Health Maintenance in Very Old Age

Medical Conditions, Functional Outcome and Nutritional Status

Huan-Ji Dong

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Every problem has a solution.

Contents

ABSTRACT

The overall aim of this thesis was to provide better understanding of the underlying factors related to health maintenance in very old people, with a focus on medical conditions, functional outcome and nutritional status. Data were gathered from the ELSA 85 project (Elderly in Linköping Screening Assessment). The ELSA 85 project was started in 2007 with a population-based survey of 85-year-old individuals (n = 650) residing in Linköping municipality, Sweden. During the study period from 2007 to 2010, we conducted surveys by postal questionnaire, home visits, geriatric clinic visits, and reviews of electronic medical records as well as the database of health service consumption. A series of cross-sectional analyses were performed on multimorbidity, health service consumption, activities of daily living (ADLs), physical functioning and nutritional status.

Of 650 eligible individuals, 496 (78% of those alive) completed the questionnaire (Paper I). Despite the prevalence of multimorbidity (68%) and frequent use of assistive technology for mobility (40%), the majority managed self-care (85%), usual activities (74%) and had high self-rated health (>60/100, visual analogue scale). Factors associated with in-patient care were an increased number of general practitioner visits, more use of assistive technology, community assistance, multimorbidity (≥2 chronic diseases) and/or heart failure and arrhythmia.

Cluster analyses (n = 496, Paper II) revealed five clusters: vascular, cardiopulmonary, cardiac (only for men), somatic–mental (only for men), mental disease (only for women), and three other clusters related to ageing (one for men and two for women). Heart failure in men (odds ratio [OR], 2.4; 95% confidence interval [CI], 1–5.7) and women (OR, 3; 95% CI, 1.3–6.9) as a single morbidity explained more variance than morbidity clusters in models of emergency room visits. Men's cardiac cluster (OR, 1.6; 95% CI, 1–2.7) and women's cardiopulmonary cluster (OR, 1.7; 95% CI, 1.2–2.4) were significantly associated with hospitalization. The combination of the cardiopulmonary cluster with the men's cardiac cluster (OR, 1.6; 95% CI, 1–2.4) and one of the women's ageing clusters (OR, 0.5; 95% CI, 0.3–0.8) showed interaction effects on hospitalization.

In Paper III, overweight (body mass index [BMI], 25–29.9 kg/m^2) and obese (BMI, ≥30 kg/m^2) individuals (n = 333) perceived more difficulty performing instrumental ADL (IADL) and had more comorbidities than their normal weight counterparts (BMI, 18.5–24.9 kg/m^2). After controlling for socio-demographic factors, obese but not overweight individuals were more likely to perceive increased difficulty in performing outdoor activities (OR, 2.1; 95% CI, 1.1–4) and cleaning (OR, 2.2; 95% CI, 1.2–4.2) than their normal weight counterparts. Although obesity was also associated with multimorbidity (OR, 3; 95% CI, 1.2–8), the health service cost of each case of multimorbidity (n = 251) was highest in individuals of normal weight and nearly three times as much as in obese individuals (ratio, 2.9; 95% CI, 1.1–8.1).

In Paper IV, 88-year-old obese women (n = 83) had greater absolute waist circumference, fat mass (FM) and fat-free mass (FFM), and lower handgrip strength (HS) corrected for FFM and HS-based ratios (HS/weight (Wt), HS/BMI, HS/FFM and HS/FM) than their normal

weight and overweight counterparts. After adjusting for physical activity levels and the number of chronic diseases, the HS-based ratios explained more variance in physical functioning in Short Form-36 (R^2, 0.52–0.54) than other single anthropometric or body composition parameters (R^2, 0.45–0.51). Waist circumference, HS, and two HS-based ratios (HS/Wt and HS/FFM) were also associated with the number of IADL with no difficulty.

In conclusion, the ELSA 85 population showed a fairly positive image of healthy perception, good functional ability as well as low use of health care among the majority of participants. Patterns of cardiac and pulmonary conditions were better associated than any single morbidity with hospitalization. Heart failure as a single morbidity was better associated than multimorbidity patterns with emergency room visits. For 85-year-olds, being obese, as opposed to overweight, was associated with self-reported activity limitations and comorbidities. Overweight elderly living in their own homes in this population had similar well-being to those of normal weight. In the cohort of 88-year-olds, obese women had high waist circumference, but their HS was relatively low in relation to their Wt and FFM. These parameters were better than BMI for predicting physical function and independent daily living.

Key words: very old, multimorbidity, health service use, physical function, activities of daily living, obesity, body composition

SAMMANFATTNING (SUMMARY IN SWEDISH)

Att åldras innebär inte bara en utveckling över tid utan också en förändring av människans fysiologi och funktion. Vi har många olika bilder av åldrandet. Ofta överväger de negativa bilderna som betonar sjuklighet och höga samhällskostnader för vård och omsorg. ELSA 85, en förkortning av the Elderly in Linköping Screening Assessment, påbörjades 2007 med avsikt att kartlägga 85-åringars hälsotillstånd och funktion. Syftet med denna avhandling var att fördjupa kunskapen om faktorer med betydelse för bevarande av hälsa hos dessa 85-åringar.

Populationsstudien genomfördes via enkätutskick (bl.a. livssituation, livskvalitet), hembesök (bl.a. aktiviteter i dagliga livet (ADL), kognitiva funktioner) och mottagningsbesök (bl.a. nutritionsstatus, rörelseförmåga, kroppslig undersökning, blodprover, läkemedel) under perioden mars 2007 till mars 2008. Vi kartlade även deltagarnas sjukvårdsbesök samt sjukvårdskostnader. Tre år senare, när individerna var 88 år, analyserades även kroppssammansättningen hos delar av populationen.

Totalt 496 Linköpingsbor födda 1922, deltog i studien. Andelen som svarade på enkäten var 78 % av alla då levande 85-åringar. Resultaten visar att majoriteten av 85-åringarna klarade att sköta sin hygien (85%) samt huvudsakliga aktiviteter (74%). Sextio procent skattade sin hälsorelaterade livskvalitet som hög trots förekomst av flera kroniska sjukdomar och frekvent användning av hjälpmedel för att förbättra rörligheten. Oberoende riskfaktorer för slutenvård var multipla besök hos distriktsläkare, användande av flera hjälpmedel, förekomst av minst två sjukdomar eller förekomst av hjärtsvikt och arytmi.

Multimorbiditet (förekomst av minst två kroniska sjukdomar) var vanligt hos 85-åringarna (68%). Olika kombinationer av sjukdomar hade varierande betydelse för behovet av sjukvård. I clusteranalys, där man försöker gruppera diagnoser med hög sannolikhet att förekomma hos en enskild individ, fann vi några cluster som var starkare relaterade till inläggning i slutenvård än andra. Clustren såg dessutom olika ut mellan män och kvinnor. För män var t.ex. kardiella och för kvinnor t.ex. hjärt-lung-cluster starkare relaterade till slutenvård än enskilda diagnoser.

Personer med fetma (body mass index (BMI) $\geq$30 kg/m^2) hade mer problem med rörlighet och instrumentell ADL (IADL) jämfört med de med normal- eller övervikt. Trots ett klart samband mellan fetma och multimorbiditet hade de normalviktiga individerna nästan tre gånger så höga hälso-sjukvårds kostnader som personer med fetma.

Bland 88-åriga kvinnor, hade personer med fetma högre bukomfång, mer fettmassa (FM) och mer fettfri massa (FFM) men lägre handstyrka (HS) än de normal- eller överviktiga. Relativ HS, handstyrka i form av kvoter (HS/Vikt, HS/BMI, HS/FFM and HS/FM) hade starkare samband med fysisk funktion (Short Form-36, SF-36$_{PF}$) än andra enskilda parametrar. Två enskilda parametrar (bukomfång och HS) samt HS/Vikt och HS/FFM var associerade med antal aktiviteter utan svårighet i IADL.

Sammanfattningsvis är 85-åringarna inte så skröpliga som de ofta beskrivs. Studien ELSA 85 visar en övervägande positiv bild med bevarad hälsa och funktion för en övervägande del av populationen. De flesta 85-åringarna klarar sig ganska bra trots förekomst av flera sjukdomar. Vissa mönster av multimorbiditet med hjärt- och lungsjukdomar är mer relaterade till slutenvård medan hjärtsvikt hade hög risk för akutmottagningsbesök. Därför är det viktigt att beakta en komplexitet av sjukdomar, inte bara enskilda diagnoser eller antalet diagnoser, i planeringen av den framtida vården. Personer med normal- eller övervikt klarar sin funktion bättre och lever mer självständigt än de som lider av fetma. Den betydande andelen feta med begränsad rörlighet och funktion bland äldre kan komma att påverka behovet av tyngre omsorgsinsatser för den gruppen och är således en varningssignal inför framtiden.

中文摘要 (SUMMARY IN CHINESE)

【目的】　　通过研究高龄老人的医疗情况，躯体功能和营养状态，提高对高龄老人健康维护相关因素的理解。

【方法】　　ELSA 85 项目（林雪平老年人普查，Elderly in Linköping Screening Assessment）是一个以瑞典林雪平城市中 85 岁高龄老人（1922 年出生，n＝650）为研究对象的人群研究。(1) 2007/03–2008/03：通过邮寄问卷，家庭访问及门诊检查的三个步骤，我们搜集的数据包括：个人和家庭的背景信息（居住情况，既往的学历和工作程度，健康相关的生活质量 EQ-5D 等），身体机能（日常生活活动能力 ADL 评定，移动性测试等）和营养状态（人体测量等）。我们同时还阅览了所有注册的电子病历和每位老年人的年卫生费用。（2）2010/06–2010/10: 在 3 年后的随访中，我们对所有 88 岁的女性老年人增加了人体组成测定和 SF-36 健康调查量表之生理功能子量表（SF-36$_{PF}$）的评估。

　　ELSA 85 项目还包括了其他医学检查项目以及为期一年的随访（2008–2009），但这些数据统计并未列入本论文中。

【结果】　　论文 1：共 496 人（参与率 78％）回寄并参与了问卷调查。总体而言，虽然慢性多病以及日常生活中频繁使用辅助身体移动的器具在 85 岁高龄老人中非常普遍，多数老年人仍然能够完成个人卫生自理和常规日常活动。他们在健康相关评价问卷中的评估自身健康状态多为良好 (EQ-5D 评估)。与住院相关的风险因素包括：全科医生的年就诊次数，有共患疾病（存在两种或两种以上的慢性病征），或者是心力衰竭和心律失常两个单病种。

　　论文 2：运用聚类分析和性别分层对共患疾病归类，生成男女组各五个集群：血管性类疾病集群，心肺疾病集群，心源性疾病集群（只存于男性组内），躯体-精神心理疾病集群（只存于男性组内），精神心理性疾病集群（只存于女性组内），以及三个和老化过程有关的集群（男性组内 1 组，女性组内 2 组）。心力衰竭（男性组内的比值比 OR＝2.4，95％ 的可信区间 CI＝1–5.7；女性组内 OR＝3，95% CI＝1.3–6.9) 作为单一病种在预测急诊就诊的模型中比任一共患疾病集群都能解释更多的变量值。男性组内的心源性疾病集群（OR＝1.6，95% CI＝1–2.7）和女性组内的心肺疾病集群（OR＝1.7，95% CI＝1.2–2.4）与预测是否住院显著有关。在住院模型中，心肺疾病集群与男性的心源性疾病集群（OR＝1.6，95% CI＝1–2.4），或与女性组内的老化相关集群（OR＝0.5，95% CI＝0.3–0.8）具有显著的交互作用。

　　论文 3：超重（体重指数 BMI：25–29.9 kg/m²）和肥胖（BMI ≥30 kg/m²）者在工具性日常生活活动评定（IADL）比正常体重者（BMI: 18.5–24.9 kg/m²）有更多的困难，再者也比正常体重者有更高伴发疾病的风险。但是在控制了混杂变量（社会人口因素）后，对照正常体重组，只有肥胖者而不是超重者的 IADL（户外活动：OR＝2.1，95% CI＝1.1–4；居室清洁：OR＝2.2，95% CI＝1.2–4.2）存在更大的困难。虽然肥胖与共患

疾病相关（OR= 3，95% CI=1.2–8），有患疾病的正常体重者的卫生服务消费却是共患疾病的肥胖者的近三倍（ratio= 2.9，95% CI= 1.1–8.1）。

论文 4：88 岁女性肥胖组相比正常体重和超重组而言，其腰围值、脂肪群值和祛脂肪群值较大。肥胖者的绝对握力值在校正祛脂肪群后以及握力比值（握力/体重，握力/BMI，握力/祛脂肪群，等等）都较其他两组低。在控制个体的体力活动程度和慢性疾病数量后，握力比值对生理功能（SF-36$_{PF}$）的解释度（R^2：0.52–0.54）高于任何单一人体测量指标或人体组成成分的测定值（R^2：0.45–0.51）。腰围值、绝对握力值及握力比值（握力/体重和握力/祛脂肪群）与 IADL 中无困难的活动项目数显著相关。

【结论】　ELSA 85 人群研究显示了一个相对健康的，个体功能良好的，且使用卫生服务较低的高龄老年群体。心源性和肺部疾病的共患与住院风险相关，而心力衰竭作为单一病种与急诊就诊有显著相关。对 85 岁高龄老人而言，肥胖（但不是超重）与个体的活动限制和伴发疾病有关。居住于自己住所内的超重高龄老人，其健康水平与正常体重者相近。在 88 岁女性高龄老人中，肥胖者有较大的腰围值和较低的握力比值（握力/体重和握力值/祛脂肪群）。这些指标比体重指数更好地反映了生理功能及高龄老人的日常独立生活能力。

LIST OF PUBLICATIONS

This thesis is based on the following papers referred to in the text by their respective roman numerals.

