geriatrics 42, 277-288.

II Lyyra T-M, Leskinen E, Heikkinen E. 2005. A cohort study found good respiratory, sensory and motor functions decreased mortality risk in older people. Journal of Clinical Epidemiology 58, 509-516.

III Lyyra T-M, Törmäkangas T, Read S, Rantanen T, Berg S. 2006. Satisfaction with present life predicts survival in octogenarians. Journal of Gerontology: Psychological Sciences 61B, in press.

IV Lyyra T-M, Heikkinen R-L. 2006. Perceived social support and mortality in older people. Journal of Gerontology: Social Sciences 61B, S147-S152.

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1 GENERAL INTRODUCTION

The enigma of longevity has fascinated demographic, epidemiological and gerontological scholars for decades. Differences between individuals in their length of life challenges us to attain a better understanding of predictors of mortality in older people, as these factors change with increasing age and thus differ from those in younger age groups. Furthermore, mortality risk factors in individuals in the higher age groups are often multiple and interact with each other.

Mortality and survival are central issues in health research, and they can be studied from different angles. Mortality is an important component in studying the changes at the population level and it is also an important indicator of the health status of the population. Mortality data can also be used as a measure of general well-being. Although several alternative measures have been developed to describe health and functional status, survival remains one of the most widely applied and effective indicators of health, or even more generally, well-being (Martelin 1994a).

In general, survival studies can be divided into three types. The first of these are studies based on general demographic descriptions, and using mainly aggregate-level vital statistics as material. In the second category are studies of centenarians and long-lived individuals. In the third type, the focus is epidemiological. Here, the main aim is to study what factors measured on the individual level at the baseline are associated with the risk of mortality over different follow-up times. The objective is to find out to what extent different factors affect mortality within a defined time frame.

Why do some individuals live longer than others? In addition to coincidence, genetic factors influence an individual's length of life. At the population level, the well-known risk factors of mortality are, for example, in addition to age, sex and fatal diseases, low socio-economic status, high blood pressure and high cholesterol, smoking, physical inactivity, and overweight (Simons et al. 1996, Calle et al. 1999, Chyou & Eaker 2000, Mustard & Etches 2003, Barengo et al. 2004). The risk factors of mortality differ between individuals and also between different age cohorts. Although there is a lot of information on the predictors of mortality among the general population, this cannot be directly applied to older age groups. The risk factors for mortality in late life differ from those in younger age groups because, for example, selection and differences in the causes of death in old age.

Earlier studies among older people have shown that low socio-economic status (Martelin 1994b, Fried et al. 1998), physical inactivity, earlier smoking (de Groot et al. 2004), low muscle strength and mobility (Rantanen et al. 2000, Guralnik et al. 2001, Markides et al. 2001) and lower cognitive capacity (Fried et al. 1998, Bassuk et al. 2000) are related to an elevated risk for mortality. Also, indicators of psychological well-being, such as higher self-esteem (O´Connor & Vallerand 1998), emotional vitality (Penninx et al. 2000) and an optimistic and positive attitude towards life (Giltay et al. 2004, Pitkälä et al. 2004) have been found to be associated with survival in old age. Good subjective ratings of health have been found to predict length of life in older people in some studies even better than so called objective health measures (Idler & Benyamini 1997). Social support has also been found to have an important effect on survival in older people (Berkman & Syme 1979, Seeman et al. 1987, Temkin-Greener et al. 2004).

Contrary to the findings among the general population, low body mass index has been found to be related to an elevated risk for mortality in older people. (Landi et al. 1999, Janssen et al. 2005). The results of studies on the relationship between serum cholesterol and mortality also differ from those observed in the general population, showing that a higher level of cholesterol is not necessarily a risk factor for higher mortality in older people (Menotti et al. 2001, Schatz et al. 2001, Schupf et al. 2005b). It seems, that the predictors of mortality in old age, indicating declined physical, psychological and social functioning, are different from those predicting mortality in younger ages. (Grabowski & Ellis 2001, Nybo et al. 2003).

Mortality research significantly contributes to our understanding of human aging and longevity. It also gives important information on the health of older people, which can then be utilized in identifying risk groups and in developing preventive programmes in order to promote the quality of life and health of these individuals.

Previous studies have produced important knowledge about the risk factors for mortality in old age, nevertheless, many unanswered questions remain. For instance, the relative role and impact of different risk factors continue to be unclear, as there are very few comprehensive studies in which several physiological and psychosocial factors have been investigated simutaneously. Most of the previous studies on mortality in elderly people have had relatively short follow-up times, and the age of the subjects has varied widely. Also, some unsolved statistical questions remain.

The main object of this doctoral thesis was to study how different physiological and psychosocial factors predict mortality in old age. The present series of studies use established prospective multidisciplinary research data, in which the age range, long follow-up time and mortality rates are well suited to investigate this particular topic.

2 REVIEW OF THE LITERATURE

2.1 Mortality in old age

The mortality of older populations has sharply decreased during recent years in most western countries. Some reasons for the decline in old age mortality have been put forward, such as public health intervention programmes, and the prevention and early diagnosis and treatment of chronic diseases (Schneider & Guralnik 1990, Branch et al. 1991). Although the reasons are not fully clear, it is evident that life expectancy at birth in the record-holding countries has risen over the last 160 years by almost 3 months per year (Oeppen & Vaupel 2002). There is an ongoing debate on the limits of life expectancy. Some researchers are confident that average life expectancy could reach 100 years (e.g. Manton et al. 1991), whereas others, such as Fries (1980) argue that it cannot rise above 85 years. However, it is clear that there are big differences between the developed and undeveloped countries. For instance, there has recently been decrease in life expectancy in Russia and other East-European countries (Deeg 2004). Trends in mortality at older ages have a continuously growing contribution to the prospects of life expectancy at birth as major further declines in mortality at younger ages are becoming unlikely.

It is unfortunately also true that while mortality has become compressed to the upper limits, the final period of life is usually characterized by a substantial deterioration in health and functional status (Liao et al. 2000). For example, in the Finnish sample of 80-year-old people only 10% of men and 4% of women had no chronic disease (Laukkanen et al. 2003). Hence, the question of the quality of life of those extra years becomes more important. The debate on relationship between increasing life expectancy and healthy (or disability-free) life expectancy also has quite a long history, and three main theories have emerged (Robine & Jagger 2005). Gruenberg (1977) predicted a pandemic of chronic diseases, and through the progress of medical care, extending the life of those with disease and disability. Compression of morbidity –scenario by Fries (1980) is more optimistic indicating that, through behavioural change and prevention, onset of disability and diseases could be postponed closer to the end of life. Manton (1982) proposed an intermediate view between these extremes, where the prevalence of disability may increase as mortality falls, but the severity of disability is reduced. Recently, it has been proposed that lengthening of life durations may be accompanied by a kind of circling back, where, first, sick people survive into old age and disability rises, then the health status of older people is improved through various means and the number of years with disabilities decreases, but finally the number of years lived with disability rises again when the average of age of death rises to the the extent where very old people are burdened with several chronic conditions and frailty (Robine & Michel 2004, Robine & Jagger 2005).

Cause-specific mortality statistics give useful information about the differences in mortality between younger and older age groups. This information comes from death certificates, which provide information about the immediate causes of death, together with contributing conditions and, finally, the underlying cause of death. In year 2003, the leading cause of death in people aged 70 and older in Finland was ischemic heart disease. The major differences can be found in the proportion of alcohol-related, accidental and suicidal deaths, which are more common in the younger population. In older population, deaths related to dementia, and cerebrovascular diseases are more common (Tables 1 and 2).

The validity of the data on the causes of death has been a subject of concern, especially in studies of older populations. In deceased older people, it may be difficult to identify the definitive cause of death, as older people are likely to have multiple health conditions. Also, the percentage of autopsies in older people is much lower than in younger populations. There also are some important issues surrounding the causes of death in older people. Is death simply the result of continued progression of the disease? Or is death the result of greater vulnerability to pathology of a given severity because of frailty or some other chronic condition? It may be difficult to separate these factors in the death certificates of older people.

Although death rates increase at a slower rate after age 80 and they are suggested even to decline after age 110 (Vaupel et al. 1998); death is finally unavoidable because of biological ageing. We are not meant to live forever. However, there is great variation in mortality in old age. Several factors have been found to be related to old age mortality, starting, for example, with the genes that we have received from our ancestors and ending up with perceived well-being. In the following review I will first concentrate on the factors, which had the special emphasis in this dissertation, and later turn to the other factors that contribute to the risk of mortality in old age according to earlier research.

TABLE 1 Cause-of-death structure in 70-year-old and older Finnish population in the year 2003 (Statistics Finland 2006).

Men				Women			
Rank	Cause of death	Deaths n	%	Rank	Cause of death	Deaths n	%
1.	Isch. heart disease	4 551	32.1	1.	Isch. heart disease	6 574	31.7
2.	Cerebrovascular disease	1 387	9.8	2.	Dementia, Alzheimer´s disease	2 864	13.8
3.	Dementia, Alzheimer´s disease	1 068	7.5	3.	Cerebrovascular disease	2 697	13.0
4.	Lung cancer	845	6.0	4.	Pneumonia	1 148	5.5
5.	Pneumonia	806	5.7	5.	Other cardiovascular diseases	919	4.4
	Other causes	5 538	39.0		Other causes	6 554	31.6
Total deaths at ages 70+		14 195	100.0	Total deaths at ages 70+		20 756	100.0

TABLE 2 Cause-of-death structure in 15-64 -year-old Finnish population in the year 2003 (Statistics Finland 2006).

Men				Women			
Rank	Cause of death	Deaths n	%	Rank	Cause of death	Deaths n	%
1.	Isch. heart disease	1356	18.5	1.	Breast cancer	325	10.6
2.	Alcohol related deaths	1016	13.8	2.	Alcohol related deaths	267	8.7
3.	Accidents	917	12.5	3.	Isch. heart disease	216	7.1
	- land traffic	186	2.5				
	- falls	217	3.0				
4.	Suicides	687	9.4	4.	Suicides	210	6.9
5.	Lung cancer	375	5.1	5.	Accidents	199	6.5
					- land traffic	59	1.9
					- falls	39	1.3
6.	Cerebrovascular disease	358	4.9	6.	Cerebrovascular disease	183	6.0
	Other causes	2629	35.8		Other causes	1655	54.2
Total deaths at ages 15-64		7338	100.0	Total deaths at ages 15-64		3055	100.0

2.2 Self-rated health and mortality risk

Self-rated health is a simple but comprehensive measure of global health (Deeg & Kriegsman 2003). It has been shown to be a predictor of subsequent mortality, independent of other health indicators, such as chronic conditions, disability, frequently used biomarkers, or health behaviour (Mossey & Shaphiro 1982, Kaplan & Camacho 1983, Idler & Angel 1990, Idler & Kasl 1991, Idler & Benyamini 1997, Benyamini et al. 1999, Idler et al. 1999, Walker et al. 2004, Jylhä et al. 2006). Good perceived health is important to successful ageing, particularly at more advanced ages when physical and psychological impairments often lead to the loss of independence. Self-assessments of health clearly correlate with the use of health services, health behaviour and perceived quality of life in general (Fylkesnes 1993, Maddox 1999). Even when they have numerous illnesses, older people often describe their health as good (Heikkinen et al. 1997). The most commonly used measures of self-rated health are four- or five-point scales running from excellent to poor. They can be classified into three main categories: non-comparative, age comparative and time-comparative self-rated health (Leinonen 2002). Vuorisalmi et al. (2005) found that non-comparative self-rated health predicts mortality better than comparative self-rated health.

The explanations suggested for the association between self-rated health and mortality fall roughly into three groups (Jylhä et al. 2006). First, it is possible that self-ratings of health measure a wide array of mortality-related physiological and pathological characteristics not captured by the covariates included in the analyses. Second, it has been suggested that positive self-ratings reflect a general optimistic disposition. The theories that link self-rated health to mortality are to some extent similar to those of other psychosocial factors; for example, self-rated health may be protective as such through positive neurological, immunological and endocrinological influences. Third, self-rated health also measures some other characteristics than health status, such as family history, health behaviour and social and psychological resources (Benyamini et al. 1999, van Doorn 1999, Ostir et al. 2000).

2.3 Physical functions and mortality risk

Both self-rated and objectively measured functional capacity has been found to associate with the risk for mortality in old age (Manton 1988, Brock et al. 1994, Corti et al. 1994, Bernard et al. 1997). One approach to the study of functional capacity in older people is to measure their level of self-reported ability in carrying out the activities of daily living, difficulties in performing these tasks have found to be associated with increased mortality (Scott et al. 1997, Tager et al. 2003). Performance-based measures of individual functioning may be more accurate than self-ratings; for instance, older people who reported no difficulty in walking showed a wide range of performance on an extended walking test (Newman et al. 2006a). Different kinds of walking tests like poor ability to complete a long-distance corridor walk and poor performance time as well as low maximal walking speed have been found to be related to increased mortality risk in older people (Äijö et al. 2002, Newman et al. 2006a). Slow walking speed is related to various chronic conditions, low muscle strength and age-related decline in speed behaviour.