I.   Nägga K, Dong HJ, Marcusson J, Skoglund SO, Wressle E: **Health-related factors associated with hospitalization for old people: comparisons of elderly aged 85 in a population cohort study**. *Arch Gerontol Geriatr* 2012, **54**(2):391–397.

II.   Dong HJ, Wressle E, Marcusson J: **Multimorbidity patterns of and use of health services by Swedish 85-year-olds: an exploratory study**. *BMC Geriatr* 2013, **13**(1):120.

III.   Dong HJ, Unosson M, Wressle E, Marcusson J: **Health consequences associated with being overweight or obese: a Swedish population-based study of 85-year-olds**. *J Am Geriatr Soc* 2012, **60**(2):243–250.

IV.   Dong HJ, Marcusson J, Wressle E, Unosson M: **Obese very old women have low relative handgrip strength, poor physical function, and difficulty in daily living.** *Submitted*

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ABBREVIATIONS

ADL	activities of daily living
ANOVA	analysis of variance
BIA	bioelectrical impedance analyser
BMI	body mass index
CI	confidence interval
COPD	chronic obstructive pulmonary disease
ELSA 85	Elderly in Linköping Screening Assessment
ER	emergency room
FFM	fat-free mass
FFMI	fat-free mass index
FM	fat mass
FMI	fat mass index
GP	general practitioner
HRQoL	health-related quality of life
HS	handgrip strength
IADL	instrumental activities of daily living
IAM	Instrumental Activity Measure
OR	odds ratio
MAC	mid-arm circumference
MAMC	mid-arm muscle circumference
MMSE	Mini-Mental State Examination
OR	odds ratio
PADL	personal activities of daily living
SE	standard error
SEK	Swedish kronor
SES	socio-economic status
SF-36$_{PF}$	Short Form 36 Physical Functioning
TUG	Timed Up and Go
VAS	visual analogue scale
WC	waist circumference
Wt	weight
WHO	World Health Organization

INTRODUCTION

Reaching very old age

The population of very old people aged 85 years and older (in some contexts, very old refers to people aged 80 years and over) is increasing in many countries [1, 2]. The world's population aged 85 years and over is projected to increase 351% between 2010 and 2050, compared with 188% for the population aged 65 years and over and 22% for the population less than 65 years [1]. Sweden, ahead of most other countries, is still a forerunner for population ageing, especially the very old [3]. Based on data from Statistics Sweden, 2.7% of the whole population is aged 85 years or older and they account for 13.8% of all those aged more than 65 years of age [4].

Population ageing is no longer a new phenomenon. The progressive demographic of ageing is due to the older population. From a local perspective in Linköping, the fifth largest city in Sweden, people in the 65–84-year-old group today are expected to exponentially increase the number of very old people in the near future [5].

Ageing, health and health maintenance

Three aspects of the ageing process (chronological, physiological and functional changes) have been discussed in normal ageing [6]. These three aspects may not develop equally. The changes over time affect health status. Health is a complex concept. As early as in 1948, the World Health Organization (WHO) formulated the definition of health [7]:

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.

However, in the context of global ageing with chronic illnesses, this definition has been much criticized for its perfection. The emphasis of 'complete' disregards individuals' capacity and ability to adapt to cope autonomously with life changes [8]. More and more researchers suggest that health must include the abilities of adaption and coping instead of a status of perfection [8-11]. Health theories have also shifted, from the absence of disease and normality of biological function [12, 13] to a concern about individuals' own vital goals [11] as well as a two-dimensional description of ability and well-being [14]. For very old people, we measure medical conditions because they are closed related to the ageing process, but our research interest in health is not only about organic functions and disorders. Instead, we prefer the health concept proposed Huber et al [8]:

Health is the ability to adapt and to self manage in the face of social, physical, and emotional challenges.

As the number of very old people is constantly increasing, much attention has been paid to health trends and health maintenance in this age strata. Gerontologists have not found enough evidence that very old people can maintain their health as they did in younger old age. For many years, the health status of young olds has improved dramatically, but this does not seem to be the case for very old people. In the Swedish Panel Study of Living Conditions of the

Oldest Old (SWEOLD) study, health status among the very old did not improve over time (1992–2011) [15]. How we should measure health is not an easy question because health is multifactorial [16]. Several health indicators are involved in evaluations and comparisons. Many studies assess health based on living conditions using subjective perceptions with or without objective parameters [12, 17-21]. Many aspects are used to evaluate health maintenance in older adults; namely, lifestyle (smoking, physical activity, alcohol misuse and nutrition), specific diseases (cardiovascular diseases, diabetes, cancer, etc.), geriatric syndromes (cognitive impairment, falls, depression, urinary incontinence, visual and hearing impairment) and medication management [22]. An overview of ageing studies with a focus on health in very old people is summarized in Table 1.

Overall, the main research focus in these ageing studies indicate a comprehensive understanding of ageing, health and health maintenance of very old people. Numerous underlying factors of the ageing process that cause heterogeneity among individuals or groups deserve attention. Medical conditions (disease and health care), changes in function (ability and capacity) and lifestyle practices (nutrition, physical exercise habits, etc.) interact with each other to maintain health status as good as possible. Therefore, these aspects are of great interest in both the observation and study of how very old people maintain their health.

Multimorbidity

The coexistence of chronic diseases in the same individual is referred to as comorbidity and multimorbidity. Although the term multimorbidity is frequently used in a variety of research areas, consensus on its definition has not been reached. For different research and clinical purposes, the definition of multimorbidity generally addresses three aspects [23]:

- A calculation of the total number of diagnoses occurring concurrently in the same individual; this is mostly used in epidemiological studies [24];
- A cumulative indices/index evaluating concurrent diseases related to negative health outcomes; eg, the Charlson Comorbidity Index [25];
- A combination of both concurrent diseases and relevant health problems, such as symptoms, limitations in cognitive and physical function, and psychosocial problems; eg, the multimorbidity matrix developed by Akner [26].

All these definitions have both advantages and weaknesses. Researchers define multimorbidity according to their research interests. Many studies define multimorbidity using a cut-off point (≥2 diseases) and their results are easily compared. However, the disadvantage of this definition is that it does not reflect how the morbidities relate to each other. As reported by John et al. [27] and applied by Marengoni et al. [14] and Formiga et al. [15], some co-occurrences exceed a level expected by chance alone. Based on the common denominator of the concurrent diseases, multimorbidity may have to be explored in a more complex context to present certain specific diseases pairs/groups that co-occur more frequently than by chance in the same individual. In this thesis, we advocate two approaches to define multimorbidity, a cut-off point (≥2 diseases) of a selected number of chronic diagnoses and specific patterns of co-occurring diseases.

Table 1 A selection of recent population-based studies on the very old.

Study description and location	Study period	Samples	Main research focus
Swedish Panel Study of Living Conditions of the Oldest Old (SWEOLD)	1992–2011	≥77 years old N = 563, 621, 997, 1009 (1992, 2002, 2004, 2011)	Living conditions, mobility, health, ill-health and inequalities [28]
Umeå 85+	2000–present	85, 90 and 95 years old N = 319 (examined)	Physical and mental health, functional status [29]
The Swedish National Study on Aging and Care in Kungsholmen (SNAC-K), Stockholm	2001–2004	≥80 years old N = 980	Medical, physical, psychological, and social health [30]
The OCTO 2 Study, Jönköping	2008–present	84–90 years old N = 600 (planned)	Social, physiological, biological and immunological aspects (unpublished)
Danish 1905 Cohort Survey National sample, Denmark	1998	92 years old N = 1425	Physical and cognitive functioning [31]
Vitality 90+, Finland	1995–present	≥90years old N = 1283 (responded)	Biological ageing, predictors of health, functioning and longevity [32, 33]
Leiden 85-plus Study, The Netherlands	1986–present	≥85 years old N = 977, 599 (1986, 1997–1999)	Cognitive function, chronic diseases, atherosclerosis, disability, and well-being [34]
Newcastle 85+, United Kingdom	2006–2011	85 years old N = 851 (completed data)	Biological, clinical and psychosocial factors associated with healthy ageing [35, 36]
The Octabaix study, Spain	2009–present	85 years old N = 328 (examined)	Multimorbidity [37], mental health [38], nutritional status [39], physical and functional status [40, 41]
The Chinese Longitudinal Healthy Longevity Survey (CLHLS), China and United States	1998–2009	65–110 years old, N = 78 928 ≥80+, n = 20 743; ≥90+, n = 18 910; ≥100+, n = 14 290	Socio-demographics, survey-based health outcomes (function, self-rated health, etc.), care needs/costs, end-of-life care [42]
Lund 80+, Sweden; Reykjavik 80+, Iceland; Fredericton 80+, Canada; Klaipeda 80+, Lithuania	1988–, 1993–, 1998– and 2003–present	≥80 years old, n = 348 (Sweden in 2005); n = 151 (Iceland); n = 400 (Canada); n = 200 (Lithuania)	Psychological and social dimensions of life [43-46]

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Health service use and the Swedish health care system

Focusing on contextual and individual determinants facilitates understanding of service use. The Behavioural Model of Health Services Use (Andersen's model) assists in defining and measuring multiple dimensions of access to care [47, 48]. People's predisposition to avail of the health services depends on contextual and individual characteristics that enable or impede use of care. Demographic (age, gender) and social (education, environment, status) factors as well as health beliefs (knowledge, attitudes and values) have an impact on health behaviour and health care service use. Andersen's model appears frequently in studies on health service use. In an earlier interim report about the long-term trends affecting the health service in the United Kingdom, diseases, disability and dependency were found to result in high health care costs in older people [49]. Jakobsson et al. [50] found that psychosocial factors also have an impact on health care use among the elderly (aged 69–96 years). For very old people, not only the individuals' medical history and living conditions but also the specific contextual character within the health care system should be considered.

In Sweden, public resources are controlled by the state. Provisions for community services, assistive technology and health care are funded by taxes and are universally available according to individual needs [51]. The basis of the health care system is primary care. Linköping, the largest town in Östergötland County, has a university hospital and primary care and the hospital disciplines have shared patient records via an electronic system (Cosmic) since 2007. A referral from a GP is mandatory for patients to visit a specialist whenever specialized health care is required. Patients' fees vary across the county councils [52]. In Östergötland County, individuals pay 150 SEK ($23) for a visit to a general practitioner (GP), 300 SEK ($46) to access emergency care and up to 80 SEK ($12) per day for a hospital stay [53]. With a GP referral to an emergency room (ER), the charge is 150 SEK instead of 300 SEK. In practice, younger patients usually refer themselves to the ER; it is more common that older patients are referred after visiting their caregivers in primary care. Younger patients may also use private health services but the consumption of private health care is not common practice in very old people because private health insurance has not been widely taken up in this generation. To a great extent, the GP plays an important role in the further care of very old patients.

The increasing dependency on the health care system of older people has been demonstrated in earlier studies [54-58]. Hospital admission can change normal ageing due to adverse health outcomes after hospitalization, especially in terms of functional decline and mortality [59-62]. The goals of geriatric medicine involve reducing morbidity and mortality, preventing hospital admission/readmission, postponing institutionalization and enhancing health-related quality of life (HRQoL) [63]. In contrast to profession-reported conditions, HRQoL reflects the concept of health perceived by individuals.

Functional outcome

Given the high risk of being dependent in the late life period, the evaluation of functional status is always an important part of understanding the ageing process. Functional status refers to one's ability to handle daily life independently in relation to the environment. Numerous risk factors are related to decline in functional status [64]. Functional maintenance can be related to a healthy lifestyle [65, 66] and adverse functional outcome often occurs after an acute health event [61, 62]. It has also been shown that ageing has an effect on the risk of functional decline [67, 68]. For very old people, therefore, a lifelong accumulation of gradual changes in functional ability can be expected. Functional ability, as indicated by the capacity to perform a given activity, may limit an individual's actual performance in everyday life [69, 70]. In individuals of the same age (85 years), the variability in their functional ability and disability is heterogeneous. The scientific interest extends to the assessment of physical and cognitive function, in which activities of daily living (ADL), mobility and cognitive performance are evaluated [71]. Function is also one of the most important roles in the HRQoL dimension, which also includes subjective mental and general health perception [72, 73].

There is no agreement on the optimal instruments because none are fully satisfactory [71, 74]. Several alternative tools have been used in both clinical practice and screening for everyday life in the community (Table 2). Taking into account age and expected functional capacity of very old people as well as culture-specific characteristics, researchers also modify the tools for global assessments to facilitate the assessment [29, 75-78].

Table 2 Some instruments of functional assessment used in ageing research.

Measurement domain	Instruments
Personal ADL (PADL)	Barthel index [29, 79, 80], Katz' ADL index [29, 31, 75], Groningen Activity Restriction Scale [81]
Instrumental ADL (IADL)	Staircase of ADL [29], Lawton IADL[77, 80], Groningen Activity Restriction Scale [81], Functional Independence Measure (FIM) [82], and Instrumental Activity Measure (IAM) [82]
Mobility (lower extremity)	Walking speed, Rising from a chair and One leg standing test [30], Chair stands test [29], Timed Up and Go (TUG) test [35], and Bergs Balance Scale [29]
Muscle strength (upper extremity)	Handgrip strength [35, 76, 83-85]
Cognitive function	Mini-Mental State Examination (MMSE) [29, 41, 75, 86], Computerized Assessment of Memory and Attention (CDR battery) [87]
Function profile in HRQoL	Short Form-36 (SF-36) [29, 88], EQ-5D [89, 90]

Nutritional status

Risk of malnutrition, usually referring to undernutrition, is associated with ageing [91]. Undernutrition is of interest because it is always related to frailty, diseases, hospital admission, disability and mortality. However, over the years, the number of overweight and obese older adults has increased progressively. Research has also gradually shifted from undernutrition to cover a broader range. In recent years, overnutrition has become a serious concern as a result of the increasing prevalence of overweight and obesity in the ageing population [92-94].

Being overweight or obese is related to negative health consequences because body weight influences health outcomes [95]. The associations between being overweight or obese and different aspects of health, such as disease burden [96, 97], functional limitations [98], poorer HRQoL [99], and higher consumption of health services [100, 101], have been widely studied. However, many of these studies rely on data from younger elderly or mixed age groups. Knowledge on overweight or obesity among the very old is incomplete. Unlike younger adults, controversy exists about the harmful aspects of being overweight or obese among older people [92]. Although compared with normal weight individuals lower mortality in overweight to moderately obese people has been demonstrated in a number of studies [92, 102-106], the adverse effects of comorbidity cannot be disregarded. Very old people are often considered as survivors over a long life course. Whether these negative effects are strengthened, weakened or diminished over the years is unclear.

Body mass index (BMI) is the most common measurement used to categorize individuals as being of normal weight, overweight or obese. The current WHO guidelines suggest using the same cut-off values for BMI in adults regardless of age and ethnicity [107]. Alternative modifications of the cut-off values have been reported and applied [79, 108, 109]. BMI is a good proxy for body fatness, but a disadvantage is that it does not distinguish between the components of body composition/compartments or reflect which part has negative effects. Estimates of body composition is another approach to explore health consequences, such as physical function and independent daily living, that may be accounted for by nutritional status.

The relationship between obesity, muscle strength, and functional limitations has been widely studied in older adults [85, 110-114], but less attention has specifically focused on people aged 85 years and older. Among the young old, adiposity or fat mass (FM) plays an important role in physical function [114, 115], and fat-free mass (FFM) is associated with muscle strength [116-118]. Reduction in muscle strength, affected by chronic morbidities and levels of physical activity, is a major predictor of physical disability [119]. Several methods have been used to determine muscle strength because the relationships are complicated and multiple factors are involved. After adjusting for age (69 ± 7 years), Jankowski et al. [115] found that adiposity (fat mass index [FMI]) was a strong predictor of physical function for community-dwelling older adults. Hulens et al. [116] used allometric modelling to measure muscle strength corrected for FFM and observed that obese women (aged 39.9 ± 11.4 years) had lower handgrip strength (HS) than lean counterparts when the effect of FFM was removed. Moreover, Choquette et al. [120] reported that the ratio of HS to BMI could determine mobility impairment for people aged 67−84 years.

RATIONALE FOR THE THESIS

The geographic and policy variations as well as heterogeneity of people in the very old age group affect the generalization of results from different studies. Even within Sweden, local variation regarding demographic factors and local control of formal service (or public service) is not negligible [3]. Therefore, to gain a good understanding of health and health maintenance, we selected the local 85-year-old age group as our cohort of very old people.

In a pilot study (unpublished) of health care service use, we found that contact with care givers, hospital care, emergency calls, etc. peaked between the ages of 80 and 89 years in the municipality of Linköping. This phenomenon is also supported by national and other regional reports [121-124]. We have conducted a comprehensive assessment of medical conditions, functional outcomes and nutritional status because these aspects interact with each other and are closely related to health maintenance. We were also motivated by the relatively scarce knowledge in this research area. First, knowledge of how living conditions are associated with health service use among very old people is lacking. These factors deserve to be addressed to present a full picture of the users of health services. Second, multimorbidity is a complex challenge when we study its impact on health service use. Third, a gender paradox has been mentioned in other ageing research whereby women have a longevity advantage over men despite more diseases and functional impairments [125-128], therefore a gender perspective needs to be included in the study design, analysis and further generalization of the conclusions. This study provides informative results from the ELSA 85 project (Elderly in Linköping Screening Assessment) that can be used as a reference point in future studies.

AIMS

The overall aim was to gain knowledge of the underlying factors related to health maintenance in 85- and 88-year-old individuals, with a focus on medical conditions, functional outcome and nutritional status.

Specific aims:

- Paper I: To characterize 85-year-old people's living conditions and actual health care use and determine the associated factors that affect hospital admission.

- Paper II: To determine patterns of multimorbidity associated with ER visits and hospitalization in an 85-year-old population.

- Paper III: To determine whether being overweight or being obese is associated with significant health outcomes in 85-year-old people.

- Paper IV: To investigate how anthropometric and body composition variables and handgrip strength affect physical function and independent daily living in 88-year-old Swedish women.

METHODS

Design

ELSA 85 is a prospective, population-based project of 85-year-old individuals residing in Linköping municipality, Sweden. Linköping, located in southern central Sweden, is the fifth largest city in Sweden with a population of 146 416 in 2010 (139 474 in 2007) [4]. More than 16% of the residents are aged 65 years or more and the number of residents aged 85 years and older (3775 in 2010) is expected double by 2030 [5].

The cohort for the ELSA 85 project was based on the local authority register for individuals born in 1922 who were living in Linköping municipality in 2007 (n = 650). The timeline of data collection (Figure 1) was divided into three steps. We started with a postal questionnaire (Step 1) in March 2007, followed up by a home visit or clinic visit (Step 2) for more detailed assessment. These two steps took approximately 1 year. In addition, the ELSA 85 project also included a 1-year follow-up completed between March 2008 and March 2009, but this stage is not included in the current thesis. Three years after the baseline investigation, we invited all eligible 88-year-old women for body composition measurement between June and October 2010 (Step 3).

Participants

A flow chart of participation in the study is presented in Figure 1.

Step 1 (Papers I and II): 90% (n = 586) of the total cohort (n = 650) replied to the invitation to participate in the study. Written informed consent was obtained from 496 individuals (78% of those alive) who also answered the postal questionnaire. There were 154 non-participants. Of these, 90 declined participation, 12 had died before the start of the study and a further 52 did not respond to the letter of invitation even after the reminder.

Step 2 (Paper III): of the individuals who completed the questionnaire, 77% (380 of 496) received a home visit. Of the individuals who participated in the home visit, 89% (338 of 380) visited the geriatric clinic.

Step 3 (Paper IV): due to gender heterogeneity in the nutrition assessment and a lack of eligible men with obesity (n = 4), we only investigated all eligible women. The exclusion criteria were as follows: score of MMSE ≤20 in previous data register; a history of any replacement arthroplasty or use of an artificial pacemaker; or a diagnosis of pathological oedema or lymphoedema. A total of 83 women (normal weight, 30; overweight, 29; and obese, 24) participated. Lack of interest, tiredness, and health reasons (e.g. illness) were the most common reasons for withdrawal (normal weight, 13; overweight, 15).

| Postal questionnaire |
| n = 650 |

| Responders | Non-responders | Ad mortem |
| n = 586 | n = 52 | n = 12 |

| **Questionnaires answered** | Declined |
| **n = 496 (Papers I and II)** | n = 90 |

| Home visit | Declined | Ad mortem |
| n = 380 | n = 107 | n = 9 |

| **Geriatric clinic visit** | Declined | Ad mortem |
| **n = 338 (Paper III)** | n = 38 | n = 4 |

| Male gender | Declined | Withdrawn | Ad mortem or lost contact | Excluded due to medical reasons |
| n = 144 | n = 34 | n = 28 | n = 22 | n=27 |

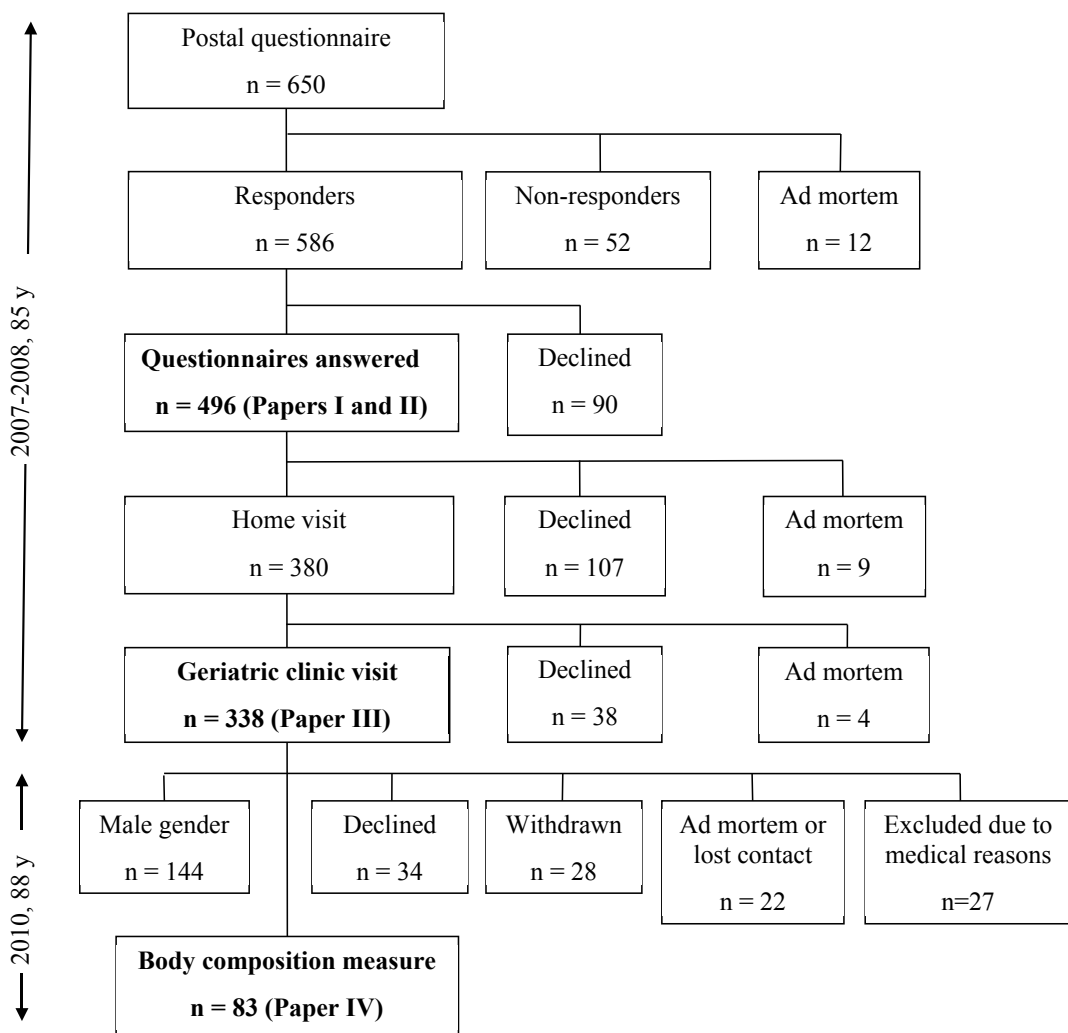| **Body composition measure** |
| **n = 83 (Paper IV)** |

2007-2008, 85 y

2010, 88 y

Figure 1 Flow chart of participation in the ELSA 85 study.