Older adults with reduced muscle strength have higher mortality (Rantanen et al. 2000, Metter et al. 2002, Snih et al. 2002, Rantanen 2003). Muscle strength is closely related to the absolute quantity of muscle mass, which also declines with ageing. This decrease in muscle mass (sarcopenia) is thought to contribute to the development of functional limitations and disability in old age, and potentially might explain part of the association between strength and mortality. The suggested pathways from disease to muscle impairment include nutritional depletion, systemic inflammation, and physical inactivity. Poor muscle strength could be a marker of disease severity, which in turn is associated with mortality (Rantanen 2003). Decreased muscle strength is also a risk factor for falls, which may lead to higher mortality risk. Rantanen (2003) argues that strong muscle strength in old age is related to better living conditions in childhood and earlier physical activity. Speed-related functioning, like slow tapping time, has found to be associated with increasing mortality in older people independently of the effects of muscle power and strength. These observations suggest that the ability to make rapid movements is one marker of longevity (Metter et al. 2005).

Reduced pulmonary function is an important predictor of cardiovascular morbidity and mortality. Respiratory functions are good indicators of health status and are especially predictive for coronary disease-related mortality (Sorlie et al. 1989, Sharps et al. 1997, Schunemann et al. 2000). The association between pulmonary function and coronary heart disease could be explained by cigarette smoking, which leads to a higher incidence of lung impairment and coronary heart disease (Marcus et al. 1989). The association between pulmonary impairment and higher mortality is well documented in general population studies, while more recent studies with accurate adjustments in modelling in older people are rare. Mannino and Davis (2006) studied lung function decline and outcomes in an older population and found that being in the most rapidly declining quartile of FEV1 (volume exhaled during the first second of a forced expiratory manoeuvre) from the baseline to year 4 was associated with an increased risk for admission to hospital for chronic obstructive pulmonary disease and all-cause death.

2.4 Life satisfaction and mortality risk

Life satisfaction is a psychological concept, which is usually defined in terms of obtaining pleasure from everyday activities, perception of life as meaningful, positive self-image, optimistic outlook and goal achievement (Neugarten et al. 1961) Studies on life satisfaction as an end-point in older people are rare, although its association with increased all-cause mortality risk and suicide has been found in samples with younger and middle-aged Finnish people (Koivumaa-Honkanen et al. 2000, 2001, 2002). In the recent study Bray and Gunnel (2006) found that associations between measures of life-satisfaction/happiness and suicide tended to be stronger in people over 65 years of age than in younger people.

Other indicators of subjective well-being, such as positive affect, optimism, emotional vitality and positive self-perceptions of ageing have been found to be associated with survival in older people (Maier & Smith 1999, Ostir et al. 2000, Penninx et al. 2000, Danner et al. 2001, Levy et al. 2002, Giltay et al. 2004, Mete 2004, Pitkälä et al. 2004), and negative affect, hopelessness and depressiveness with mortality risk (Penninx et al. 1999, Stern et al. 2001, Wilson et al. 2003a, Adamson et al. 2005). Possible causal pathways have been put forward linking subjective well-being and health. First, it has been suggested that positive emotions promote a more active lifestyle and a motivation toward self-care (Scheier & Carver 1992). Second, positive affect is also associated with social engagement, which has been found to be related to better survival in older people (e.g. Berkman & Syme 1979). Third, older people with better subjective well-being may have better coping capabilities; optimists usually avoid strategies like denial and giving up (Segerström et al. 1998). Another major research interest concerns different psychophysiological patterns, where the focus is on cardiovascular reactivity or immune response (Friedman 2000).

2.5 Social support and mortality risk

Social networks and support are manifested in interpersonal relationships. There is an ongoing debate about how social support affects the course of diseases as well as mortality risk. There is also a disagreement about its operationalization (Penninx 1996). A number of studies have documented the beneficial effect of social support on various health outcomes, including survival. In addition to all-cause mortality, this effect has been confirmed in relation to several causes of death, including cancer, coronary heart disease and other cardiovascular diseases (Berkman & Syme 1979, Blazer 1982, Seeman et al. 1987, Kaplan et al. 1988, Seeman et al. 1993, Penninx et al 1997, Avlund et al. 1998, Maier & Smith 1999, Ceria et al. 2001, Murberg 2004, Temkin-Greener et al. 2004, Brummett et al. 2005). Broadly speaking, two hypotheses relating to the possible causal pathways by which the protective effects of social support may act to reduce mortality have been proposed. These are known as the "stress-related" and "direct effect" models. Within the former category the stress-buffering model states that social support is protective because it diminishes the deleterious effects of stress in a person´s life (Uchino 2004). The direct effect hypothesis in turn works in two ways: firstly, environments are seen to influence attitudes and behaviours, including the regulation of health behaviours and access to health care, by providing informational resources relating e.g. to economic assistance and transportation (Berkman & Syme 1979, Penninx et al. 1997). Secondly, there is an impact on self-esteem, which is bolstered by feelings of belongingness and also by a sense of security (Thoits 1983, van Baarsen 2002). The recent study by Loucks et al. (2006) indicated the existence of a potential biological mechanism for the observed associations between social integration and coronary heart disease.

2.6 Other factors affecting mortality risk in old age

2.6.1 Genetic, perinatal and early-life factors

Genetic influences on the human life span have been found in analyses of survival data on adopted children (Sörensen et al. 1988) and twins. Ljungquist et al. (1998) followed a large sample of Swedish twin pairs. Over the total age range examined, they found that a maximum of one-third of the variance in longevity was attributable to genetic factors. According to Herskind et al. (1996) 25% of the variation in time of death was genetically explained on the basis on studies in Danish twins, and Iachine et al. (1998) argued using the same Danish data together with Swedish and Finnish twindata, that up to 50% of the variation in time of death could be attributed to genes. Hjelmborg et al. (2006) have recently found that the genetic influences on the lifespan are minimal prior to age 60 but increase thereafter. The latest studies have focused on the heritability of cause-specific mortality, e.g. coronary heart disease (Wienke et al. 2005). Several studies have sought to find a specific gene that might be responsible for exceptional longevity. Indeed, Indy (for "I'm not dead yet") is one of the longevity genes already identified in fruit fly *Drosophila melanogaster* (Rogina et al. 2000). The apo E genotype is one candidate gene for longevity in humans. It affects the probability of remaining a cognitively “well-functioning” nonagerian, but its independent influence on survival remains unclear (Bathum et al. 2006). In a recent study the glutathione S-transferase superfamily genes GSTT1 and GSTM1 have been found to be associated with oxidative stress and longevity in twins (Christiansen et al. 2006).

In the 1990´s, Barker´s hypothesis (1994) gained wide publicity in arguing that perinatal experiences, like mother´s poor nutrition during pregnancy affect a person’s health and mortality risk in later life. Forsdahl (2002), on the basis of a study of the population of Finnmark, also suggests that there is an association between very poor living conditions in childhood and adolescence and high mortality in adulthood. Other early-life predictors of human longevity have been presented by Gavrilova et al. (2003), who argue that even the season of birth, paternal age at a person’s birth and the death of siblings in early life are related to longevity in later life.

2.6.2 Sociodemographic and socioeconomic factors

In addition to age, the variables of gender, race and ethnicity are associated with the risk for death. There is a strong association between chronological age and the risk for death, although there is also great individual variation. High biological age, senescence, is an important factor explaining the probability of death in old age. Women tend to live longer than men, but the extent of the women's higher longevity varies globally. For instance in Finland in the year 2003, women had a life expectancy of 82 years, and men of 75 years (Statistics Finland 2006). Gender differences in mortality are due to a variety of environmental, behavioural and biological factors. Men are, for example, at higher risk for death from coronary heart disease and also accidents. This difference can partly be explained by behavioural risk factors (Satariano 2006).

In American populations, racial and ethnic minorities are at an elevated risk for death, especially males. According to Satariano (2006) this is due not only to an elevated risk for acute and chronic diseases, but also to limited access to care and rehabilitation. However, there are findings that indicate that racial differences in mortality risk have recently been reduced among those aged 75 years and older. In the European and especially in the Nordic countries, studies on racial or ethnic differences in mortality are rare. According to studies with Finnish samples representing a wider age scale the Swedish-speaking ethnic minority has a longer active life and lower death rate than the Finnish-speaking majority (Hyyppä & Mäki 2001, Saarela & Finnas 2005).

It is obvious that the elevated risk for mortality in racial and ethnic minorities is, at least partly, due to their below-average socio-economic status. Socio-economic differences in relation to mortality risk have usually been studied over wider age range (e.g. Kunst et al. 1998, Kåreholt 2001). The results show clear gender differences, even in as many as 90% of studies, the socio-economic differences in mortality risk are larger in men than in women (Mustard & Etches 2003). However, consistent differences have also been found at older ages according to various indicators of socio-economic position, such as education and occupational class (Martelin 1994b, Kåreholt 2000, Huisman et al. 2004).

2.6.3 Lifestyle

It is well known that the specific types of health behaviours are associated with a subsequent risk for death. This is evident in the whole population, but in older people it is less pronounced.

Smoking is one of the best-known risk factors for mortality, and earlier smoking history has been found to be related to risk of death, also in older people (de Groot et al. 2004), although it is clear that the selection of heavy smokers tends to attenuate the excess risk in older age groups in comparison to the younger age groups.

In adults the relationship between alcohol use and all-cause mortality is generally U- or J –shaped, with abstainers and heavy drinkers having higher mortality than light and moderate drinkers (Poikolainen 1995). The effects of alcohol use on the health and mortality of older people has received less attention, and the results of studies are contradictory. In the review by Reid et al. (2002) it was found that the magnitude of the risk posed by alcohol use for falls or fall injuries, functional disability, cognitive impairment, and all-cause mortality among older adults remains uncertain, while Moore et al. (2006) found that at-risk drinking (determined by the amount of alcohol consumed and comorbidities) in older men was associated with higher mortality rates than not-at-risk drinking. In women, neither abstinence nor at-risk drinking was associated with higher mortality risk. Some findings also suggest that drinking, and perhaps wine-drinking in particular, is associated with lower mortality even in old age (Tolvanen et al. 2005). The effect of alcohol on the health and mortality of older people may vary depending on presence of chronic conditions and medication.

There is a wealth of research data indicating that those older individuals who engage in less physical activity are at an elevated risk for many leading causes of death and all-cause mortality (Kaplan et al. 1987, Hakim et al. 1998, Sihvonen et al. 1998, Äijö et al. 2002). Physical activity has beneficial effects on survival especially in older people with mobility limitations (Hirvensalo et al. 2000). The reasons for the beneficial effects of physical activity include, for example, increased aerobic capacity and muscle strength and reducing of functional limitations (Keysor 2003).

Social activity is related to several positive end-points in older people. Participating in voluntary work and religious activity has been found to decrease mortality risk in older people (Wolinsky et al. 1995, Harris & Thoresen 2005, Hill et al. 2005). Glass et al. (1999) found that social activities, like art hobbies, gardening and cooking are protective for mortality in old age. Passive art hobbies, such as going to different cultural events and concerts and reading books, have similar effects on mortality risk (Bygren et al. 1996).

An active lifestyle promotes cognitive capacity and health (Menec & Chipperfield 1997, Mendes de Leon et al. 2003, Barnes et al. 2004, Glei et al. 2005, Newson & Kemps 2005), enhances life satisfaction and subjective well-being (Longino & Kart 1982), and protects from dementia (Wang et al. 2002, Verghese et al. 2003).

2.6.4 Diet and nutrition

Although obesity is a well-known risk factor for cardiovascular mortality, low body mass index has been found to influence the risk for mortality, especially in older people (Landi et al. 1999). Especially unintendent weight loss is associated with an increased risk for death in older adults (Amador et al. 2006). Weight loss is associated with older age, health deterioration and frailty; older people with weight loss have higher rates of diseases such as diabetes, and lower base-line levels of blood pressure and serum total cholesterol (Knudtson et al. 2005).

Some researchers suggest a U-fold risk in both under and over 65-year-old individuals (Gu et al. 2006). In Corrada and co-worker's (2006) study obesity was significantly associated with increased mortality only among persons under the age of 75 years.

Indicators of nutritional status such as low carotenoid and selenium levels in serum have also been found to be related to higher mortality in older ages

(Ray et al. 2006). Selenium and the carotenoids play an important role in antioxidant defences and are also involved in inflammation. The findings suggest that specific antioxidant nutrients may play some role in health status by suppressing the serum concentration of interleukin 6 (Walston et al. 2006). Malnutrition is also associated both with abnormally high and low homocysteine concentrations, and both of these are associated with higher mortality. Serum homocysteine levels, which increase with age, are recognized as a vascular risk factor and are also related to the development of heart failure and dementia. They are considered to have an effect of an inflammatory-malnutrition process associated with a poor prognosis (Rodriguez et al. 2006).