Assessments of health-related factors

Background characteristics

The postal questionnaire (Papers I, II, III and IV) included items on demographics; social network including contact with relatives (living nearby or not), friends (living nearby or not) and neighbours (close contact or not); need for community assistance, transportation service or personal alarm; assistive technology use; presence of visual or hearing impairment (yes/no); physical exercise habits (regular or not); and presence of insomnia (yes/no). Two questions concerned the presence of feelings of loneliness and worries about the future (including influencing factors), both with the same response alternatives (very often, sometimes, seldom

18

and never). These were followed by questions on medical history and current use of prescribed drugs. Socio-economic status (SES) referred to working status measured by previous occupation with the categories low (blue collar), intermediate (white collar) and high (self-employed or academic profession) [129].

Medical conditions

Morbidity and multimorbidity (Papers I, II and III) were assessed from the patients' medical records, which are part of the electronic medical reporting system of the County Council of Östergötland, which contains all health care records (both in-patient and outpatient data) for all citizens of Linköping and the County of Östergötland. Details of medical history before 2007 were available in paper medical records kept at the central hospital archives of Linköping University Hospital. The 10th version of the International Classification of Diseases (ICD-10) was used [130]. The presence of chronic disease was then registered if the disease fulfilled one or more of three criteria: the disease was permanently present, the disease was caused by an irreversible pathological condition, and treatment for the disease required rehabilitation or a long period of care. A predetermined list of disease categories was devised: cardiovascular disease, cerebrovascular disease, respiratory disease, musculoskeletal disease, mental disease, neurological disease, digestive disorders, urological disorders, endocrine disease, haematological disorders, autoimmune disease, infection, skin changes and malignancy (solid and blood). Multimorbidity was defined as the presence of two or more chronic diseases.

Data on health care use (Papers I, II and III) were collected over the preceding 12 months for each individual. Details on hospital care included data on the number of open-clinic visits to specialist care, the number and duration of in-patient care episodes (hospitalization) and frequency of visits to the emergency department (ER visit). Primary care data included the number of visits to a primary care centre, categorized into visits to a GP, nurse, occupational therapist or physiotherapist. These visits were also categorized according to location (primary care centre or home visits).

Health care costs (Paper III) were categorized into medication costs and costs for biochemical tests, radiology examinations, and physician consultations. Patients with multimorbidity consumed relatively more health services, so we analysed the medical costs for the elderly who exhibited multimorbidity.

Functional outcome

ADLs (Papers III and IV) included personal activities of daily living (PADL) and instrumental activities of daily living (IADL). PADL consisted of four basic personal-care functions: bathing or showering, dressing and undressing, toileting, and eating. Each category was scored as 0 (managed without help), 1 (needs some help), or 2 (needs much help). IADL was examined using the Instrumental Activity Measure (IAM). A four-level ordinal scale was used to assess perceived difficulty (none, little, great, or impossible) in performing eight activities: mobility outdoors, preparing simple meals, cooking, using public transportation, small-scale shopping, large-scale shopping, cleaning (e.g. making a bed, daily tidying up,

vacuuming, etc.), and washing (various tasks for managing laundry) [131]. Good construct validity has been reported in a previous study [82, 131]. Good reliability was demonstrated in our study population (Cronbach's alpha of 0.89 in Paper III and 0.91 in Paper IV).

The Timed Up and Go (TUG) test (Paper III) times how long it takes a person to stand up from an armchair, walk 3 metres, walk back to the chair, and sit down [132]. If accomplishing this task requires more than 14 seconds, a person is at a high risk for falls.

HS (Paper IV) of the dominant hand was measured using an electronic grip force instrument, the Grippit (AB Detektor, Sweden) [133]. Seated comfortably, the participants were required to grip a handle with maximal voluntary effort for 10 seconds and the peak value was recorded. The best value of three trials was taken as the score for maximal voluntary strength. Participants performed the test at 1- to 2-minute intervals and verbal encouragement was given between each trial.

The MMSE (Paper IV) was developed to assess cognitive capacity under clinical conditions [134]. It assesses orientation to time and place, attention, memory, and language and visual construction. The MMSE has a maximum of 30 points and a higher score indicates better cognition. It is known that MMSE varies by age and education [135]. We therefore used a cut-off score of 21 ($\geq$21) as an inclusion criterion in Paper IV according to the population-based norms of MMSE for individuals aged 85 years and over with the lowest education level [135].

The EQ-5D (Papers I, II and III) is a generic instrument that assesses HRQoL in terms of mobility, self-care, usual activities, pain/discomfort and anxiety/depression [136, 137]. Response alternatives were no problems, moderate problems or extreme problems. A visual analogue scale (VAS) was used to record the individual's self-rated health, ranging from 0 (worst imaginable health status) to 100 (best imaginable health status) [138]. The estimate of reliability using the Cronbach's alpha was 0.72, indicating good internal consistency.

The Short Form-36 physical functioning (SF-36$_{PF}$) (Paper IV) is part of the SF-36 Health Survey, one of the most widely used and internationally validated instruments [139]. The assessment is available for clinical practice and in a general population. The physical functioning subscale of SF-36 assesses limitations in physical activities because of health problems (SF-36$_{PF}$) [139]. This subscale consists of 10 items, measuring limitations in vigorous activities, moderate activities, carrying groceries, climbing one stair or several stairs, bending/kneeling, walking 100 metres, 0.5 kilometre or more than 1 kilometre, and self-care. An ordinal 3-point scale (severe limitations, some limitations, no limitations) was given for each item. The scores were summed and transformed into a scale score ranging from 0 (worst score) to 100 (best score). Higher scores (range, 0–100) indicate better physical functioning [139, 140]. Good reliability was demonstrated with a Cronbach's alpha of 0.88.

Nutritional status

Anthropometry measurements (Papers III and IV) included weight (Wt) and height (Ht), measured with subjects lightly clothed and shoeless using an electronic scale and measuring

tape, respectively. Body mass index (BMI) was calculated (Wt [kg]/Ht [m^2]) and classified according to the criteria developed by the WHO [107]: <18.5 kg/m^2, underweight; 18.5–24.9 kg/m^2, normal range; 25.0–29.9 kg/m^2, overweight; and ≥30.0 kg/m^2, obesity. Mid-arm circumference (MAC) and waist circumference (WC) were measured using a flexible non-elastic measuring tape. Tricep skinfold (TSF) thickness was measured vertically on the posterior mid-point between the acromion process and the tip of the olecranon while the arm was relaxed with the forearm in supination. Mid-arm muscle circumference (MAMC) was calculated using the formula MAMC = MAC (cm) − π × TSF (cm).

Body composition (Paper IV) was measured by a bioelectrical impedance analyser (BIA-103, RJL systems, Detroit, MI) using a low-intensity current (800 μA) with a frequency of 50 kHz applied between the right wrist and foot ankle in the supine position [141]. The BIA estimates total body water, FM, and FFM by measuring the reactance and resistance of the body. The fat-free mass index (FFMI) and FMI are height-normalized indices (kg/m^2). To ensure precise measurements, certain conventions were followed: no eating or drinking for 3–4 hours before the test; no type of physical activity in the previous 12 hours; emptying bladder before the test; no consumption of alcohol for the previous 2 days; and no use of medication that affects body water (e.g. diuretics).

Ratios of HS (Paper IV) to parameters of body measurements included kg adjusted HS/Wt, HS/FFM and HS/FM, and kg/m^2 adjusted HS/BMI [120]. HS corrected for FFM was calculated using an allometric model: a × FFM^b [116, 142]. The exponent b was generated from log-linear regression for normal weight, overweight, and obesity groups. The values of HS corrected for FFM were then derived from the corresponding equations for participants according to their BMI.

Procedure

Two months after the participants 85th birthday (between March 2007 and March 2008), they received a postal questionnaire and an invitation letter to participate at the beginning of every month. The letter contained information about the study and the option to participate in each phase (postal questionnaire, home visit, and geriatric clinic visit). A questionnaire on socio-demographics, EQ-5D, assistance use, and questions about chronic diseases was used as an initial approach to the target population. If the individuals had limited autonomy, such as mental incapacity or physical limitations, their close relatives could act as their proxy, accepting the invitation and helping to complete the questionnaire.

After the participants consented to the next stage of the study, ADLs and MMSE were evaluated during a home visit. Records of medication prescriptions, anthropometry and assessment of functional mobility were completed at the geriatric clinic visit. Other investigations, such as the Downton Fall Risk Index and Geriatric Depression Scale during the home visit, and physical examination and a series of laboratory tests during the clinic visit, were also included in the ELSA 85 project (data not reported in this thesis).

Patients' case reports were reviewed by our research team: a research nurse collected medical histories from the electronic documents and a doctor completed the data registration by reviewing the records written in patients' case reports. Medical history before 2007 was also checked in paper medical records kept for all individuals at the central hospital archives of Linköping University Hospital. The results of the physical examination and laboratory tests conducted during the clinic visit were included in the latest medical documentation. The research team compared the documentation in the medical records with the self-reported information in terms of diseases and drug treatments. The self-reported information was the response to two separate questions in the postal questionnaire on chronic and acute medical conditions/diseases. All diseases/conditions indicated were noted for each patient. A disease or condition was only registered if there was clear documentation of the disease and its treatment, regardless of the patients' self-reports. Health service consumption data were retrieved from the local health care register.

In 2010, 3 years after the baseline investigation, we paid a home visit to 88-year-old women to measure anthropometry, handgrip and body composition. Meanwhile, we also completed evaluation of SF-36$_{PF}$ and ADLs.

Statistical analysis

An overview of the statistical methods used is summarized in Table 3. A p value of <0.05 was considered statistically significant. In Papers III and IV, a reduced p value <0.017 was used for the Mann–Whitney U test, which served as a post hoc test for the Kruskal–Wallis test to control for the risk of mass significance [143]. All analyses were accomplished using the software PASW (IBM SPSS Statistics, Chicago, IL), version 18.0 or higher.

For Paper I, the use or non-use of in-patient care during the preceding 12 months, as well as health service use, was selected as the basis for comparisons between variables. Multivariate logistic analyses (stepwise, likelihood ratio forward measure) were performed to identify possible predictors of in-patient care. The choice of potential explanatory variables entered in the model was based on a lax criterion with a p value <0.2 in univariate analyses [143]. Model 1 was applied to predict the possible influence of multimorbidity as an independent variable. In model 2, specific diagnosed diseases were selected as independent variables in a stepwise analysis. Our sample size was regarded as suitable according to the rule of thumb that the number of observations should be at least 10 times the number of independent variables [143, 144].

For Paper II, effect size was calculated using Cohen's d for the Student t test, rank-biserial correlation coefficient r (r_{rb}) for the Mann–Whitney U test and Cramér's phi (φ) or Cramér's V (φ_c) for the Pearson chi-squared test. A hierarchical cluster dendrogram was generated using Yule's Q as the similarity measure between clusters, with a higher value indicating greater similarity measurement. Yule's Q correlation matrix was calculated as a transformation of the odds ratio (OR) between two variables from (0 to infinity) to (–1 to +1): $Q = (OR – 1)/(1 + OR)$ [145, 146]. We chose the average linkage between groups for the agglomeration because this method takes into account the cluster structure and is relatively robust [147].

Table 3 Overview of statistical methods in Papers I−IV.

	Paper I	Paper II	Paper III	Paper IV
Descriptive data				
Number (%)	X	X	X	X
Mean ± SD	X	X	X	X
Median (q1-q3)	X	X	X	X
Geometric means (95% CI)			X	
Parametric test				
Student t test	X	X		
One-way ANOVA			X	X
Pearson's correlation analysis			X	
Effect size calculation		X		X
Non-parametric test				
χ2 test or Fisher exact test	X	X	X	X
Mann−Whitney U test	X	X		
Kruskal–Wallis test			X	X
Effect size calculation		X		X
Analysis for classification				
Cluster analysis		X		
Regression analysis				
Multiple linear regression				X
Binary logistic regression	X	X	X	
Ordinal logistic regression			X	

SD, standard deviation; q1-q3, lower quartile-upper quartile; CI, confidence interval.