2.6.5 Cognitive capacity

Decline in cognitive capacity may be an early sign of dementia, which is second in the list of the most common causes of death in Finnish women aged 70 years and older (Table 1). Substantial excess mortality has been found among demented compared with non-demented older people (Boersma et al. 1999). Many studies have shown that reduced cognitive capacity and an increased rate of decline of cognitive functions are related to elevated risk for mortality in older people (Perls et al. 1993, Smits et al. 1999, Schupf et al. 2005a). The impact of cognitive decline on mortality may partly reflect poor underlying health status. Deeg et al. (1990) found that the rate of decline in cognitive functioning was an independent predictor of longevity, especially in older persons. The rate of decline in cognitive functioning was strongly associated with subsequent survival at age 70 years and over, but no association was found in the age group 65–69 years. Some researchers have noted a terminal decline in cognitive functions in the last years of life. Decline in the episodic, semantic and working memory and in perceptual speed, and in visuospatial ability have been found to greatly increase during the 3 to 6 years prior to death (Wilson et al. 2003b). Bassuk et al. (2000) also found a more pronounced elevated risk for mortality among those whose cognitive decline was recent than among those whose cognitive performance was compromised but stable.

2.6.6 Diseases and comorbidity

Diseases and comorbidities are central issues with respect of survival and mortality. As shown in Table 1, leading conditions causing death in older people are cardiovascular diseases, stroke, dementia, pneumonia and various forms of cancer. In Finnish women aged 70 years and older the highest cancer mortality rates are in cancers of digestive system. In men aged 70 years and older, the highest cancer mortality rates are in lung cancer (Finnish Cancer Register 2006).

People aged 70 years and older usually have 2-3 chronic conditions (Nilsson et al. 2002). Comorbidity is especially common in older people (Satariano 2006), and the number and types of illnesses are related to higher mortality (Feinstein 1970). For example, diabetes increases the mortality of older people up to four times compared to non-diabetic people (Barnett et al. 2006).

Chronic obstructive pulmonary disease and kidney diseases also predict mortality from multiple causes in the older people (Chen & Mannino 1999, Fried et al. 2005). Older people with Parkinson´s disease are at a higher risk for death compared with subjects free of it (Elbaz et al. 2003). Among psychological conditions, both minor and major depression as well as duration and severity of depression are related to higher risk for death in older persons (Penninx et al. 1999, Geerlings et al. 2002), and major depression is also related to the first cardiac event and cardiac mortality (Penninx et al. 2001, Bremmer at al. 2006).

2.6.7 Other indicators of health status

High blood pressure, a well-known risk factor for cardiovascular mortality besides smoking and overweight, is a stronger predictor of mortality in middle-aged than in older individuals (Sairenchi et al. 2005). Some studies have even found that low systolic blood pressure is associated with risk for death in old-old people, as it is partially related to poor general health and poor vitality. (Rastas et al. 2006).

Similarly, elevated serum cholesterol is a more important predictor of mortality in middle-aged than in older people. A low cholesterol level is associated with higher mortality risk, contrary to the findings in samples of larger age ranges (Menotti et al. 2001, Schatz et al. 2001, Schupf et al. 2005b). It can be assumed that low body mass index and cholesterol levels are associated with diseases, comorbidities and frailty, indicating imminent death. A low serum albumin level is also an indicator of an illness predicting mortality (Sullivan et al. 2005). Among the other health status indicators, anemia is independently associated with increased mortality in older people (Penninx et al. 2006), and it is also a risk factor for functional and cognitive decline (Denny et al. 2006). In high-functioning older persons, a measure of inflammation, such as C-reactive protein, can identify those at a higher risk for mortality (Reuben et al. 2002). In older people poor oral health is also associated with higher mortality risk (Hämäläinen et al. 2003).

2.7 Theoretical models of mortality in old age

There have been several attempts to construct a model of longevity or mortality in old age. The one of the earliest was constructed by Rose and Bell (1971) on the basis of the results of the Normative ageing study in Boston. This quite simple theoretical model includes three main categories of factors that influence longevity: physical, social and genetic. Over a decade later Palmore (1982) proposed his well-known and more comprehensive model on the basis of the Duke longitudinal study. He condensed 50 variables into eight categories of longevity-related factors: Age of parents, intelligence, socioeconomic factors, physical and social activity, sexuality, lifestyle, satisfaction with life and health. Palmore

(1982) calls this model a theoretical model, but in fact it is a description of univariate statistical associations. As Sihvola (1989) also observes, these two models were quite general, lacking assumptions of mediating mechanisms and lumping together factors that represent different levels and types of explanation.

Martelin (1994a) proposed a general model of factors affecting mortality at old ages, where the intention was to make explicit the hypothesized causal ordering of factors suggested in the literature in order to clarify the role of sociodemographic factors as predictors of mortality. The factors were taken account also throughout the lifespan. Recently, a general model integrating epidemiologic and demographic approaches and perspectives has been proposed by Seeman and Crimmins (2001). This model emphasizes the need to combine biological, psychological and social factors of health and mortality. This biopsychosocial model of health and aging operates at the level of the individual within a framework of cumulative effects during the life span (Figure 1). It is suggested that these relationships are influenced by broader environmental effects deriving from the sociocultural and physical environments in which the individual lives throughout the life-course. It seems that as knowledge about the factors that influence the health and survival of older people accumulates, the more extended and complicated the general theoretical models get.

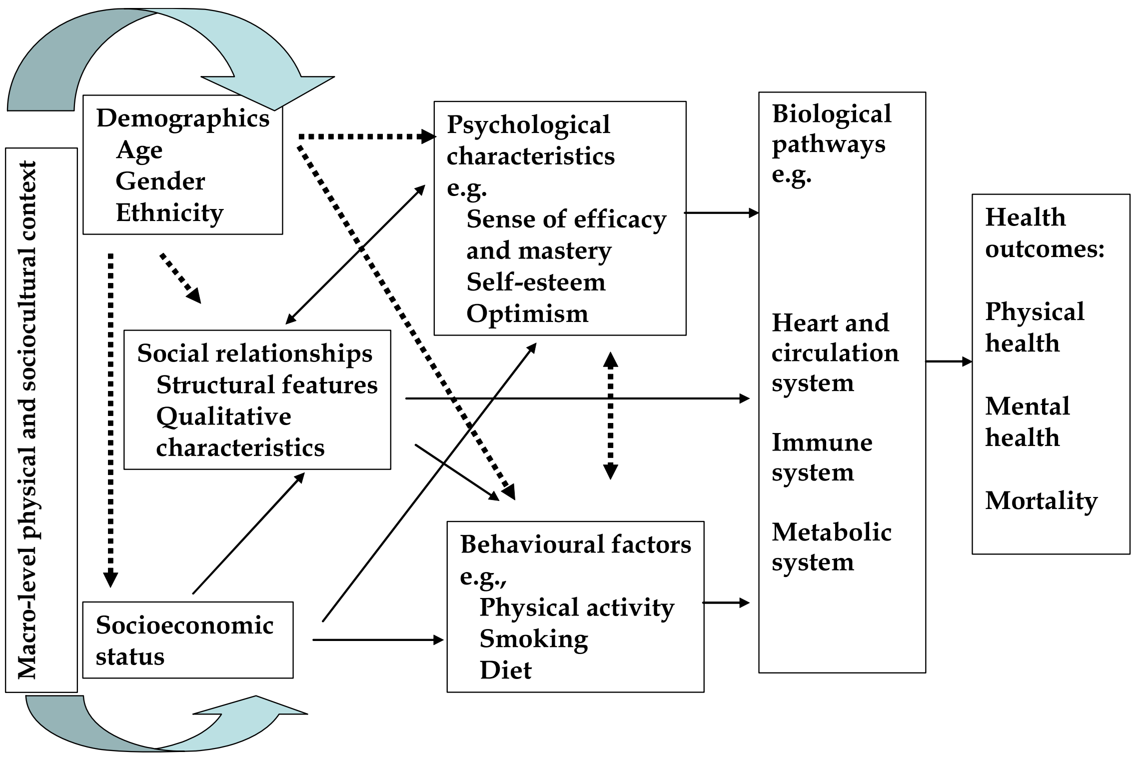

FIGURE 1 Biopsychosocial model of health and aging (Seeman & Grimmins 2001).

Satariano (2006) has proposed an epidemiological model with a more ecological emphasis. Unlike the previous two models, here the impact of macro-level society is not elicited, and the factors included are defined more on the individual level. The idea of the ecological approach is to encourage multidisciplinary work in the health sciences. The ecological model is based on the assumption that patterns of health and well-being are affected by the dynamic interplay between biological, behavioural and environmental factors. This model can be used to describe and explain the effects of multilevel factors on both the causes (etiology) of health conditions as well as the consequences of those conditions, like mortality or longevity. The idea of the ecological model is that it illustrates the range of relevant variables while also underscoring the point that the variables are interrelated. The model is divided into three circles, where the top circle contains demographic, socio-economic, environmental, social, psychosocial and physiological factors. The second circle contains health and functional outcomes, and the third circle represents vital status. The basic idea is that causal links cannot be presented between independent, intermediate or dependent variables.

In this thesis, I chose not to present a causal theoretical model, however the ecological model of epidemiology of ageing presented by Satariano (2006) describes my multidisciplinary approach well (Figure 2).

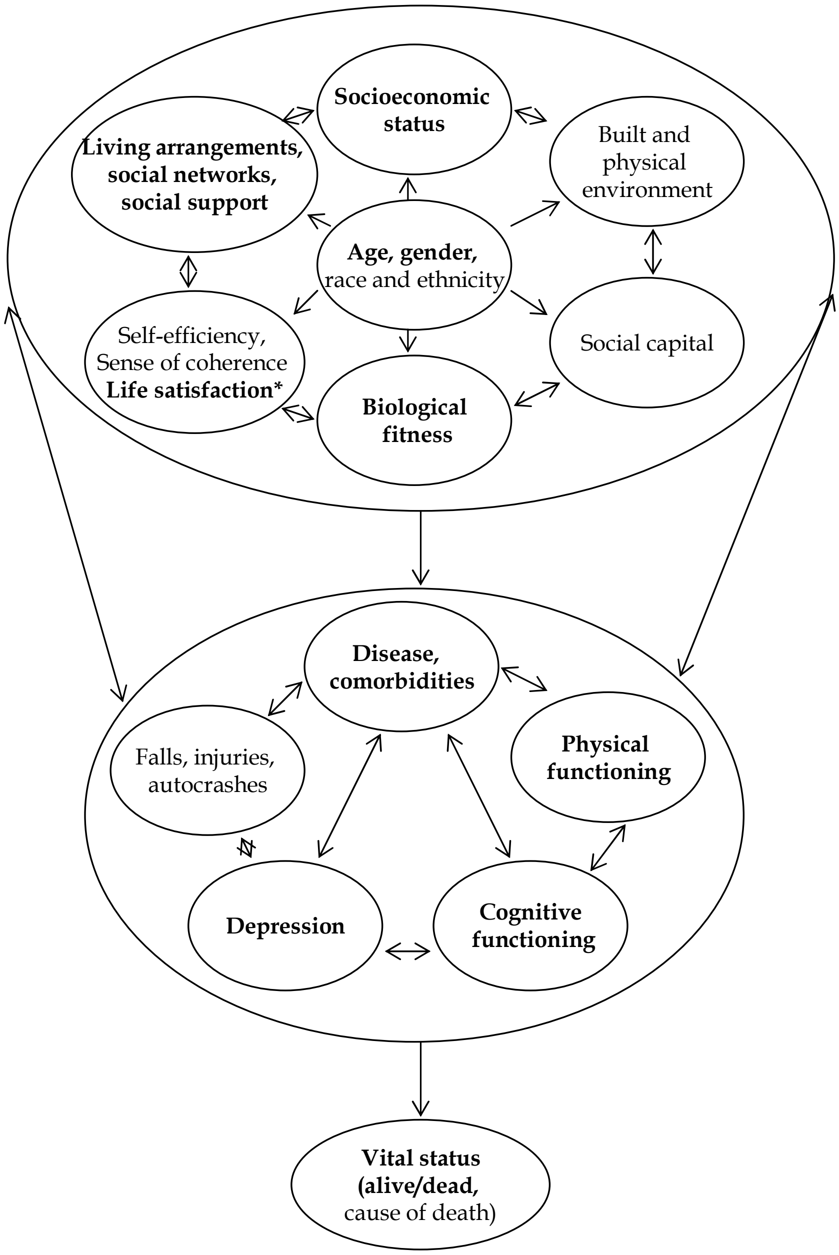

FIGURE 2 Ecological model of the epidemiology of ageing (Satariano 2006).
Notes: Factors studied in present series of studies are highlighted in bold, *) Life satisfaction is added into the model.

3 AIM OF THE STUDY

The aim of this study was to explore the impact of physical and psychosocial factors on mortality in old age with special emphasis on self-rated health, physical functions, life satisfaction and perceived social support.

The specific goals of the study were:

1) To examine whether the association between self-rated health and mortality could be explained by clinical and performance-based measures of health and functioning in middle-aged and older men.
2) To examine the effects of physical measures on mortality in older men and women.
3) To examine the effect of life satisfaction on mortality in old-old people.
4) To examine the effect of perceived social support on mortality in older men and women.

4 METHODS

4.1 Samples

The series of present studies used pre-existing established data from three different research projects. Samples used, Roman numeral of study, age and number of participants at the baseline, numbers and percentages of deceased participants and the length of follow-up times are presented in Table 3.

1) The Evergreen project is a multidisciplinary, longitudinal research programme which aims at profiling and following-up the health and functional capacity of older residents in the city of Jyväskylä, central Finland and identifying the factors that predict changes in functional capacity and health, including mortality. A total of 1999 subjects aged 65-85 years were recruited at the baseline. The design of the project is described in detail elsewhere (Heikkinen et al. 1990, Heikkinen & Suutama 1991, Heikkinen 1997, Heikkinen 1998).

2) The Functional capacity of men born in 1906-10, 1926-30 and 1946-50 is an interdisciplinary research project focusing on health and functional capacity in three different male age cohorts. The participants were drawn randomly from the municipal population register of the city of Jyväskylä, central Finland. At the baseline the cohorts were 31-35, 51-55 and 71-75 years of age and contained a total of 449 men. The study design is described in detail elsewhere (Heikkinen et al. 1984).

3) The OCTO-twin study is a longitudinal study of intact pairs of same-sex twins, aged 80 and older, living in Sweden. A total of 549 twin pairs were identified from the population-based Swedish Twin Registry. The twin pairs were included if they were born in 1913 or earlier, and if both co-twins were alive. Of those contacted, a total of 351 pairs (702 individuals) participated in the first measurement occasion during 1991–1994. The study design is described in detail elsewhere (Cederlöf & Lorich 1978, McClearn et al. 1997).

TABLE 3 Samples of this study; age and numbers of all participants at the baseline, participants in this study, number and percentages of deceased participants and the length of follow-up times.

Study	Age at the baseline		All participants		Participants in this study		Died during the follow-up[1]		Mortality follow-up, years
			n	%	n	%	n	%	
I	51-55 years	Men	151	100	138	91.4	36	26.1	18
	71-75 years	Men	146	100	119	81.5	107	89.9	18
II, IV	75 years	Total	355	100	295	83.1	156	52.9	10
		Men	119	100	104	87.4	45	43.3	
		Women	236	100	191	80.1	111	58.1	
	80 years	Total	262	100	206	78.7	128	62.1	10
		Men	74	100	61	82.4	42	68.9	
		Women	188	100	145	77.1	86	59.3	
III	80 years and older	Total	702	100	320	45.6	232	72.5	10
		Men	234	100	126	53.8	108	85.7	
		Women	468	100	194	41.5	124	63.9	

1) % of participants in this study

4.1.1 Evergreen (II, IV)

Two populations of the Evergreen project were used in this study: 1) 75-year-old residents (born 1914) of Jyväskylä, who were alive at the beginning of the year 1989 and 2) 80-year-old residents (born in 1910), who were alive at the beginning of the year 1990. In 1991, the proportion of people aged 65 and over in the city of Jyväskylä was 12.4% compared to 13% for Finland as a whole.

Of the 75-year-olds, 93.4% of the total sample (N=388) took part in the home interviews. Participation in the baseline examinations, which were carried out in 1989 at the study centre was 77.6% (n=295, 104 men and 191 women). Reasons for nonparticipation were ascertained by telephone. Of the 80-year-olds, 91.9% of the total sample (n=291) took part in the home interviews. Participation in the baseline examinations carried out in the study centre in the year 1990 was 71.9% (n=206, 61 men and 145 women). Those who took part both in the interviews and in the examinations in the study centre had more chronic diseases than those who only took part in the interviews (Laukkanen et al. 1995).

4.1.2 Functional capacity of men born in 1906-10, 1926-30 and 1946-50 (I)

Two oldest age cohorts (born in 1906-10 and 1926-30) from the Functional capacity of men were used in this study. At the baseline the participants were 51-55 and 71-75 years of age, containing 138 and 119 men, 72% and 68% from those contacted, which had answered the postal questionnaire and attended the clinical examinations at the study centre in year 1981. The most common reasons for non-participation were unwillingness and disease.

The participants were drawn randomly from the municipal population register of the city of Jyväskylä, central Finland. When the baseline examinations were carried out in 1981, the city had a population of 64 200.

4.1.3 OCTO-Twin (III)

The OCTO-twin study is a longitudinal study of intact pairs of same-sex twins, aged 80 and older, living in Sweden. A total of 549 twin pairs were identified from the population-based Swedish Twin Registry (Cederlöf & Lorich 1978). The twin pairs were included if they were born in 1913 or earlier, and both co-twins were alive. Of those contacted, a total of 351 pairs (702 individuals) participated in the first measurement occasion. Data on the variables that were used in this study were available for 126 men and 194 women. Failure to complete the measures was mainly due to participants´ poor physical and mental functioning. The assessment was done five times at two-year intervals. The data from the first measurement occasion during 1991–1994 were used in the present study.

4.2 Measures

A summary of the measurements used in the final analysis of the present series of the studies is shown in Table 4. The measures are described in more detail in the original articles (I-IV).

4.2.1 Survival time

Times of death for all participants who died during follow-ups were obtained from the Finnish Population Register Center and the National Swedish Population Register. Survival time was calculated in days from the last baseline examination date to the date of death or the end of the follow-up period (I,II,III,IV).

4.2.2 Health measures

Self-rated health was elicited by a non-comparative question "Do you consider your health at the moment to be poor (1), rather poor (2), average (3), fairly good (4) or good (5)" (I).

In the Evergreen study chronic diseases were evaluated in a medical examination by a physician according to the International Classification of Diseases (WHO 1977). Information from medical records and prescriptions were also used where available (Laukkanen 1998) (II,IV). In the study of the Functional capacity of men born in 1906-10, 1926-30 and 1946-50 the physician checked the parts of the questionnaire filled in beforehand by participants on diseases lasting more than 3 months and medication. The subject's general health status was checked in a conventional way by a physician (Heikkinen et al. 1984) (I). In the OCTO-Twin study, the data was based on medical records that were obtained from hospitals, outpatient clinics, district physicians and primary health care centers (Nilsson et al. 2002) (III).

Serum total cholesterol from a blood sample taken before the exercise tests was analyzed enzymatically according to the Boehringer Mannheim GmbH Monotest Cholesterol-test package (Heikkinen et al. 1984) (I).

4.2.3 Physical measures

An adjustable dynamometer chair was used to measure the maximal isometric muscle strength of hand grip, arm flexion and knee extension on the side of the dominant hand in the sitting position (Heikkinen et al. 1984). Maximal isometric trunk flexion and extension strengths were measured in the standing position according to the method developed at the University of Jyväskylä (Viitasalo et al. 1977). The best result of three trials was selected for the analysis (I,II).

In the study III, physical functioning was measured by a battery of tests requiring balance, upper body strength, flexibility and dexterity. Balance was tested by normal gait, Romberg´s test and semi-tandem and tandem stand. The reach and mobility of the upper extremities were tested with the subject lifting a glass and a one-kilogram package and some basic tasks. Manual ability was assessed in various tasks of importance for independent ADL functioning using a special apparatus. The tasks were inserting and turning a key, putting a plug in a socket, screwing in a light bulb, putting coins in a slot, and dialing a number (Aniansson et al. 1980, Lundgren-Lindquist & Sperling 1983).

Maximal walking speed, defined as the time taken to walk 10 meters, was assessed in the laboratory corridor using a stop-watch (Era & Rantanen 1997) (II,IV).

Body mass and height were measured in the laboratory using standard procedures. Vital capacity (litre) was measured using electronic spirometry (Medikro 202) in a standing position. Tapping rate over 2.5 seconds was measured using an electric counter and vibration threshold with 100 Hz frequency was measured from the inner malleolus of the left ankle (Era et al. 1986, Era 1987) (I,II).

4.2.4 Psychological measures

The tests of cognitive performance carried out in the study centre and in the participants´ home included psychometric assessments of memory and intelligence. Short–term memory was measured by Digit Span (Wechsler 1945) (I, II, IV) and crystallized intelligence by Synonyms measuring verbal meaning (Thurstone 1938, Dureman & Sälde 1959) (III). Fluid intelligence was tested by Arithmetic, measuring numerical facility (Wechsler 1958) (I), Word Finding, measuring word fluency (Thurstone 1938, Schaie 1979) (I, II, IV), Block Design, measuring spatial orientation (Wechsler 1958, Dureman & Sälde 1959) (I, III), Digit Symbol, measuring perceptual speed (Wechsler 1945) (IV) and Figure Grouping, measuring inductive reasoning (Wechsler 1958, Dureman & Sälde 1959) (III).

Satisfaction with life was measured by the 13-item Life Satisfaction Index Z (Wood et al. 1969), which is a short form of the Life Satisfaction Index A (Neugarten et al. 1961). A 5-point scale was used from 1=strongly disagree to 5=strongly agree. A higher score indicated greater satisfaction with life (III).

TABLE 4 The variables used in the original papers in final analyses.

Variables	Studies	Reference/ Method
Survival time	I,II,III,IV	Cox & Oakes 1984
Health		
Self-rated health	I	
Number of chronic conditions	I	Heikkinen et al. 1984
Number of serious illnesses	II,III,IV	
Serum total cholesterol	I	
Physiological measures		
Vital capacity, VC	I,II	Medicro 202
Tapping rate per. 2.5 sec.	I,II	Era et al. 1986
Vibration threshold	I,II	Era 1987
Knee extension	I,II	Heikkinen et al. 1984
Arm flexion	I,II	Heikkinen et al. 1984
Body extension	I,II	Viitasalo et al. 1977
Body flexion	I,II	Viitasalo et al. 1977
Walking speed	II,IV	Era & Rantanen 1997
Physical functioning	III	Lundgren-Linquist & Sperling 1983
Manual ability	III	Aniansson et al. 1980
Body height	I	
Body mass	I	
Psychological measures		
Arithmetic	I	Wechsler 1958
Block design	I,III	Wechsler 1958, Dureman & Sälde 1959
Digit span	I,II,IV	Wechsler 1945
Digit symbol	IV	Wechsler 1958
Figure grouping	III	Wechsler 1958, Dureman & Sälde 1959
Vocabulary	III	Thurstone, 1938, Dureman & Sälde 1959
Word fluency	I,II,IV	Thurstone 1938, Schaie 1979
Life satisfaction Index Z	III	Neugarten et al. 1961, Wood et al. 1969
Depressiveness, CES-D	III,IV	Radloff 1977
Social measures		
Social Provision Scale	IV	Weiss 1973, Cutrona & Russell 1987
Frequency of social contacts	III	
Living alone or not	III,IV	
Education		
Length in years	II,III,IV	

Depressive symptoms were assessed by the Center for the Epidemiologic Studies Depression Scale (CES-D), developed for the purpose of screening for depressive symptomatology in community and epidemiological studies (Radloff 1977). The questionnaire consists of 20 items, each rated on a 4-point scale indicating the frequency of mood problems during the past week (0 = rarely or never, 1 = some of the time, 2 = occasionally, 3 = most of the time) (III,IV).

4.2.5 Social measures

Perceived social support was measured with the Social Provision Scale (Weiss 1973, Cutrona & Russell 1987, Manchini & Bliesner 1992), which measures the kind of support a person gets from his or her social network. The scale has 24 items divided among six sub-scales (attachment, social integration, opportunity to nurturance, reassurance of worth, reliable alliance and guidance) consisting of four items each: two measuring the presence and two the absence of each of the six dimensions. The respondents were asked to assess on a scale from 1 (strongly disagree) to 4 (strongly agree) how each statement described their current social relationships (IV).

Household composition was elicited in interviews to find out whether the subject was living alone or not at the baseline (III,IV). Frequency of social contacts was measured by a question asking how often the respondent sees or phones children, siblings, relatives, friends or acquaintances. (1 = never, 2 = hardly ever, 3 = every year, 4 = every month, 5 = every week, 6 = several times a week, 7 = every day)(III).

Education was measured as the length of formal education in years (II,III,IV).

4.3 Statistical analyses

4.3.1 Time-to-event models (I,II,III,IV)

When data is in the form of times from a time origin until the occurrence of some particular end point, like mortality data, survival analysis is the most accurate statistical method. Such studies are generally referred to as survival or failure time analyses or time-to-event studies. A typical feature of survival data is that survival times are frequently censored. The survival time of an individual is said to be censored when an end-point (in this case death) has not been observed. Survival analysis is concerned with studying the time between entry to a study and a subsequent event (such as death) (Collett 2003). The Cox regression model (Cox & Oakes 1984) is a well-recognised statistical technique for exploring the relationships between survival and several explanatory variables. It allows us to estimate the hazard (or risk) of death, or other event of interest, for individuals, given their predictive and covariating variables.

In present series of studies, the association between covariates and mortality were studied using the Cox regression model and its applications. The proportional assumptions for the covariates were evaluated using log-log plots (Collett 2003). In the analyses in papers I and IV the Cox regression model was used as the main method. In papers II and III, some special questions arose, like multicollinearity and the correlation between twins. In order to solve these statistical problems, principal component estimation in the Cox regression model and shared frailty modelling were used.