To determine predictors of an ER visit or hospitalization, logistic regression was performed by a forward stepwise method (using a likelihood ratio, with entrance/exit tolerances of 0.05/0.10). Model 1 used all single morbidities as candidate variables. Model 2 substituted cluster scores for single morbidities. Interaction of morbidity clusters was included in model 3. According to John et al. [27], the effects of multimorbidity patterns are evaluated in the form of cluster scores (a count of all morbidities in one cluster) and their interactions (multiplication of two cluster scores to determine if the clusters' effects are dependent on each other). Other candidate variables such as socio-demographic factors, individuals' needs, self-rated health, and the number of visits to a GP were included for model fitting. Collinearity and correlation were analysed before model fitting. Marital status and living situations were not included concurrently in the analysis owing to high collinearity ($r > 0.6$). The Nagelkerke R^2 (Cox and Snell R^2 adjusted, range 0–1) was used to estimate the amount of variance in the outcomes explained by the predictors [148].

For Paper III, the health service cost (Swedish crown) was normalized by log transformation before analysis and is reported as geometric means with 95% confidence intervals (CI). Pearson's correlation was performed between BMI as a continuous variable and the time required to perform the TUG test. Ordinal or binary logistic regression examined the

contributions of BMI (categorical and continuous) with IADL (a 4-level ordinal scale of perception of increased difficulty: none, little, great, and impossible) and comorbidity (1, disease; 0, no disease). These associations were adjusted for socio-demographic factors (gender, co-residence, type of housing, education level, and SES) and presented as ORs and 95% CIs. Marital status was excluded due to its high collinearity and correlation with co-residence.

For Paper IV, effect size was established using $\eta 2$ for one-way analysis of variance (ANOVA) and the Kruskal–Wallis test, where >0.06 is a medium effect and >0.14 is a large effect [149]. For Pearson's chi-squared test, effect size was calculated using Cramer's V (φc) where the medium effect is >0.3. Linear regression analyses were used to estimate the effects of each parameter of body measurement and HS on physical function (score for SF-36PF) and independence (number of IADL with no difficulty). The parameters and HS were examined as a single predictor or as a ratio of HS to one parameter. Model fit was assessed by examining the distribution of the standardized residuals. Normality of the residuals was evaluated using the Shapiro–Wilk test in combination with visualized Q-Q plots.

ETHICAL CONSIDERATIONS

All participants were informed that taking part in the project was voluntary and participation could be terminated at any time. Written informed consent was obtained from all participants before participation. Ethical approval was obtained from the Regional Research Committee in Linköping, Dnr 141-06 (Paper I-III) and Dnr M183-09 (Paper IV).

RESULTS

Characteristics of participants

Papers I and II (n = 496)

A total of 496 individuals (189 men and 307 women, 76%) completed the questionnaire. The majority had primary school education (70%) and low-intermediate (94%) occupational status. More women than men were living by themselves, had lower education and working status. Despite the statistical significance, the differences correspond to a small effect size (Table 4).

Table 4 Socio-demographic characteristics of the participants.

Characteristics	Total N = 496	Men n = 189	Women n = 307	p value	Effect size, φ or φ_c
Type of housing, n (%)				0.079	0.079
Ordinary housing	441 (89)	174 (92)	267 (87)		
Sheltered accommodation/ nursing home	55 (11)	15 (8)	40 (13)		
Marital status, n (%)				<0.001	0.34
Married/cohabiting	266 (54)	142 (75)	124 (40)		
Widowed/divorced/ unmarried	230 (46)	47 (25)	183 (60)		
Living situation, n (%)				<0.001	−0.35
Alone	288 (58)	68 (36)	220 (72)		
With others	208 (42)	121 (64)	87 (28)		
Level of education[a], n (%)				<0.001	−0.18
≤7 years	285 (57)	97 (52)	188 (64)		
>7 years	195 (39)	89 (48)	106 (36)		
Working status[b], n (%)				0.004	−0.15
Low (blue collar)	255 (51)	81 (44)	174 (59)		
Intermediate (white collar)	188 (38)	85 (46)	103 (35)		
High (self-employed or academic profession)	33 (7)	17 (9)	16 (6)		

χ^2 test; φ: Cramér's phi, φ_c: Cramér's V.
[a]Missing data for 16 participants. [b]Missing data for 20 participants.

The most frequently used assistive technology (a walker) was related to improving mobility (40%). Food delivery was the only item of assistance reported by few elderly (7%). Over 70% individuals had regular physical exercise. Self-rated health showed that 60% of the participants estimated their health at >60/100 (VAS), indicating good health in general. Men

(69 ± 19) were more positive than women (65 ± 20, $p = 0.018$, Cohen's d = 0.21). Two aspects in EQ-5D, mobility (50%) and pain/discomfort (67%), were perceived to be moderate-severe problem by most participants (Figure 2).
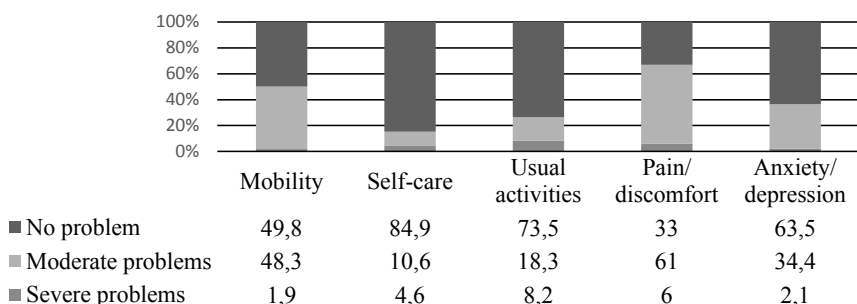

	Mobility	Self-care	Usual activities	Pain/ discomfort	Anxiety/ depression
■ No problem	49,8	84,9	73,5	33	63,5
▨ Moderate problems	48,3	10,6	18,3	61	34,4
■ Severe problems	1,9	4,6	8,2	6	2,1

Figure 2 HRQoL measured in the EQ-5D dimensions (%).

Eighty-five percent of the population had one or several diagnoses of chronic diseases (median, 3; range, 0–10), the most common being related to the cardiovascular system: hypertension (50%), hyperlipidemia (22%) and heart failure (15%) (Table 5). During the observation year, more than three-quarters of the elderly had visited a GP (77%), but less than one-third had visited an ER (30%) or been hospitalized (25%) for in-patient care (hospitalization).

Paper III (n = 338)

The mean BMI was 26 ±4.0 kg/m^2. Men had a lower mean BMI (24.9 ± 4.6 kg/m^2) than women (26.8 ± 2.7 kg/m^2) ($p < 0.001$). Nearly half of the participants were overweight (156 of 338, 46%) and approximately one-fifth were obese (58 of 338, 17%). A total of 48% (69 of 144) of men and 45% (87 of 194) of women were overweight, and 8% (11 of 144) of men and 24% (47 of 194) of women were obese. Only five participants (5 of 338, 1.5%) were underweight.

Paper IV (n = 83)

The obese group had greater absolute values of FM and FFM. No difference between groups of different BMI categories was evident in physical activity levels, the number of diagnosed chronic diseases, and absolute HS ($p > 0.05$), whereas the lowest ratios of HS to each parameter and HS correcting for FFM were weakest in obese women compared with those in the normal weight and overweight groups ($\eta^2 = 0.134$).

Table 5 Prevalence of morbidity grouped according to ICD-10 classification (n, %).

Diseases of circulatory system (353, 71.2%)	Mental and behavioural disorders (99, 20%)	Diseases of nervous system (16, 3.2%)	Musculoskeletal diseases (96, 19.4%)
Hypertension (250, 50.4%)	Dementia (33, 6.7%)	Epilepsy (7, 1.4%)	Osteoarthritis (39, 7.9%)
CVD (87, 17.5%)	Affective Disorders (60, 12.1%)	Parkinson's disease (6, 1.2%)	Osteoporosis (24, 4.8%)
Arrhythmia (78, 15.7%)	Psychosis diseases (7, 1.4%)	Facial nerve paralysis (1, 0.2%)	Polymyalgia (11, 2.2%)
Chronic heart failure (75, 15%)	Anxiety disorders (24, 4.8%)	Poliomyelitis (1, 0.2%)	Rheumatism (8, 1.6%)
Myocardial infarct (55, 11.1%)			Hernia, Fracture, Spinal stenosis, muscles inflammation, joint pain, trochanteritis (14, 2.8%)
Thrombosis and PVD (35, 7.1%)			

Respiratory diseases (48, 9.7%)	Endocrine and metabolic diseases (183, 36.9%)	Genitourinary diseases (167, 33.7%)	Neoplasms (51, 10.3%)
Asthma (25, 5%)	Hyperlipidaemia (107, 21.6%)	Urinary incontinence (103, 20.8%)	Solid malignancy (48, 9.6%)
COPD (20, 4%)	Diabetes (75, 15.1%)	Others (79, 15.9%)	Haematological malignancy (3, 0.6%)
Lung fibrosis, asbestosis (2, 0.4%)	Thyroid dysfunction (33, 6.6%)		
Sarcoidosis (1, 0.2%)	Gout (8, 1.6%)		

CVD, cerebral vascular diseases (includes stroke, transitional ischemia attack, cerebral haemorrhage, cerebrovascular lesion, and Lacunae infarction); COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular diseases

Characteristics of non-participants

A larger proportion of non-participants (45 of 154, 30%) than participants (55 of 496, 11%) lived in sheltered accommodation/nursing homes ($p < 0.001$). No gender difference was found between participants and non-participants (46 men vs 108 women, $p = 0.063$).

After completing the questionnaire, more women (113 of 307, 37%) than men (45 of 189, 24%, $p = 0.003$) dropped out. More dropouts (28 of 158, 18%) than participants (27 of 338,

8%, $p = 0.001$) lived in non-ordinary housing. Almost one-third of the dropouts (50 of 158, 31%) and less than one-fourth of the participants (73 of 338, 22%) had been admitted to a hospital at least once during 2007 ($p = 0.016$). Other socio-demographic factors (marital status, co-residence, levels of education, and SES) were distributed similarly among dropouts and participants.

There were no significant differences in Wt, WC, and BMI measured at baseline between participants in Paper IV (n = 83) and those who were excluded for any reason during the period 2007–2010 (n = 111).

Morbidity and multimorbidity

Prevalence of diagnosed chronic diseases (Papers I, II and III)

For users and non-users of in-patient care (Paper I), the main diseases were heart failure (44 of 123, 25%) among users of in-patient care and urinary incontinence (86 of 373, 23%) among the non-users. Multimorbidity doubled the risk of hospitalization (OR, 2.1; 95% CI, 1.3–3.5, $p < 0.002$).

In the comparisons between men and women (Paper II), the significant differences were the greater proportions of men with myocardial infarction (30 of 189, 16%) and malignancy (28 of 189, 14%) and the greater proportions of women with urinary incontinence (84 of 307, 27%), affective disease (46 of 307, 15%), dementia (26 of 307, 8%) and osteoporosis (23 of 307, 7%).

When participants were grouped according to BMI categories (Paper III), overweight and obese participants outnumbered those with normal weight in the number of chronic diseases (median number, 3, 3, and 2, respectively). Nearly 90% of obese participants (52 of 58) had multimorbidity, whereas the prevalence was significantly lower in both the overweight group (115 of 156, 74%) and the normal weight group (84 of 119, 70%, $p = 0.018$). The most frequent morbidity was hypertension. Significant differences between participants in different BMI categories were shown for the three morbidities, urinary incontinence, diabetes, and COPD/asthma, which were dominant in obese participants.

Patterns of multimorbidity (Paper II)

Using the measure of similarity (Yule's Q) and the cluster algorithm (average linkage between groups), we found a large decrease in agglomerative coefficients between 0.2 and 0.3, indicating an increase in heterogeneity between clusters. A cut-off in this range of coefficients provided three to five clusters for men (Figure 3) and four to six clusters for women (Figure 4). A higher cut-off coefficient resulted in several smaller clusters, whereas a lower cut-off coefficient provided larger clusters. We evaluated that a five-cluster structure identifies the most clinically meaningful multimorbidity for both genders. To show the magnitude of similarity between clusters/variables, we took Cluster 1 as an example and read off the distance for each node in Cluster 1 in the dendrograms.
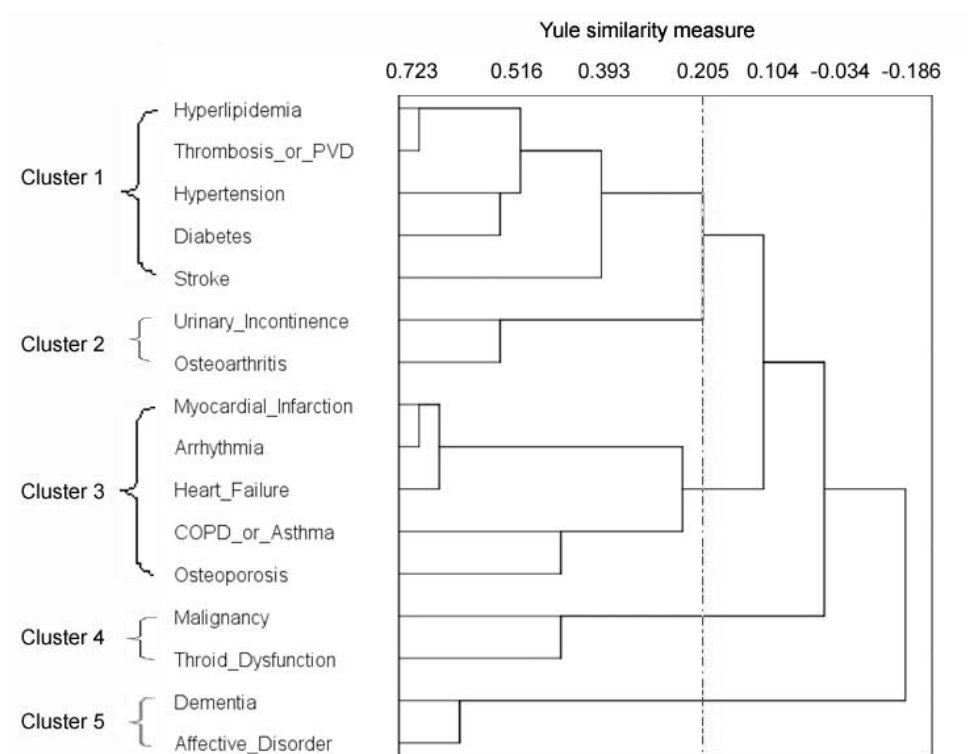
In the men's dendrogram, Cluster 1 was identified as a vascular cluster. Heart and pulmonary conditions were structured in Cluster 2 (cardiopulmonary) and Cluster 4 (cardiac). Two clusters were related to ageing: Cluster 3 containing a somatic–mental combination and Cluster 5 aggregating malignancy with osteoarthritis.
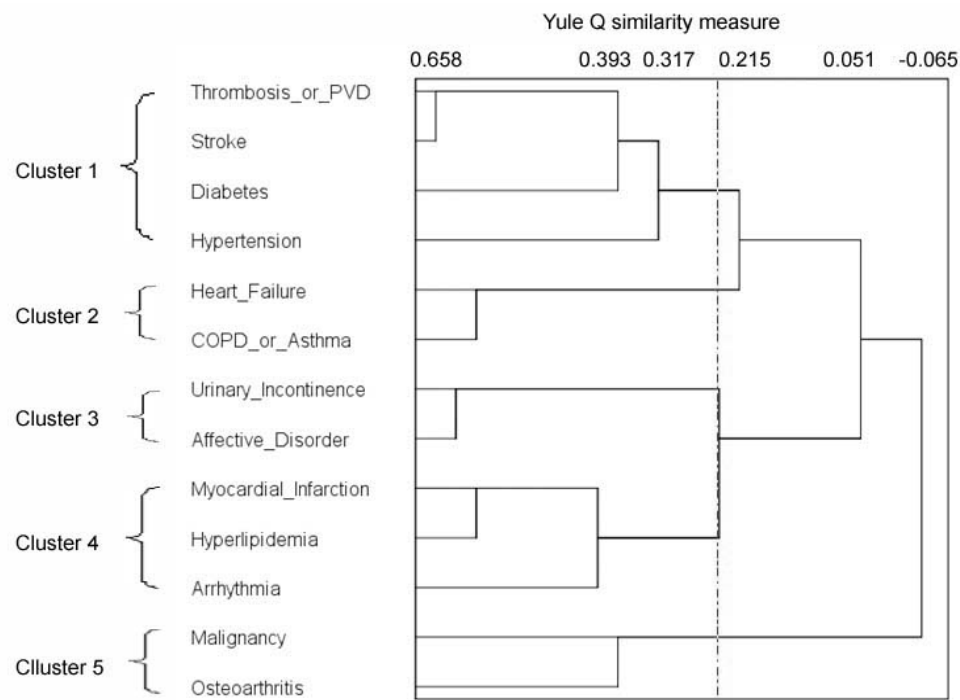
In the tree diagram, the distance between two clusters (or variables) is calculated according to the measure of similarity (Yule's Q) and the cluster algorithm (average linkage between groups). The shorter the distance, the closer are the clusters. Three to five clusters are obtained by shifting the cut-off (vertical line) between Q values of 0.2 and 0.3. We evaluated that a five-cluster solution identifies the most clinically meaningful multimorbidity. The agglomerative coefficients given to the terminal node in each cluster are: Cluster 1, 0.317 (OR, 1.9); Cluster 2, 0.587 (OR, 3.8); Cluster 3, 0.62 (OR, 4.3); Cluster 4, 0.581 (OR, 3.8); Cluster 5, 0.393 (OR, 2.3).

Figure 3 Morbidity clusters for men.

In the women's dendrogram, the vascular cluster (Cluster 1) was similar to that in the men's dendrogram but included hyperlipidemia. The cardiopulmonary cluster (Cluster 3) was larger than that of men; myocardial infarction, arrhythmia, and heart failure were connected, and chronic obstructive pulmonary disease (COPD)/asthma was associated with osteoporosis. There were combinations related to ageing in Cluster 2 in which urinary incontinence was combined with osteoarthritis and in Cluster 4 in which malignancy and thyroid dysfunction were merged. A mental disease cluster (Cluster 5) comprised dementia and affective disorders.

Yule similarity measure

0.723   0.516   0.393   0.205 0.104 -0.034 -0.186

Cluster 1
- Hyperlipidemia
- Thrombosis_or_PVD
- Hypertension
- Diabetes
- Stroke

Cluster 2
- Urinary_Incontinence
- Osteoarthritis

Cluster 3
- Myocardial_Infarction
- Arrhythmia
- Heart_Failure
- COPD_or_Asthma
- Osteoporosis

Cluster 4
- Malignancy
- Throid_Dysfunction

Cluster 5
- Dementia
- Affective_Disorder

Four to six clusters are obtained by shifting the cut-off (vertical line) between Q values of 0.2 and 0.3. We evaluated that a five-cluster solution identifies the most clinically meaningful multimorbidity. The agglomerative coefficients given to the terminal node in each cluster are: Cluster 1, 0.393 (OR, 2.3); Cluster 2, 0.557 (OR, 3.5); Cluster 3, 0.244 (OR, 1.6); Cluster 4, 0.45 (OR, 2.6); Cluster 5, 0.619 (OR, 4.3).

Figure 4 Morbidity clusters for women.

Health service consumption

Factors associated with an ER visit (Paper II)

Single morbidity models (Model 1) explained more variance than did morbidity cluster models (Model 2). Heart failure was the most significant factor associated with ER visits for both men and women (Model 1). The men's cardiac cluster (Cluster 4, Table 6) and women's cardiopulmonary cluster (Cluster 3) led to an increased likelihood of an ER visit (Model 2, Table 7).

Table 6 Association of single morbidity and morbidity clusters with ER visits in men.

Model 1: single morbidity		Model 2: morbidity clusters	
Predictors	OR (95% CI)	Predictors	OR (95% CI)
Heart failure	2.4 (1–5.7)	Cluster 4	1.6 (1–2.5)
No. of GP visits	1.3 (1.1–1.5)	No. of GP visits	1.3 (1.1–1.5)
Nagelkerke R^2	0.135	Nagelkerke R^2	0.11

ORs with 95% CI in parentheses and p value are shown. Cluster 4: hyperlipidemia, myocardial infarction, and arrhythmia.

Predictors excluded in model 1: type of housing, marital status, level of education, working status, no. of assistive technologies use, no. of assistance services used, self-rated health, thrombosis/PVD, stroke, diabetes, hypertension, COPD/asthma, urinary incontinence, affective disorder, myocardial infarction, hyperlipidemia, arrythmia, malignancy, and osteoarthritis.

Predictors excluded in model 2: type of housing, marital status, level of education, working status, no. of assistive technologies used, no. of assistance services used, self-rated health, Cluster 1, Cluster 2, Cluster 3 and Cluster 5.

Table 7 Association of single morbidity and morbidity clusters with ER visits in women.

Model 1: single morbidity		Model 2: morbidity clusters	
Predictors	OR (95% CI)	Predictors	OR (95% CI)
Low working status	Reference	Cluster 3	1.5 (1.1–2)
Middle working status	2.2 (1.1–4.1)	No. of GP visits	1.4 (1.2–1.6)
High working status	3.5 (1.1–11.3)		
Heart failure	3 (1.3–6.9)		
Arrhythmia	2.2 (1–4.8)		
Diabetes	0.3 (0.1–0.9)		
No. of GP visits	1.3 (1.1–1.6)		
Nagelkerke R^2	0.219	Nagelkerke R^2	0.143

ORs with 95% CI in parentheses and p values are shown. Cluster 3: myocardial infarction, arrhythmia, heart failure, COPD/asthma, and osteoporosis.

Predictors excluded in model 1: type of housing, marital status, level of education, no. of assistive technologies used, no. of assistance services used, self-rated health, hyperlipidemia, thrombosis/PVD, hypertension, stroke, urinary incontinence, osteoarthritis, myocardial infarction, COPD/asthma, osteoporosis, malignancy, thyroid dysfunction, dementia, and affective disorder.

Predictors excluded in model 2: type of housing, marital status, level of education, working status, no. of assistive technologies used, no. of assistance services used, self-rated health, Cluster 1, Cluster 2, Cluster 4, and Cluster 5.

Factors associated with hospitalization (Paper I and II)

An increased number of GP visits, more use of assistive technology and community assistance were positively related to in-patient care (Table 8). Multimorbidity as a single variable (Model 1) or certain specific morbidities increased the risk of being hospitalized.

Table 8 Association of in-patient hospitalization with living conditions and medical aspects.

	Model 1: multimorbidity		Model 2: specific diagnosed diseases	
	β estimate	OR (95% CI)	β estimate	OR (95% CI)
Constant	−2.9	0.06	−2.5	0.08
No. of visits to GP	0.3	1.3 (1.2−1.5)	0.3	1.3 (1.2−1.5)
No. of assistive technologies used	0.2	1.2 (1.1−1.4)	0.2	1.6 (1.1−1.5)
Community assistance	0.6	1.9 (1.1–3.2)		
Multimorbidity	0.6	1.9 (1−3.5)		
Specific diagnosed diseases				
Congestive heart failure			0.8	2.1 (1.2−4
Arrhythmia			0.7	2.1 (1.1–3.8)
Urinary incontinence			−1	0.4 (0.2–0.8)
Nagelkerke R^2	0.178		0.229	

Logistic regression, stepwise forward using likelihood ratio test.
Predictors excluded in model 1: type of housing, physical exercise, transportation service, personal alarm, SES, feelings of loneliness, having worries, EQ-5D VAS.
Predictors excluded in model 2: type of housing, physical exercise, transportation service, personal alarm, SES, feelings of loneliness, having worries, EQ-5D VAS, hypertension, dementia, COPD/asthma, hyperlipidaemia

The men's cardiac cluster (Cluster 4) in combination with the cardiopulmonary cluster (Cluster 2) and women's cardiopulmonary cluster (Cluster 3) were positively associated with hospitalization (Table 9). One of the women's ageing clusters (Cluster 2, including urinary incontinence) dampened the effect via a cluster interaction with the cardiopulmonary cluster (Cluster 3).

Table 9 Association of cluster interactions and hospitalization.

	Predictors	OR (95% CI)
Men	No. of assistive technologies used	1.6 (1.2–2)
	No. of GP visits	1.2 (1.0–1.5)
	Cluster 2 × Cluster 4	1.6 (1.0–2.4)
	Nagelkerke R^2	0.22
Women	Sheltered accommodation/nursing home	2.5 (1.0–5.9)
	No. of GP visits	1.4 (1.2–1.6)
	Cluster 3	2.3 (1.5–3.5)
	Cluster 2 × Cluster 3	0.5 (0.3–0.8)
	Nagelkerke R^2	0.213

ORs with 95% CI in parentheses and p values are shown.