4.3.2 Cox regression model with principal component estimation (II)

When different domains of the same phenomenon are studied simultaneously, the variables tend to correlate with each other, thus violating the results of multiple regression models. The principal component analysis and estimation procedure was applied in order to eliminate the problem of multicollinearity in regression parameter estimation (Lott 1973, Leskinen 1981). The first step in this procedure was to compute the principal component score coefficients for the covariates; and the second step was to estimate a Cox regression model using this principal component as a covariate. At the third step the final Cox regression coefficients, their standard errors and the test statistics for each covariate were calculated by weighting this Cox regression parameter by the principal component score coefficients obtained in the first step.

4.3.3 Shared frailty model (III)

The basic assumption in time-to-event analyses is that the individuals investigated are independent of each other so that the survival time of one individual does not affect the survival time of another. A twin pair may have a similar risk for mortality, i.e. the mortality times are not independent between the co-twins. In the twin sample, the aim was to study mortality risk at the individual level, and thus the assumed dependency within the sampled twin pairs due to influences from genetic background and shared environment had to be taken into account. The semiparametric Cox regression mixed effects model (i.e. shared frailty model) was used to examine mortality risk. Frailty modelling can be used in the analysis of clustered time-to-event data to directly account for a correlation among participants, e.g. the survival times among twin pairs. More details of this method can be found in McGilchrist (1991).

4.3.4 Exploratory factor analysis (III)

Exploratory factor analysis based on the polychoric correlation matrix was carried out in aim to study the factor structure of the life satisfaction scale. The analysis was conducted using maximum likelihood estimation together with

Promax-rotation to allow for correlation among factors. The factor scores were computed and divided into quartiles for further analyses.

4.3.5 Other analyses (I,II,III,IV)

Survival functions were estimated using the Kaplan-Meier method, and the equality of the curves was tested using the log rank and Breslow tests (I,II). Student's t-test was used to test for the differences in continuous covariates between survivors and non-survivors, and Pearson´s chi-square test for differences in categorical covariates between survivors and non- survivors (I,II,IV). In paper III, these tests were corrected for the twin design.

Fisher's transformation for the correlation coefficient was used in testing differences between the correlation coefficients of men and women (Table 8).

The few missing values were imputed either by the regression method, which replaces missing values with the linear trend of that point using the information of existing values (I,IV), or by using PRELIS (Jöreskog & Sörbom 2001), where the value to be substituted for the missing value of the case was obtained from another case that had similar pattern over a set of matching variables (II).

Exploratory factor analysis based on the polychoric correlation matrix was carried out using PRELIS (Jöreskog & Sörbom 2001), shared frailty models were constructed with STATA version 8 (StataCorp 2003) (III). The other analyses were performed using SPSS (SPSS 1999, Chicago, IL, USA) (I,II,IV). The statistical analyses are described in more detail in the original articles. The summary of the measures, analyses and software is presented in Table 5.

TABLE 5 Summary of the measures, analyses and software used in the main statistical analyses.

Study	Measures used in the final analysis	Main Statistical methods	Software
I	Self-rated health Body mass index Serum total cholesterol Tapping rate Cognitive functioning Muscle strength Number of chronic diseases Survival time	Cox regression model	SPSS
II	Vital capacity Tapping rate per 2.5 sec Vibration threshold Muscle strength Cognitive functioning Number of serious illnesses Survival time	Cox regression model with principal component estimation	SPSS
III	Life satisfaction Education Living alone Depressiveness Physical functioning Cognitive functioning Frequency of social contacts Number of serious illnesses Survival time	Exploratory factor analysis Cox regression mixed effects model i.e. Shared frailty model	PRELIS STATA
IV	Perceived social support Education Depressiveness Cognititve functioning Walking speed Living alone Number of serious illnesses Survival time	Cox regression model	SPSS

5 OVERVIEW OF THE RESULTS

5.1 Total mortality

In the older age groups (71-92 years) at the 10-year follow-up the percentage of deceased participants varied between 59 and 86, showing differences by participants age and/or gender (I,II,III,IV). In middle-aged (51-55 years) men at the 10-year follow-up 12% of the participant had died. At the 18-year follow up 90% of the older men and 26% of the middle-aged men had died (I). In the three samples, including both sexes, the hazard ratio for death was higher among men compared to women (II,III,IV).

5.2 Differences between deceased and surviving participants

In the older men (71-92 years) those who survived over the ten-year follow-up had better baseline vital capacity, tapping rate, muscle strength, mobility, self-rated health, higher body mass index, physical and cognitive functioning and different distribution of life satisfaction. Those who died in all the samples had more serious illnesses than their surviving counterparts. In study IV those who died were also on average older at the baseline than those who survived. In middle-aged men (51-55 years) the means for self-rated health and number of chronic diseases at the baseline differed significantly between the deceased and survivors at the 18-year follow-up (I).

The women who survived over the 10-year follow-up had better baseline vital capacity, tapping rate, muscle strength, mobility, physical and cognitive functioning and lower vibration threshold than their deceased counterparts. They also had fewer chronic diseases and their perceived social support was higher in the subscales of worth, integration, attachment and nurture (II,III,IV). In study III they were also on average younger at the baseline than those who died during the follow-up.

5.3 Self-rated health, other health indicators and mortality risk

Indicators of both poor subjective and objective health were highly related to mortality risk in this study. Although our results confirmed the hypothesis that the predictive value of self-rated health for mortality could be explained by diagnosed diseases, its predictive power remained quite strong when the performance-based measures of functioning and indicators of anthropometrics and clinical chemistry were added into the multivariate Cox proportional hazards model (I). This was found in both middle-aged men over the 18-year follow-up and the older men over 10-year follow-up (Table 6). Number of chronic or serious illnesses was related to the higher mortality risk in all samples in this series of studies in the full models of final analyses, except in 80-year-old women in study IV. Other indicators of health status, such as low body mass index was related to higher mortality in older men over the 10-year follow-up. Instead, in middle-aged men, a high level of serum total cholesterol predicted mortality over the 18-year follow-up (I).

5.4 Physical functions and mortality risk

Poor results in the performance-based measures of physical functions were related to higher mortality risk in the older people (II). In the Cox regression model with principal component estimation 75-year-old women who at the beginning of the study were in the lowest tertile of all the performance-based measures of physical functioning (vital capacity, tapping rate, vibration threshold, muscle strength, walking speed) had higher mortality risk than those in the highest tertile. In the 75-year-old men the results were similar, except in vibration threshold (Table 7). Correlations between physical and cognitive functions and number of chronic diseases in 75-year-old men and women are prestented in Table 8. Physical risk factors showing significant association with mortality risk in men and women separately were combined into principal component scores, these scores were then divided into tertiles. It showed that those in the lowest tertile had a mortality risk at least three to four times higher than those in the highest tertile. The survival functions are presented in Figure 3.

In final Cox regression models over the 10-year follow-up older men (71-75) had higher risk for mortality if they had lower muscle strength at the baseline (I). Both older men and women had higher risk for mortality if, at the beginning of the study they had poor performance in physical functioning including tests requiring balance, upper body strength, flexibility and manual ability (III). Poor physical functions were not related to higher mortality risk in middle-aged men (I)

TABLE 6 Hierarchical Cox proportional hazards model for mortality in Finnish men 51-55 years (n = 138) of age at baseline with 18 years follow-up, and 71-75 years of age at baseline (n=119) with 10 years follow-up. Estimates of regression coefficients (ß), standard errors (s.e.) and statistical significance (p), (I)

	Model a		Model b		Model c		Model d		Model e		Model f	
	ß (s.e.)	p	ß (s.e.)	p	ß (s.e.)	p	ß (s.e.)	p	ß (s.e.)	p	ß (s.e.)	p
51-55-year-old men, follow-up 18 years												
Self-rated health												
Poor vs good	1.24 (0.46)	0.007	1.26 (0.46)	0.006	1.21 (0.46)	0.009	1.11 (0.46)	0.017	1.10 (0.47)	0.021	0.69 (0.52)	0.182
Average vs good	0.56 (0.41)	0.172	0.48 (0.42)	0.243	0.41 (0.42)	0.317	0.31 (0.42)	0.456	0.32 (0.42)	0.451	0.20 (0.42)	0.633
Body mass index, kg/m²			-0.04 (0.06)	0.482	-0.03 (0.06)	0.542	-0.04 (0.05)	0.427	-0.04 (0.05)	0.419	-0.06 (0.05)	0.298
Serum total cholesterol, mmol/l			0.25 (0.13)	0.048	0.28 (0.13)	0.036	0.30 (0.14)	0.023	0.31 (0.14)	0.024	0.31 (0.14)	0.022
Tapping rate, times per 2.5 s.					-0.08 (0.06)	0.188	-0.04 (0.06)	0.550	-0.04 (0.06)	0.568	-0.04 (0.07)	0.596
Vocabulary and WAIS subscales, pc-score							-0.34 (0.21)	0.099	-0.34 (0.21)	0.104	-0.34 (0.22)	0.122
Strength of four major muscle groups, pc-score									-0.04 (0.21)	0.869	0.02 (0.21)	0.928
Number of chronic diseases											0.23 (0.11)	0.038
-2 Log Likelihood	337.7		333.8		332.1		329.4		329.4		325.3	
Significance of change	0.030		0.143		0.195		0.102		0.869		0.044	
71-75-year-old men, follow-up 10 years												
Self-rated health												
Poor vs good	1.22 (0.43)	0.004	1.11 (0.43)	0.011	1.19 (0.43)	0.006	1.15 (0.44)	0.008	1.01 (0.44)	0.022	0.33 (0.50)	0.507
Average vs good	0.74 (0.40)	0.062	0.77 (0.40)	0.056	0.91 (0.41)	0.025	0.97 (0.41)	0.019	0.96 (0.42)	0.017	0.65 (0.44)	0.140
Body mass index, kg/m²			-0.16 (0.05)	0.001	-0.16 (0.05)	0.001	-0.16 (0.05)	0.001	-0.17 (0.05)	<0.001	-0.19 (0.05)	<0.001
Serum total cholesterol, mmol/l			-0.17 (0.11)	0.131	-0.14 (0.11)	0.195	-0.16 (0.11)	0.147	-0.16 (0.11)	0.150	-0.12 (0.11)	0.286
Tapping rate, times per 2.5 s.					-0.11 (0.04)	0.006	-0.09 (0.05)	0.050	-0.06 (0.05)	0.213	-0.05 (0.05)	0.248
Vocabulary and WAIS subscales, pc-score							-0.24 (0.17)	0.151	-0.20 (0.17)	0.233	-0.33 (0.17)	0.048
Strength of four major muscle groups, pc-score									-0.47 (0.18)	0.009	-0.61 (0.19)	0.002
Number of chronic diseases											0.26 (0.08)	0.001
-2 Log Likelihood	478.4		464.7		457.3		455.33		448.4		438.1	
Significance of change	0.011		0.001		0.007		0.150		0.010		0.001	

TABLE 7 Multivariate Cox proportional hazards models with principal component estimation for association between tertiles of covariates[1] and all-cause mortality in 75-year-old men and women: Estimates of regression coefficients (ß), standard errors (s.e.), statistical significance (p), estimates of hazard ratios (HR) with 95% confidence intervals (CI), (II)

	Men (n=104)				Women (n=191)			
	ß (s.e.)	p	HR	CI	ß (s.e.)	p	HR	CI
Vital capacity (3)								
VC (1)	0.42 (0.12)	<0.001	1.52	(1.16-1.88)	0.40 (0.09)	<0.001	1.49	(1.23-1.75)
VC (2)	0.39 (0.12)	<0.001	1.49	(1.14-1.63)	0.23 (0.09)	0.015	1.25	(1.03-1.47)
Tapping rate (3)								
TR (1)	0.35 (0.10)	<0.001	1.42	(1.13-1.71)	0.42 (0.09)	<0.001	1.52	(1.25-1.79)
TR (2)	0.33 (0.10)	<0.001	1.39	(1.12-1.66)	0.24 (0.10)	0.015	1.27	(1.02-1.52)
Vibration threshold (3)								
VT (1)	-	-	-	-	0.24 (0.05)	0.006	1.27	(1.15-1.39)
VT (2)	-	-	-	-	0.13 (0.06)	0.015	1.14	(1.01-1.27)
Muscle strength (3)								
MC (1)	0.45 (0.13)	<0.001	1.57	(1.17-1.97)	0.51 (0.11)	<0.001	1.67	(1.31-2.03)
MC (2)	0.43 (0.13)	<0.001	1.53	(1.14-1.92)	0.29 (0.12)	0.015	1.34	(1.03-1.65)
Walking speed								
WS (1)	0.46 (0.13)	<0.001	1.58	(1.18-1.98)	0.53 (0.12)	<0.001	1.69	(1.29-2.09)
WS (2)	0.43 (0.13)	<0.001	1.54	(1.15-1.93)	0.30 (0.12)	0.015	1.35	(1.03-1.67)

[1]Tertiles are: 1) lowest, 2) medium and 3) highest group as reference.

TABLE 8 Pearson correlation coefficients between physical functions and cognitive performance and number of chronic diseases in 75-year-old men and women. Men (n=104) above the diagonal and women (n=191) below the diagonal.