Men: Cluster 2, heart failure, asthma/COPD; Cluster 4, hyperlipidemia, myocardial infarction, and arrhythmia.

Women: Cluster 2, incontinence, osteoarthritis; Cluster 3, myocardial infarction, arrhythmia, heart failure, asthma/COPD, and osteoporosis.

Predictors excluded in men's model: type of housing, marital status, level of education, working status, no. of assistance services used, self-rated health, Cluster 1, Cluster 2, Cluster 3, Cluster 4, Cluster 5, Cluster 1 × Cluster 4, Cluster 3 × Cluster 4, Cluster 5 × Cluster 4.

Predictors excluded in women's model: marital status, level of education, working status, no. of assistive technologies used, no. of assistance services used, self-rated health, Cluster 1, Cluster 2, Cluster 4, Cluster 5, Cluster 1 × Cluster 2, Cluster 4 × Cluster 2, Cluster 5 × Cluster 2, Cluster 1 × Cluster 3, Cluster 4 × Cluster 3, Cluster 5 × Cluster 3.

Health service cost (Paper III)

Neither medication nor other health care fees showed any differences among the groups with different BMI (Table 10). However, by stratifying the multimorbidity (n = 251), normal weight participants exhibited the highest health service total cost for each case of multimorbidity, nearly three times as much as for obese participants (ratio, 2.9; 95% CI, 1.1–8.1). The difference was mainly due to the fee excluding medication costs (ratio, 2.8; 95% CI, 2.0–7.0).

Table 10 Health service cost grouped according to BMI categories

	Normal weight (n = 119)	Overweight (n = 156)	Obesity (n = 58)	p value
Medication	1 915 (1148–3 194)	1316 (821–2 111)	1189 (509–2781)	0.485
Other fees	8 521 (5574–13 026)	6189 (4393–8720)	4096 (1 960–8 559)	0.145
Total cost	11 740 (7644–18 038)	8694 (6116–12 359)	5985 (2771- 12 930)	0.21
Cost for cases with multimorbidity*				
Medication cost	3 122 (1813–5 375)	2129 (1258–3 600)	1414 (592–3 378)	0.271
Other fees	13 561 (8806–20 888)	8649 (5950–12 574)	4914 (2277–10 605)	0.032[abc]; 0.027[ac]
Total cost	18 997 (12 373–29 174)	12 462 (8531–18 205)	7029 (3159–15 642)	0.041[abc]; 0.036[ac]

Given by geometric mean with 95% CI.
One-way ANOVA and post hoc test (Bonferroni method) after log transformations.
*Cost: unit Swedish crown.
[a] Normal weight; [b] overweight; [c] obesity. p values for comparisons across the three groups. Significant differences between normal weight and obesity [a and c]; overweight and obesity [b and c].

Use of assistive technology and formal services

Users of in-patient care (Figure 5, Paper I) used more assistive technology and formal services than non-users. Women used a significantly higher number of assistive technologies than men (Paper II) (median: women 2, men 0; $p < 0.001$) and formal services (median: women 1, men 0; $p < 0.001$). Obese participants used more than participants of normal weight or overweight, with a median number of 2 assistive technologies (q1−q3, 1–3.5, $p = 0.001$) and 1 formal service (q1−q3: 0–2, $p = 0.001$) (Paper III).
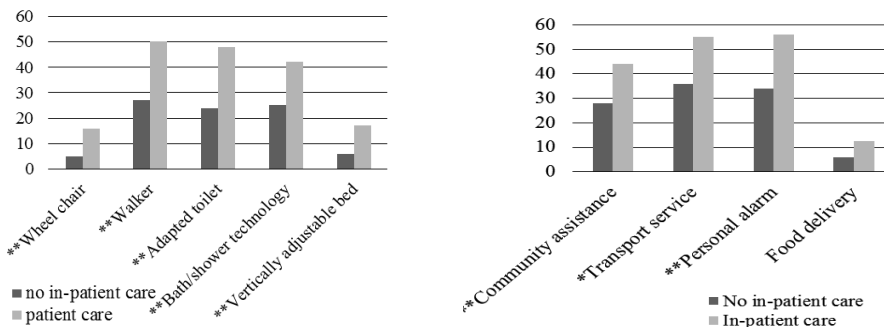

Figure 5 Use of assistive technologies and formal services.

ADLs

Very few participants perceived limitations in PADL among both the 85-year-old cohort (50 of 333, 15%; Paper II) and 88-year-old cohort (12 of 83, 14%; Paper IV).

More than half of the 85-year-old participants of normal weight perceived no difficulty, whereas the proportions perceiving no difficulty in the other two groups were substantially lower with regard to mobility outdoors, public transportation use, small- and large-scale shopping, cleaning, and washing ($p < 0.05$, 0.01). In the 88-year-old population, the majority (69 of 83, 83%) perceived difficulty in all IADL. When counting the number of IADLs with no difficulty, there was no significant difference among the groups of different BMI categories.

Physical functioning

In the TUG test (Paper III), obese participants performed significantly slower in the mobility test among the three groups and 81% (41 of 58) had a high risk for falls (≥ 14 seconds). In comparison, 57% (68 of 119) of normal weight participants and 63% (98 of 156) of overweight participants were at high risk for falls ($p = 0.007$).

For SF-36$_{PF}$ (Paper IV), the mean score in the obese group (mean $\pm$ SD, 42 ± 20) was significantly lower than that in the normal weight group (60 ± 25, $p = 0.032$), but was not significantly different from the mean score in the overweight group (53 ± 27, $p = 0.346$, $\eta^2 = 0.079$).

Nutritional aspects

Associations between overweight/obesity and comorbidity (Paper III)

Binary logistic regression detected that urinary incontinence had a weak but still statistically significant association with obesity (adjusted OR, 2.2; 95% CI, 1.1–4.7) (Table 11). Diabetes as well as chronic heart failure had increased adjusted ORs (0.2 and 0.6, respectively). Conversely, hypertension lost the significance of association with obesity after adjustment (adjusted OR, 1.6; 95% CI, 0.8–3.2). However, being overweight was not found to have a significant association with any comorbidity.

Table 11 Associations of overweight/obesity with comorbidity, and with increased difficulty in IADL.

	Overweight (n = 156)[*] OR (95% CI)		Obesity (n = 58)[*] OR (95% CI)	
	Crude	Adjusted [†]	Crude	Adjusted[†]
Comorbidity				
Hypertension	1.2 (0.7–1.9)	1.1 (0.7–1.9)	1.9 (1–3.7)	1.6 (0.8–3.2)
Urinary incontinence	1.4 (0.8–2.5)	1.3 (0.7–2.4)	3 (1.5–5.8)	2.2 (1.1–4.7)
Diabetes	1 (0.5–1.8)	0.9 (0.5–1.9)	2.6 (1.2–5.4)	2.8 (1.3–6.4)
Chronic heart failure	1.2 (0.6–2.3)	1.2 (0.6–2.5)	3.4 (1.6–7.2)	4 (1.7–9.3)
Multimorbidity	1.2 (0.7–2)	1.1 (0.6–1.9)	3.6 (1.4–9.2)	3 (1.2–8)
IADL, measured by IAM[‡]				
Mobility outdoors	1.4 (0.9–2.3)	1.2 (0.8–2.1)	2.6 (1.3–2.7)	2.1 (1.1–4)
Public transportation	1.1 (0.6–1.7)	0.8 (0.5–1.4)	3.1 (1.7–5.8)	1.9 (0.9–3.9)
Small-scale shopping	1.8 (1–3.1)	1.5 (0.8–2.6)	2.4 (1.2–4.8)	1.5 (0.7–3.2)
Large-scale shopping	1.4 (0.9–2.3)	1 (0.6–1.7)	2.3 (1.3–4.3)	1.1 (0.6–2.3)
Cleaning	1.4 (0.9–2.2)	1.2 (0.8–2)	3 (1.7–5.4)	2.2 (1.2–4.2)
Washing	1.8 (1.1–2.9)	1.4 (0.8–2.5)	2.3 (1.2–4.2)	1.7 (0.9–3.5)

Reference variable: normal weight group, n = 119.
[†]Analysis adjusted for gender, co-residence, type of housing, education level, and SES.
[‡]A four-level ordinal scale (none, little, great, and impossible).

Functional outcomes in relation to nutritional status (Papers III and IV)

The ordinal logistic regression showed that obese participants were more likely to perceive increased difficulty in six activities, and overweight participants were only more likely to have increased difficulty with small-scale shopping and washing (Table 11). After adjusting for all socio-demographic factors, the association of obesity with increased difficulty in mobility outdoors (OR, 2.1; 95% CI, 1.1-4) and cleaning (OR, 2.2; 95% CI, 1.2-4.2) remained significant, although the magnitude of the ORs decreased. However, the association between overweight and the perceptions of difficulty with small-scale shopping and washing disappeared.

In the linear regressions of each variable on nutritional status with the number of IADLs with no difficulty among the 88-year-old women, WC showed an inverse association (coefficient B = −0.44, SE = 0.02, R^2 = 0.38). No body composition variable was observed to have a significant relationship. Higher HS and HS-based ratios (HS/FFM and HS/Wt) predicted more independent daily living, because a greater number of IADLs were perceived to be managed with no difficulty (Table 12).

Anthropometric (Wt and WC) and body composition (FM and FFM) variables showed negative effects on physical functioning as measured by the SF-36$_{PF}$ (Table 12). HS and HS-based ratios (HS/Wt, HS/BMI, HS/FFM, and HS/FM) were positively associated with physical

functioning. Moreover, the HS-based ratios ($R^2 = 0.52$–0.54) explained slightly more variance of the SF-36$_{PF}$ score than the single variables ($R^2 = 0.45$–0.51).

Table 12 Linear regressions of the number of IADL with no difficulty, and with physical functioning (SF-36$_{PF}$)

	No. of IADL with no difficulty		Score of SF-36 $_{PF}$	
Predictor	Coefficient B (SE)	R^2	Coefficient B (SE)	R^2
Wt (kg)	−0.22 (0.02)	0.36	−0.41 (0.16)[*]	0.46
BMI (kg/m^2)	−0.05 (0.05)	0.36	−0.79 (0.43)	0.44
WC (cm)	−0.44 (0.02)[*]	0.38	−0.69 (0.19)[†]	0.51
MAMC (cm)	−0.84 (0.09)	0.35	−1.48 (0.82)	0.44
FM (kg)	−0.03 (0.03)	0.36	−0.52 (0.23)[*]	0.45
FFM(kg)	−0.03 (0.05)	0.35	−0.93 (0.42)[*]	0.45
FMI (kg/m^2)	−0.07 (0.07)	0.36	−1.12 (0.58)	0.44
FFMI (kg/m^2)	−0.09 (0.14)	0.35	−1.47 (1.25)	0.43
HS (Newton)	0.02 (0.01)[*]	0.40	0.17 (0.06)[†]	0.48
HS corrected for FFM (Newton)	0.01 (0.02)	0.35	0.1 (0.13)	0.43
HS/Wt	0.93 (0.43)[*]	0.40	13.0 (3.5)[†]	0.54
HS/BMI	0.32 (0.16)	0.39	4.18 (1.36)[†]	0.52
HS/FFM	0.76 (0.27)[†]	0.41	9.42 (2.25)[†]	0.53
HS/FM	0.12 (0.08)	0.38	1.91 (0.65)[†]	0.52

Adjusted for number of chronic diseases and levels of physical activity. [*]$p < 0.05$; [†]$p < 0.01$. SE, standard error.

DISCUSSION

Summary of the main findings

The ELSA 85 population showed a fairly positive image of health perception, good functional ability as well as low use of health care among the majority of participants, despite a high prevalence of multimorbidity and frequent use of assistive technology. In-patient care users required more medical resources, social assistance and had lower self-rated health. Patterns of cardiac and pulmonary conditions were better associated than any single morbidity with hospitalization, and heart failure as a single morbidity was better associated than multimorbidity patterns with ER visits.

The overweight or obese participants perceived more difficulties in a variety of ADLs and had more comorbidities than their normal weight counterparts, but they did not have poorer overall HRQoL or incur more health service cost. Significant associations were found only between obesity and activity limitations and between obesity and comorbidity (or multimorbidity), but not for overweight. In the cohort of 88-year-old women, WC, HS, and HS-based ratios (HS/Wt and HS/FFM) were significantly associated with physical function and their independent daily living, suggesting that obesity is related to loss of muscle strength, reduced physical function, and loss of independent daily living.