		VC	TR	VT	MS	WS	CP	CD
VC	Vital capacity, l/m²		0.372***	0.094	0.311***	0.414***	0.267**	-0.215*
TR	Tapping rate, times/2.5s.	0.302***		-0.083	0.286**	0.374***	0.418^{***a}	-0.132
VT	Vibration threshold, log units	-0.039	-0.103		-0.096	-0.078	-0.097	0.074
MS	Muscle strength, pc-score	0.349***	0.319***	-0.275***		0.602***	0.487^{***b}	-0.233*
WS	Walking speed, m/s	0.381***	0.297***	-0.185**	0.657***		0.634^{***c}	-0.286**
CP	Cognitive performance, pc-score	0.331***	0.151^{*a}	0.015	0.154^{*b}	0.220^{**c}		-0.203*
CD	Number of chronic diseases	-0.208**	-0.114	0.253***	-0.130	-0.320***	-0.111	

*** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, one-tailed test
Difference between males and females ^{a} = $p < 0.001$, ^{b} = $p < 0.01$, ^{c} = $p < 0.05$

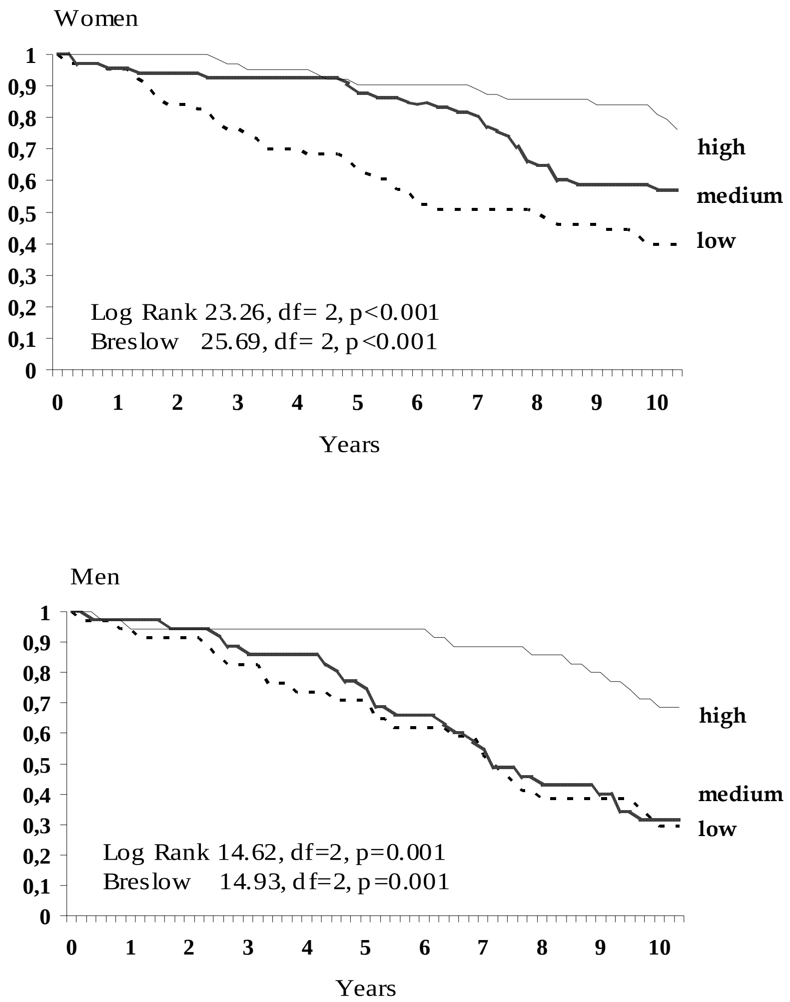

FIGURE 3 Survival functions over a 10-year follow-up by level of principal component for combined physical functions for 75-year-old men and women (II)

5.5 Life satisfaction, other psychological factors and mortality risk

Low perceptions of life satisfaction with present in terms of mood and zest were a significant predictor of mortality in both old-old men and women. At the 10-year follow-up, the mortality risk for men and women in the quartile with least satisfaction with present life was about two times higher than for those in the highest quartile (III). The association remained strong even when cognitive, physical and social capacity were added into the model (Tables 9 and 10). Lower cognitive capacity measured by verbal fluency, arithmetic, digit span and block design was related to a higher mortality risk in older men in final model (I). Depressiveness was not related to higher mortality risk in any of the models (III,IV).

TABLE 9 Six Models of the Association Between the Zest Factor Quartiles and 10-year Mortality in Swedish Octogenarians: hazard ratios (HR) and 95% confidence intervals (n = 320, pairs = 235), (III)

Measure	Model 0		Model 1		Model 2		Model 3		Model 4		Model 5 (Full)	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95%CI	HR	95%CI	HR	95%CI
Present life satisfaction (Zest) quartiles												
Lowest vs. highest	1.80	(1.23-2.61)	2.01	(1.38-2.91)	2.04	(1.40-2.97)	1.99	(1.35-2.93)	1.84	(1.25-2.70)	1.90	(1.27-2.83)
Middle vs. highest	1.07	(0.78-1.49)	1.12	(0.82-1.55)	1.13	(0.82-1.57)	1.12	(0.81-1.55)	1.11	(0.80-1.53)	1.13	(0.82-1.56)
Sex , women vs. men	0.54	(0.41-0.71)	0.53	(0.40-0.70)	0.55	(0.41-0.74)	0.53	(0.40-0.70)	0.53	(0.40-0.70)	0.57	(0.42-0.76)
Age			1.17	(1.11-1.23)	1.17	(1.11-1.23)	1.17	(1.11-1.23)	1.16	(1.10-1.22)	1.17	(1.11-1.23)
No. of serious illnesses			1.53	(1.38-1.70)	1.53	(1.38-1.70)	1.53	(1.37-1.69)	1.46	(1.31-1.63)	1.46	(1.31-1.63)
Living alone, no vs. yes					1.08	(0.80-1.45)					1.15	(0.85-1.55)
Years of education[a]					0.94	(0.72-1.21)					1.06	(0.80-1.41)
Depressiveness (CES-D)							1.00	(0.98-1.02)			1.00	(0.98-1.02)
Physical functioning									0.96	(0.93-0.99)	0.96	(0.93-0.99)
Social functioning									1.02	(0.91-1.14)	1.02	(0.91-1.15)
Cognitive functioning									0.84	(0.69-1.02)	0.82	(0.67-1.01)
Variance of frailty[b], p		0.377		0.498		0.498		0.498		-		0.498

Note: two middle quartiles combined.
[a] Split at median (less vs. more education)
b Frailty not estimable for Model 4.

TABLE 10 Six models of the association between the Mood Factor quartiles and 10-year mortality in Swedish octogenarians: hazard ratios (HR) and 95% confidence intervals (n = 320, pairs = 235), (III)

Measure	Model 0		Model 1		Model 2		Model 3		Model 4		Model 5 (Full)	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95%CI	HR	95%CI	HR	95%CI
Present life satisfaction (Mood) quartiles												
Lowest vs. highest	2.15	(1.49-3.10)	2.07	(1.44-2.99)	2.08	(1.44-3.00)	2.07	(1.41-3.04)	1.78	(1.21-2.61)	1.82	(1.22-2.71)
Middle vs. highest	1.41	(1.02-1.96)	1.38	(1.00-1.91)	1.38	(1.00-1.92)	1.38	(1.00-1.92)	1.26	(0.91-1.76)	1.27	(0.91-1.77)
Sex, women vs. men	0.56	(0.43-0.72)	0.56	(0.42-0.73)	0.56	(0.42-0.76)	0.56	(0.42-0.73)	0.56	(0.42-0.73)	0.58	(0.43-0.78)
Age			1.18	(1.12-1.24)	1.18	(1.12-1.24)	1.18	(1.12-1.24)	1.16	(1.11-1.23)	1.17	(1.11-1.23)
No. of serious illnesses			1.48	(1.34-1.64)	1.48	(1.34-1.65)	1.48	(1.34-1.65)	1.43	(1.28-1.59)	1.42	(1.28-1.59)
Living alone, no vs. yes					1.03	(0.78-1.38)					1.09	(0.82-1.46)
Years of education [a]					1.01	(0.78-1.31)					1.11	(0.84-1.47)
Depressiveness (CES-D)							1.00	(0.98-1.02)			1.00	(0.98-1.01)
Physical functioning									0.96	(0.93-0.99)	0.96	(0.93-0.99)
Social functioning									1.00	(0.89-1.13)	1.01	(0.89-1.13)
Cognitive functioning									0.86	(0.70-1.05)	0.83	(0.67-1.03)
Variance of frailty, p		0.498		0.498		0.498		0.498		0.498		0.498

Note: two middle quartiles combined.
[a] Split at median (less vs. more education).

5.6 Social support and mortality risk

In a conceptual framework supported by initial analyses, the items of Social Provision Scale were divided into two categories: assistance-related and non-assistance -related (Cutrona & Russell, 1987). The risk of death was two and half times higher in 80-year-old women in the lowest tertile of non-assistance-related social support, comprising infrequent experiences of reassurance of worth, emotional closeness, sense of belonging and opportunity to nurturance, than in those in the highest tertile (IV). The risk remained strong even when the indicators of baseline sociodemographics, lifestyle and psychological and physiological health and functioning were controlled for (Table 11). Assistance-related social support, consisting of guidance (advice or information) and reliable alliance (assurance that there are people who can be counted on in special circumstances) was not significantly related to mortality in older women. Among men, none of the subscales of perceived social support were related to mortality risk.

Other social factors like frequency of social contacts or living arrangements were not associated with mortality risk in the final models (III, IV).

TABLE 11 Five models of the association between non-assistance-related social support tertiles and 10-year mortality in 80-year-old women: Hazard ratios (HR) and 95% confidence intervals. (n=145), (IV)

Measure	Model 1 (Crude) HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95%CI)	Model 4 HR (95%CI)	Model 5 (Full) HR (95%CI)
Non-assistance-related social support tertiles					
Lowest vs. highest	2.48 (1.45-4.26)	2.60 (1.50-4.51)	2.40 (1.39-4.15)	2.03 (1.17-3.54)	2.14 (1.22-3.76)
Average vs. highest	1.50 (0.85-2.63)	1.47 (0.83-2.60)	1.44 (0.82-2.53)	1.49 (0.84-2.62)	1.55 (0.87-2.75)
Education in years		0.93 (0.87-1.00)			0.96 (0.89-1.03)
Living alone no vs. yes		1.54 (0.96-2.46)			1.49 (0.92-2.40)
Depressiveness (CES-D)			1.01 (0.98-1.04)		1.02 (0.99-1.04)
Cognitive functioning (pc-score)				0.76 (0.60-0.97)	0.82 (0.63-1.06)
Walking speed (m/s)				0.49 (0.24-1.01)	0.54 (0.26-1.12)
Number of serious illnesses ≥ 1 vs. 0		1.30 (0.81-2.11)	1.50 (0.94-2.40)	1.34 (0.83-2.17)	1.25 (0.77-2.02)

Notes: Model 2 controlled for education and living alone or not and serious illnesses, Model 3 controlled for depressiveness and serious illnesses, Model 4 controlled for cognitive functioning, walking speed and serious illnesses, Model 5 controlled for all six indicators of sociodemographics, physical and psychological health and functioning.

6 DISCUSSION

The purpose of the present series of studies was to examine how self-rated health, physical functions, satisfaction with life and perceived social support influence the risk of mortality in older people.

In general, the findings were consistent with those of the the previous literature, showing that poor subjective and objective health, poor results in various measures of physical functioning, low psychological well-being and low perceptions of social support predicted mortality in older people. However, some new findings emerged: 1) the association between self-rated health and mortality was explained by diagnosed diseases, but not with performance-based measures of functioning; 2) no single predictor of mortality from performance–based measures of functioning emerged; 3) low life satisfaction related to the present, in terms of zest and mood, was a more important predictor of mortality than congruence representing the satisfaction with past life; 4) the perceived non-assistance related social support was more important predictor of mortality than perceived assistance-related social support in the older women, and 5) social support was not related to mortality risk in older men.

Self-rated health and mortality

Previous studies of self-rated health and mortality have shown that poor self-rated health predicts subsequent death even when several sociodemocraphic and health indicators are controlled for (Mossey & Shapiro 1982, Idler & Benyamini 1997, Benyamini & Idler 1999, Shadbolt et al. 2002). Nevertheless, in most previous studies objective measures of health and functioning have not been included in the analyses. When information about potential confounders is based on self-reports, these confounders are likely to be influenced by individual styles of responding and thus, be biased in the same direction as self-rated health itself. Very few studies have included data from performance-based measures, clinical examinations or laboratory analyses (Kaplan et al. 1996, Simons et al. 1996, Jylhä et al. 2006).

In study I, conducted with a sample only containing men, self-rated health was a significant predictor of mortality when performance-based indicators of functioning were controlled for, but not when the number of diagnosed diseases was included in the model. Jylhä et al. (1998) have argued earlier that self-rated health is a personal, subjective summary of all the information people have about anything they understand as elements of "health". Jylhä et al. (2006), on the basis of the findings that self-rated health showed a graded association with frequently used biomarkers, concluded that self-rated health also has a biological basis. When biomarkers were included in the model, self-rated health still was a significant predictor of mortality.

There are also some evidence of gender differences in self-rated health and mortality risk (Deeg & Kriegsman 2003), but a male-only sample did not allow this issue to be studied in study I.

Physical functioning and mortality

Among the performance-based measures of functioning, poor mobility was one of the strongest predictors of mortality (I,II). In earlier studies impaired mobility has been shown to be a major risk factor for disability, falling, loss of independence, hospitalization and mortality (Guralnik et al. 2000, Hirvensalo et al. 2000, Penninx et al. 2000, Guralnik et al. 2001, Stel et al. 2003).

Slow walking speed has been found to be related to several chronic conditions and weakened muscle strength. In this study older people whose muscle strength was weak, were at higher risk for death. Several other studies have found also a similar association (Rantanen et al. 2000, Metter et al. 2002, Snih et al. 2002, Rantanen 2003). The suggested pathways from disease to muscle impairment include nutritional depletion, systemic inflammation, and physical inactivity. Poor muscle strength could be a marker of disease severity, which in turn is associated with mortality (Rantanen 2003). Decreased muscle strength is also a risk factor for falls, which in turn may lead to higher mortality risk. A recent study confirmed that strength is a more important predictor of mortality in older people than muscle mass (Newman et al. 2006b).

Speed-related functioning, like slow tapping time has been found to be associated with increasing mortality in older people independently of the effects of muscle power and strength (Metter at al. 2005). Era (1987) found higher means for tapping rate in 71-year-old male survivors than non-survivors at a 5-year follow-up. These studies support the present finding that slow tapping rate is related to higher risk for mortality.

In study II, low vital capacity was related to higher mortality risk. Earlier studies have shown that reduced pulmonary function is an important predictor of cardiovascular morbidity and mortality (Sorlie et al. 1989, Sharps et al. 1997, Schunemann et al. 2000). Respiratory functions are good indicators of health status and especially the coronary disease related mortality. The association between pulmonary function and coronary heart disease can partly be explained by cigarette smoking, which leads to both lung impairment and incidence of coronary heart disease (Marcus et al. 1989). In present study this was not the case, as in the initial analyses it was shown that controlling for smoking did not reduce the hazard ratios. Also, in this sample of Finnish 75-year-old people, the percentage of smokers was very low, especially in women.

The main finding of study II was that the functions measured were related to higher mortality risk to a similar extent, and thus no single dominant predictive factor emerged. It was possible to draw this conclusion, because several performance-based measures were studied simultaneously. Furthermore, the application of the principal component estimation procedure in the Cox regression model yelded a truer picture of the impact of an individual's functional status and mortality. The levels of the various functions studied showed significant intercorrelation, indicating that a decline in one function also contains information about the other physical functions of an individual. A study by Heikkinen et al. (1993) found that in older male age group (71–75-years) intercorrelations in measures of functiong were higher than in younger age groups.

It could be argued that the older people with higher risk for death represented the frailty phenotype. Frailty is a robust concept with the risk of adverse outcomes being largely established by age 70 (Rockwood et al. 2006). Ferrucci et al. (2003) have put forward hypothesis on the development of frailty, according to which disease, disuse and ageing "per se" trigger a mechanism that exhausts the redundancy of muscular and nervous backup systems, so that the damage goes beyond the threshold of possible compensation and leads to a measurable decline in physical performance and in the end, to death.

At the other end of continuum there is a group of survivors, whose good level of physical functions may represent general vitality or robustness, thus protecting those individuals from premature death. The explanation for this could be found in their earlier lifestyle and partly in genetic influences. Recent studies have suggested that genetic influences contribute to about one third of the variation in postural balance, muscle strength and mobility in older people (Pajala et al. 2004, Tiainen et al. 2004, 2005, Pajala et al. 2005, 2006).

It also seems that the protective effects of good physical functions are partly additive. When these functions were studied univariately, the risk for death for those in the lowest tertile was high, and when gathered together in an index the information of different functions showed an even higher risk for mortality for these individuals.

Life satisfaction and mortality

Life satisfaction has mainly been used as an endpoint in earlier ageing research, providing a lot of useful information about its determinants and predictors. Studies of the impact of life satisfaction on various health outcomes in an older population are few, although this issue is particularly important in old age when various deficits in health, functional capacity and social network accumulate. Although many studies have found other indicators of psychological well-being than life satisfaction to be highly related to lower risk for mortality in old age (Maier & Smith 1999, Ostir et al. 2000, Penninx et al.

2000b, Danner et al. 2001, Levy et al. 2002, Giltay et al. 2004, Pitkälä et al. 2004), no studies using validated measures of life satisfaction and mortality in older people were located.

Life satisfaction index Z (LSIZ) (Wood et al. 1969), a well-validated measure and designed especially for older people, was applied in study III. In order to study the factor structure of LSIZ and the mortality risk related to its different subscales, exploratory factor analysis was conducted. The analysis yielded three factors. The first factor was identified as Zest, and it represented satisfaction with present life and zest. The second factor was identified as Mood, and represented present life satisfaction and mood. The third factor, Congruence, represented past life satisfaction and congruence. This factor structure has earlier been found in Life satisfaction index A, which is the original, larger version of LSIZ (Adams 1969, Hoyt & Creech 1983, Liang 1984, Shmotkin 1991). From these three factors Zest and Mood, representing satisfaction with present life, were associated to mortality risk. The Congruence factor, representing satisfaction in past life and achieving personal goals, was not related to higher mortality.

It seems that old-old people perceive their satisfaction with the life they are now living as more important than issues that are usually considered important in younger age groups. There are similar findings in earlier study of the life-lines of older people by Takkinen and Suutama (2004). Socioemotional selectivity theorists also argue that when people perceive their time in life to be limited, futuristic goals become less relevant and present-oriented, emotional goals become more important (Carstensen et al. 1999, Cheng 2004).

Studies showing that optimistic attitude and feelings of hope are related to better survival in old age (e.g. Giltay et al. 2004), support our finding. Positive emotions may promote a more active social and physical lifestyle and also motivation toward self-care (Scheier & Carver 1992). Older people with better subjective well-being may also have better coping capabilities; optimists usually avoid strategies like denial and giving up (Segerström et al. 1998).

Social support and mortality

Earlier studies on social support and mortality have mostly focused on quantitative parts of social network (e.g. Avlund et al 1998). In study IV, perceived social support was measured with well-validated instrument, the Social Provision Scale (Weiss 1973, Russell et al. 1984, Cutrona & Russell 1987, Törmäkangas et al. 2003), which measures the kind of support a person gets from his or her social network.

Although there is much evidence of beneficial effects of social support on the health of older people, the different subscales and their association with mortality have not been studied earlier. Thus, the items of Weiss's Social Provision Scale were divided into two categories: assistance-related and non-assistance-related (Cutrona & Russell 1987). Perceptions of poor non-assistance-related perceived social support, consisting of reassurance of worth, emotional closeness, sense of belonging and opportunity for nurture, predicted mortality of older women. Assistance-related social support, consisting of guidance (advice or information) and reliable alliance (assurance that there are people who can be counted on in certain circumstances) was not related to survival in the women. This finding is in line with earlier studies showing that emotional social support is more important to the health of older people. In fact, there have been some studies showing that receipt of instrumental social support is unfavourable for health outcomes, probably because underlying poor health status that requires instrumental support; favorable effects have been mainly demonstrated for emotional support (Seeman et al. 1996, Penninx et al. 1997).

Identity theorists argue that being imbedded in a social network is protective because it gives the individual meaningful roles; these in turn generate self-esteem and a sense of purpose in life (Thoits 1983, Unchino 2004). Good social relationships also help older people to cope with different losses that ageing may bring alone (Akiyama & Akiyama 1991). The absence of close attachments and recognition of worth causes emotional loneliness and depressiveness (Heikkinen & Kauppinen 2004, Taylor & Lynch 2004). The feeling of being needed and valued is important; it gives one the strength to take care of oneself. Those who are alone and forgotten, despite formal support, are at a higher risk for death. Older women themselves also connect good social relationships with their experienced health (Lyyra & Heikkinen 2006).

Differences between age groups

In the final models of study I the significance of certain predictors of mortality varied between the middle-aged and older men: in the middle-aged group high serum total cholesterol predicted mortality. In the older age group the variables indicating poor physical strength and cognitive performance were associated with higher mortality, indicating that the predictors of mortality in older people are different from those predicting mortality in middle-aged people.

Low body mass index was associated with a higher mortality risk in the older age group. Consistently with the studies by Grabowski and Ellis (2001) and Landi et al. (1999) the result of this study suggested that a higher body mass index might be protective in older people. In study I body mass index in middle age was not related to mortality over an 18-year-follow-up. It is possible that longer follow-up would have produced a different result, as in the study by Yan et al. (2006), where the mean follow-up was 32 years; they found that those who were obese in middle age had a higher risk for hospitalization and mortality in older age than those who were normal weight.

A similar phenomenon was found regarding to serum total cholesterol. In study I, higher serum total cholesterol was associated with increased mortality in the middle-aged but not in older men. The results of several studies have shown either an inverse or no relation between total cholesterol and mortality in older people (Pijls et al. 1993, Krumholz et al. 1994, Chyou & Eaker 2000, Brescianini et al 2003). One explanation could be that the men at highest risk may already have died prior to the study. Some findings also suggest that between older and younger populations the cholesterol metabolism may differ

(Chyou & Eaker 2000). Menotti et al. (1998) have found that out of 11 powerful cardiovascular risk factors predicting mortality only five remained significant when measurements were done 10 years later for 50-year-old men, suggesting that their predictive power declines with advancing age. There is ongoing debate on the use of lipid-lowering drugs in older populations and obviously more randomised controlled trials are needed.

Differences between sexes

The pattern of the associations between physical functions and mortality was similar in both sexes (II). The only difference was found in vibration threshold, which was related to mortality in the 75-year-old women, but not in men. Higher vibration threshold has been found to associate with several chronic conditions, such as diabetes. Vibration threshold also correlated strongly with number of chronic diseases in the women in this sample.

A significant association between mortality and social support was found only in the 80-year-old women (IV). This is contradictory to the findings of earlier studies (House et al. 1982, Kaplan et al. 1988). Studies performed exclusively with older people have found that social support predict survival in both sexes (Jylhä & Aro 1989, Seeman et al. 1993). Men tend to maintain close, intimate relationships with only a few people, primarily with their spouses. Being married has been found to be more protective for men (Berkman & Syme 1979). In this study the majority of the men were married, whereas most of the women were widowed and lived alone. For the women living alone the quality of social relationships seems to be more important than it is for men who are married. Earlier studies have also shown that in women the social network and contacts increase after the death of a spouse (Barrett & Lynch 1999, Lennartsson 1999, Pinquart 2003). In men, the situation is the reverse: becoming widowed leads to a decrease in social contacts (van Grootheest et al. 1999).

Methodological issues

Longevity and mortality are central research questions in old age epidemiology. Length of life is the single indicator that may best condense information about population health. Mortality studies also give important information about the ageing process as well as the speed of ageing. When the time of death of the study subjects is known, it is possible with observational epidemiological studies to obtain information about potential harmful or beneficial factors and their mechanisms in relation to length of life.

Follow-up times in mortality studies can easily be extended to decades. For the individual researcher, it is seldom possible to be involved in a follow-up study for such a long time. Mortality studies with pre-existing databases provide numerous possibilities for study of the health of older people and facilitate the effective utilization of the pre-existing data. Finally most of databases can be used in mortality studies and new data continues to be available until the last participant in a study has died.

This series of studies sought to further improve our understanding of the predictors of mortality in old age. The use of established prospective multidisciplinary research data collected within well-known study projects with representative samples presented an ideal opportunity to study the physical, psychological and social predictors of mortality in old age on the multidisciplinary basis. The wide range of the study variables used also enabled the models to be adjusted widely by using objective measures of health and functioning.

In the study Functional capacity of men born in 1906-10, 1926-30 and 1946-50 the response rate to the basic questionnaire was good (82%), whereas the percentage of those who took part in laboratory examinations was lower (71%) (Heikkinen et al. 1984). The comparisons between respondents and non-respondents made on the basis of 6 items did not show significant differences between the groups (Heikkinen et al. 1984). In the Evergreen study, the participation rate was also high; the response rate to the basic questionnaire was 93% in the 75-year-old people and 92% in the 80-year-olds. The participation rate in the tests in the study centre was over 80% in the 75-year-olds and in 75% older age group. In the OCTO-Twin study, the percentage of those who participated in the first measurement occasion was about 65%. The samples were representative and the results can be generalized with older people in the Nordic countries.

In Jyväskylä, the home interviews and the examinations in the study centre were carried out by specially trained students of the University of Jyväskylä. Some of the personnel were also health care professionals, registered nurses and medical doctors. In the OCTO-Twin study trained research nurses did the interviews and the tests face-to-face in the participant's homes. Different nurses assessed each twin of a pair to minimize bias. The measurements used in this study have widely been used in previous studies.

A considerable advantage in the series of present studies was the absence of attrition in the study samples, which is usually a major problem in gerontological longitudinal studies. Those who died during the follow-up times were all included in the analyses. Times of death for all participants who died during follow up times were obtained from the Finnish Population Register Centre and the National Swedish Population Register. The quality of mortality studies depends on the quality of information on vital status, defined to mean whether the person is alive or dead. Because of the infrastructure of the Nordic societites, the data on dates of deaths were reliable and conclusive. The long follow-up times and mortality rates in the present samples were well suited for mortality reasearch.

In present series of studies, the association between covariates and mortality were studied by using the Cox regression model and its applications. The Cox regression model is a well-recognized statistical technique for exploring the relationships between the mortality of subjects and several explanatory variables. Also, some new statistical innovations were included in this study; principal component estimation in Cox regression model allowed the impact of several factors on mortality to be studied simultaneously without the problem of multicollinearity. By applying frailty Cox semiparametric modelling it was possible to take into account the dependence between twins and this allowed full utilization of all the available data on the twin pairs.

These studies also had limitations that deserve to be mentioned and taken into account in future research. The study samples were relatively small and the response rate to the life satisfaction questionnaire in study IV was low. Information about the severity of diseases was not available, and using only the number of chronic or serious diseases may not give enough information on the impact of a disease on the imminence of death. There may have been medical conditions at the baseline that were not diagnosed at the time. Indeed, chronic diseases have long preclinical phases that may change some endogenous factors like hormones or lipids, or exogenous factors like physical or social activity. This pattern of "reverse causation" may modify possible risk factors so that the relationship with mortality is inverse or neutral (Harris 2004).

The results might have been slightly different if we had analysed disease-related, accidental and suicidal deaths separately. However, we chose to use all-cause mortality as an end-point, partly because it would have been difficult to ascertain the exact causes of death for the older participants, as older people are likely to have multiple health conditions. Also, the percentage of autopsies in older people is low. Risk factors for, for example, suicidal deaths are quite similar with those in all-cause mortality. Most of the older people who commit suicide are depressed (Henriksson 1995) and have illnesses that cause functional limitation, pain and breathlessness (Conwell et al. 2000, Harwood et al. 2006). Also, bereavement and financial problems increase the risk of suicide in old age (Harwood et al. 2006).

Future research

Within the framework of the present series of studies it was not possible to look more closely at the mechanisms and pathways between risk factors and mortality. More work remains to be done on the links between risk factors and relevant health outcomes. For instance, investigating different coping strategies might be fruitful, especially in psychosocial factors. Potential biological pathways also deserve more attention. Utilization of the life-course approach would give more information about the development of risk factors on mortality during the lifespan. The study of impact of changes would give more information of the processes leading to death, for example, by including time-dependent covariates in the Cox regression modelling.

There are some statistical innovations in process. For instance, the use of discrete time-to-event modelling allows studying more closely the short- and long-term predictors of mortality (Leskinen & Lyyra 2005, Muthén & Masyn, 2005). The development of earlier mentioned discrete time-to-event analysis also opens up new possibilities to study genetic mechanisms along the pathway between risk factors and mortality within structural equation modelling -framework.

Practical implications

A deeper understanding of the predictors of mortality in old age enables identification of risk groups and the developing of programmes for preventive actions. The results of the present series of studies suggest that in addition to improving the physical capacity of older people, it is also essential to promote their psychosocial well-being in order to improve their quality of life and health as measured with the most comprehensive indicator of health, survival.

This study showed a strong association between good physical functions and survival in older people. Assessment methods concerning management of daily activities should be complemented with tests measuring physical and sensory functions and psychological well-being. Finding, for example, preclinical mobility difficulties are important in order to promote the physical capacity of the risk groups. There are a lot of intervention studies showing that physical capacity can be improved even in very old age. Various exercise programmes, including strength training, have produced good results. Individual counselling programmes have also given promising preliminary findings. However, models of good practice need further development. When implementing these actions, it is also important to take into account the autonomy and individual interests of an older person. Possibilities for participation in both physical and social activities should be available on a more equal basis both economically and regardless of the status of one´s functional capacity.

This study showed that psychosocial well-being is highly related to survival in old age. Interventions including psychosocial factors are rare, but there have been some promising attempts. A strong association was found between survival and perceived social support that consisted of feelings of worth, emotional closeness, belonging and opportunity for nurturance. This presents a challenge to find and develop new social innovations and interventions to promote perceptions of emotional social support in older people. It is important to make sure that older people have access to various kinds of social relations in which they can experience a sense of proximity and a sense of togetherness as well as respect. Feelings of worth in older people can be promoted both on the societal and individual level by according older people the value that they deserve.

TIIVISTELMÄ

Kuolleisuuden ennustetekijät iäkkäässä väestössä. Itsearvioidun terveyden, fyysisten toimintojen, elämään tyytyväisyyden ja sosiaalisen tuen yhteys iäkkäiden ihmisten eloonjäämiseen

Tämän tutkimuksen tarkoituksena oli selvittää, kuinka erilaiset fyysiset ja psykososiaaliset tekijät ovat yhteydessä iäkkäiden ihmisten kuolemanriskiin.

Tutkimuksen aineisto koostuu kolmen tutkimusprojektin yhteydessä kootusta tutkimustiedosta. Ikivihreät -projektin tavoitteena on kuvata ikääntymiseen liittyviä keskeisiä muutoksia sekä tunnistaa ikääntyvien ihmisten elinoloihin ja elämäntapoihin liittyviä tekijöitä, jotka ennustavat terveyden, hyvinvoinnin ja toimintakyvyn muutoksia. Tässä tutkimuksessa on mukana kaksi Ikivihreät -projektin tutkimusryhmää, alkumittauksessa vuosina 1989 ja 1990 mukana olleet 75- ja 80-vuotiaat jyväskyläläiset miehet ja naiset (n=650).

Vuosina 1906–1910, 1926–1930 ja 1956–1950 syntyneiden miesten toimintakykytutkimuksesta on mukana kaksi vanhinta ikäryhmää, joille alkumittaukset tehtiin vuonna 1981 heidän ollessaan 51–55 ja 71–75-vuotiaita (n=257).

OCTO-Twin -tutkimus koostuu ruotsalaisista, alkumittauksessa vuosina 1991–1994 80 vuotta ja sitä vanhemmista kaksosista, joista tähän tutkimukseen osallistui 320 miestä ja naista. Kuolleisuuden seuranta-ajat olivat 10–18 vuotta.

Tämä väitöskirjatutkimus koostuu neljästä osatutkimuksesta. Ensimmäisessä tarkasteltiin sitä, voidaanko huonon itsearvioidun terveyden ja kuolleisuuden välinen yhteys selittää erilaisilla objektiivisesti mitatuilla terveyden ja toimintakyvyn indikaattoreilla keski-ikäisillä ja vanhemmilla miehillä 10 ja 18 vuoden seurannassa. Tulokset osoittivat itsearvioidun terveyden ennustearvon säilyvän, kun fyysistä toimintakykyä kuvaavat mittaukset huomioidaan. Sen sijaan diagnosoitujen sairauksien lukumäärä selitti itsearvioidun terveyden ja kuolleisuuden välisen yhteyden.

Toisessa osatutkimuksessa tarkasteltiin sitä, miten erilaiset kliinisesti mitatut hengitystä, sensorisia ja psykomotorisia funktioita, antropometriaa, isometristä lihasvoimaa ja liikkumiskykyä kuvaavat tekijät ennustavat kuolleisuutta 75-vuotiailla miehillä ja naisilla kymmenen vuoden seuranta-ajalla. Tulokset osoittivat keuhkojen huonon vitaalikapasiteetin, hitaan käden liikenopeuden, korkean vibraatiotuntokynnyksen, heikon lihasvoiman ja hitaan kävelynopeuden lisäävän kuolemanriskiä samantasoisesti. Tilastollisesti merkitsevistä kuolleisuuden ennustajista muodostetun pääkomponentin alimpaan kolmannekseen kuuluvien kuolemanriski oli kolmesta neljään kertaan suurempi kuin parhaimpaan kolmannekseen kuuluvilla miehillä ja naisilla.

Kolmannessa osatutkimuksessa tarkastelun kohteena oli Life Satisfaction Index Z -mittarilla mitattujen elämään tyytyväisyyden osa-alueitten yhteydet kuolleisuuteen 80 -vuotiailla ja sitä vanhemmilla ruotsalaiskaksosilla 10 vuoden seuranta-ajalla. Konfirmatorisen faktorianalyysin avulla muodostettiin kolme elämääntyytyväisyyden faktoria: elämänhalu (Zest), mieliala (Mood) ja kongruenssi (Congruence). Elämänhalu ja mieliala -faktorit kuvaavat tyytyväisyyttä tämänhetkiseen elämään ja niissä alhaisia pisteitä saaneet olivat suuremmassa

kuolemanriskissä kuin parempia pisteitä saaneet iäkkäät miehet ja naiset. Yhteys säilyi merkitsevänä myös, kun fyysistä, psyykkistä ja sosiaalista toimintakykyä ja terveyttä kuvaavat tekijät huomioitiin. Sen sijaan kongruenssifaktori, joka kuvaa tyytyväisyyttä menneeseen elämään mittaamalla lähinnä sitä, onko henkilö saavuttanut elämässään asetetut tavoitteet, ei ollut yhteydessä lisääntyneeseen kuolemanriskiin.

Neljännessä osatutkimuksessa tutkittiin onko 80-vuotiailla jyväskyläläisillä alkumittauksessa arvioitu koettu sosiaalinen tuki yhteydessä kuolleisuuteen 10 vuoden seuranta-ajalla. Koetun sosiaalisen tuen mittarina käytettiin Social Provision -asteikkoa. Asteikon neljä osa-aluetta (koettu turvallisuudentunne, sosiaalinen integraatio, arvostuksen tunne ja sosiaalisen tuen antamismahdollisuus) muodostivat informaalista tukea kuvaavan faktorin. Loput kaksi osa-aluetta (kokemukset siitä, että on olemassa ihmisiä, joilta saa apua ja neuvoja ja siitä, että on olemassa ihmisiä joiden puoleen voi kääntyä hädän hetkellä) muodostivat formaalia sosiaalista tukea kuvaavan faktorin. Vähiten informaalista tukea kokeneilla naisilla oli lähes 2,5 -kertainen kuolemanriski verrattuna parhaimpaan kolmannekseen kuuluviin. Yhteys säilyi merkitsevänä myös kun sosiodemografiset tekijät, depressiivisyys, psykologiset ja fysiologiset toimintakyvyn indikaattorit sekä vakavat sairaudet huomioitiin. Formaaliin tukeen liittyvät tekijät eivät olleet yhteydessä naisten suurempaan kuolemanriskiin. Miehillä kumpikaan koetun sosiaalisen tuen muoto ei ollut merkitsevästi yhteydessä kuolemanriskiin.

Tämän tutkimuksen tulokset osoittavat, että fyysiseen toimintakykyyn liittyvien tekijöiden ohella myös psykososiaaliset tekijät, kuten elämään tyytyväisyys ja koettu sosiaalinen tuki ovat tärkeitä iäkkäiden ihmisten terveydelle, jopa mitattuna perustavaa laatua olevalla terveysmittarilla, eloonjäämisellä. Saadut tulokset mahdollistavat erilaisten riskiryhmien tunnistamisen edesauttaen näin terveyden ja toimintakyvyn heikkenemistä ennaltaehkäisevien toimien kehittämistä esimerkiksi erilaisten interventiotutkimusten avulla. Jatkossa tarvitaan lisätutkimusta siitä, millä tavoin todetut kuoleman riskitekijät ovat yhteydessä toisiinsa, sekä niistä mekanismeista, joilla edellä mainitut tekijät lisäävät kuolemanriskiä iäkkäässä väestössä.

Vaikka fyysisen toimintakyvyn ylläpitämisestä ja parantamisesta on saatu hyviä tuloksia erilaisissa interventiotutkimuksissa hyvinkin iäkkäillä ihmisillä, hyvän toiminnan malleja on vielä syytä kehittää. Tasavertaisen aktiivisen osallistumisen mahdollistaminen terveydentilaltaan heikompien tai huonommassa taloudellisessa tilanteessa olevien kohdalla on tärkeää.

Psykososiaalinen hyvinvointi on vahvasti yhteydessä iäkkäiden ihmisten eloonjäämiseen. Etenkin tyytyväisyys tämänhetkiseen elämään ja turvallisuuden ja arvostuksen tunteet olivat tärkeitä. Saatu löydös asettaa haasteita sellaisten uusien sosiaalisten innovaatioiden kehittämiselle, joiden avulla iäkkäät ihmiset voivat kokea yhteenkuuluvuuden ja tarpeelliseksi itsensä kokemisen tunteita. Sekä yhteiskunta että yksittäiset kansalaiset voivat osaltaan edesauttaa iäkkäiden ihmisten kokemusta ansaitsemastaan arvostuksen tunteesta.

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