Multimorbidity and morbidity clusters

Multimorbidity and specific diseases (heart failure and arrhythmia) were shown to be important predictors of in-patient care. We also found that the difference in comorbidity decreased between groups with different nutritional status. Overweight in comparison with normal weight was not significantly associated with any comorbidity. Unlike the younger elderly, obesity-related conditions were more common in the older elderly and even in normal weight older elderly [150]. Thus, it is reasonable to assume that the likelihood of having certain chronic diseases was similar for normal weight and overweight elderly individuals.

Beyond the statistical results from the cluster analysis of the morbidity clusters, some patterns of multimorbidity were expected and supported by findings from other studies. First, in Cluster 1, all morbidities shared the common pathophysiological mechanism of vascular disorders except diabetes. However, we still have good reason to believe that in the long term very old people who have complications associated with diabetes have other co-occurring vascular morbidities. Similar findings were also reported by previous studies using cluster analysis [27, 37]. Second, the cardiopulmonary cluster is another expected cluster. Heart failure in the men's cardiopulmonary cluster was only related to COPD/asthma. The cluster was closer to vascular diseases (Cluster 1) than the cardiac cluster (Cluster 4). The women's cardiopulmonary cluster contained all heart conditions as well as COPD/asthma. COPD/asthma was first linked to osteoporosis, suggesting that osteoporosis was a consequence of long-term treatment of corticosteroids for COPD/asthma [151, 152]. This cardiopulmonary pattern was also reported by Marengoni et al. [153] and John et al. [27] but with no gender specificity. A third finding is the clusters of mental diseases. The women's mental and somatic

morbidities were independent of each other. Comparatively, men had a somatic–mental cluster as only affective disorder was included in the analysis. Its association with urinary incontinence has not been formally documented in any psychiatric journal according to Vasudev et al. [154] even though the impact of urinary incontinence on mental health has been reported by other researchers [155, 156].

Some morbidities emerged in the same cluster but did not seem to follow pathophysiological pathways, such as urinary incontinence and osteoarthritis (Cluster 2 in women). In women, osteoarthritis-related disability may negatively affect urinary control [157]. Another exception is the comorbidity of malignancy. It is difficult to anticipate which comorbidity coexists with a certain type of malignancy, because cancer patients manifest multiple health problems [158]. One reflection from daily clinical practice is that patients with a malignancy diagnosis have usually undergone complete clinical and laboratory examinations, and therefore, some comorbidity such as osteoarthritis or thyroid dysfunction would not be missed. Another hypothesis is based on the selection of survival of concurrent ailments. Among cancer patients, some co-occurrences (e.g. severe heart disease) are more likely than others (e.g. osteoarthritis) to cause a high risk of mortality.

Health service consumption

Stewart [56] stated that older patients in hospital and their prescription costs are explained by declining health. The majority of previous studies reported that the increase in health care use is associated with increasing age [57, 159, 160]. Some datasets indicate that younger (<75 years) and older (>90 years) people tend to use less health care [58, 161]. The perceived need of health care services is largely explained by social structure and health beliefs rather than evaluated need, which represents professional judgment about individuals' health status and need for health care; thus multiple dimensions have an impact on health service use and health status [47]. In this 85-year-old cohort, we attempted to provide a full description of assistance needed and health care service consumption for very old people.

In terms of hospitalization, our results are consistent with those of other studies that found that persons with multimorbidity were more likely to be hospitalized [162, 163]. We confirmed multimorbidity as a single predictor for in-patient care. We also showed that morbidity cluster and cluster interaction models provide more information. Morbidity cluster and cluster interaction models address what morbidity cluster was the leading cause of hospitalization. In addition, we noted the mixed characteristics through gender stratification. For both men and women, the cardiac and pulmonary condition was a major factor associated with hospitalization. For women, urinary incontinence and its comorbidity with osteoarthritis suggests that old women with certain conditions might be treated using care services other than hospitalization (e.g. primary care).

Patients using ER services are heterogeneous with respect to the medical services they require. The slightly lower R^2 value in the morbidity cluster models reveals that the selected morbidity clusters (men's cardiac cluster and women's cardiopulmonary cluster) did not improve explained variance. In other words, single-morbidity models are more precise in predicting ER visits. A reflection of real clinical practice is that a single morbidity (e.g. heart

failure) as a medical condition may already be enough for an ER visit. Unexpectedly, several common morbidities such as COPD/asthma, stroke and even myocardial infarction were not significantly related to ER visits in this study population. Seemingly, in this very old population, these diagnoses were not clearly related to exacerbations or new attacks, but more likely suggested permanent chronic conditions in patients' medical records.

In all the models of hospitalization and ER visits, the number of GP visits as a predictor maintained its robust significance. In the context of the Swedish health care system, an increased number of GP visits reflected the medical needs of very old people.

In terms of living conditions, more assistive technology and community assistance also had a positive association with in-patient care. With gender stratification, increased assistive technology use for men and sheltered accommodation/nursing home living for women were closely related to hospitalization. These factors directly indicated the everyday needs of those who availed of hospitalization. Meanwhile, we were aware of the different living situations for very old men and women. Greater use of assistive technology by men implied severe physical disability or illness because men are more reluctant than women to use assistive technology due to shame, embarrassment, and feelings of victimization [164]. Moving to sheltered accommodation/nursing home, on the other hand, reflected women's frailty and needs because more very old women than men were living alone.

During the year of observation, similar health care costs were found among the groups with normal weight, overweight and obesity in this study cohort. In younger age populations, overweight and obesity as a health care burden often result in greater health service use [165, 166] and higher costs [100, 167]. What is less clear is why normal weight individuals with multimorbidity had higher health care costs than obese individuals. A longitudinal study may provide a deeper understanding because the total health care expenditure might include costs associated with last-year-of-life care.

IADL and physical functioning related to nutritional status

The limitations in IADL, which were more likely perceived by obese 85-year-old participants, could be attributed to their mobility limitations. Mobility problems were further proved by the actual physical performance on the TUG test. We observed that overweight participants as a whole performed as well as normal weight participants and significantly better than obese participants. This indicated that a BMI value within the overweight range did not decrease functional mobility for very old participants. Negative consequences did not occur until the BMI reached the range of obesity. Socio-demographic factors weakened the association between being overweight and limitations in IADL and the statistical significance was lost after adjustment. As pointed out in other studies, socio-demographic factors could not be ruled out because home activities were related to gender, cohabitation, and other cultural factors [131].

Apart from BMI, we tested other objective variables of body measurement as well as HS to explore their impact on independent daily living and physical functioning. In younger age groups, many studies have emphasized that WC is a predictive marker of functional disability

and ADL limitations [168-171]. This conclusion also applies to very old people because of the negative consequence of accumulation of visceral fat over a life span in very old people compared with their younger peers. Besides WC, HS and HS-based ratios were also related to physical function and IADL independence in our study. According to Schutz's reference value for FFMI in Caucasian women aged 75 years and older [172], the mean FFMI in our participants was above the 50th percentile level. With an adequate FFMI, higher HS, which is a surrogate measurement of overall muscle strength, predicts better physical function and independent daily living. Muscle strength in obese women was relatively weak when it was associated with high Wt and FFM (HS/Wt and HS/FFM). Relative muscle strength had a larger impact than single parameters (except WC) on physical function and independent daily living. Muscle strength is not always determined by FFM and may only apply for normal weight individuals [119]. If muscle strength does not proportionally increase with Wt and FFM, high Wt and FFM can become a burden for very old people with respect to maintaining good physical function and independence. A longitudinal study reported a constant decline in muscle strength during ageing [173]. This adverse effect accumulates over a long life time, and therefore, loss of strength is recognized in very old people more easily than in young old people.

Methodological issues

Many independent factors in regression analysis risk being confounded and interacting with each other, therefore we chose stepwise and LR forward regression analysis to select all target variables for exploratory purposes [58]. The low R^2 reminds us that reasons for the use of health services are multifaceted phenomena. According to Andersen's behavioural model, the use of health services is determined by predisposing characteristics (e.g. demographics, social structure, and health belief), enabling resources (e.g. the number of medical personnel and facilities), or a need for health care (health conditions including mortality, morbidity, and disability) [48]. Even if need is the dominant reason why older people use the ER [59, 174], the measures of need as well as other contextual factors can vary [175]. Working status and education were measured separately instead of transforming to SES. The effect of SES on the use of health services is not consistent in all studies [59, 176, 177], probably because of the use of different measures and different methods of financing health care.

There is no consensus about how to best measure multimorbidity. According to the theory that associations among morbidities must be involved when comorbidity rates exceed those that are statistically expected (coincidental) [178], hierarchical cluster analysis helps to identify the conjunction between morbidities in a small population with a high prevalence of multimorbidity. Cluster score and cluster interactions have revealed synergistic effects on associative morbidities [27]. However, we realize that very different results may be obtained from the same data using different hierarchical clustering methods [147]. It is important to relate the statistical results to real-life clinical practice to verify the interpretable clusters.

In the analysis of body composition, we observed a difference between measurement by BIA and other methods. FFM can be slightly overestimated by approximately 3 kg in obese individuals because the resistance measured by a BIA may be affected by increased adipose tissue [179, 180]. A minimal difference and high correlation with measurements obtained by

dual-energy X-ray absorptiometry (r = 0.99) was noted. We chose the BIA for practical reasons; it is more portable and less expensive than other techniques (e.g. dual-energy X-ray absorptiometry and imaging scans). The BIA is suitable for home visits, which is the typical location for examining very old people.

Strength and limitations

The contrast between actual health care delivery and good self-rated health with multimorbidity provided an opportunity to explore related factors that could influence hospitalization. We have described the relationship between the need for daily assistance, assistive technology and multimorbidity linked to greater health care use for elderly people of advanced age (Papers I and II). Specifically, patterns of multimorbidity were included and we applied multimorbidity cluster structures in further regression analysis to verify the risk factors in relation to health service use (Paper II). We also focused on nutritional status and overweight and obesity at this advanced age; usually malnutrition and hospitalized patients receive much more attention (Paper III). Since ageing is a complex process and long life expectancy is also attributed to multiple factors, it is inappropriate to deduce the advantages or negative effects based on only one or a few apparent variables in comparison with younger old adults. Moreover, to obtain a deeper understanding of the negative effects of obesity on independent living and functioning of very old people, we assessed more estimates than BMI alone, including HS and body composition (Paper IV). Few studies have reported these findings in a population of very old persons.

Several limitations and lessons are evident in retrospect. First, the representativeness of our results is based on the characteristics of all voluntary participants. The rate of participation decreased as more investigations and assessments were planned over the time period of the study. The voluntary sample may be biased due to the study procedure, because the study design unintentionally selected individuals with a strong interest in the study. The external validity (generalization) is problematic. We maximized the sample information in various ways (e.g. checking the address and registered health care service use). The non-participants were possibly frailer [181] or paradoxically healthier but with a depressed mental state [34]. In the ELSA 85 project, the non-participant group was found to include a higher percentage of people residing in sheltered accommodation and institutions. The possibility of a larger proportion in long-term care must be considered irrespective of the seemingly lower use of primary care.

Second, socio-demographic characteristics and health policies vary due to differences in health care resources. This also affects comparisons of the findings with other population-based ageing studies. In the Swedish context, the guiding principle in eldercare is for elderly individuals to remain in their own homes for as long as possible [51]. We have a larger proportion of very old people living in ordinary housing (85% of the whole population sample and 89% of participants) compared with other countries, e.g. 77% in the Newcastle study [36] and 83% in the Leiden study [34]. Individuals in sheltered accommodation or institutions were usually under closer surveillance with regard to medical care, which consequently influenced their health care needs [51]. Another reflection is that the participants' actual use of assistance could be underestimated because the elderly might receive overt support with daily activities

from their family, discouraging them from engaging in activities that may increase the risk of falling [182].

Third, diseases with no treatment and asymptomatic conditions could be missed by self-reported surveys and neglected by doctors when recording a medical history, such as hyperlipidemia [183] and osteoporosis in men [184]; these diseases are often missing in the patients' case reports due to lack of medical examination or no intention of treatment.

Fourth, the results presented here are all from cross-sectional analyses. We cannot draw any causal conclusions, although underlying aetiological links probably exist between the factors. Like some other ageing studies (SNAC-K [30], Newcastle 85+ [35], Umeå 85+ [29]), a follow-up of the very old people in ELSA 85 could validate the relationships observed in these results. The interval between baseline and follow-up must also be carefully considered because clinical significance derived from the variations takes time.

Health maintenance in very old age is always somewhat of a myth. Its complexity is due to the heterogeneity of individuals. The objective of epidemiological approaches and clinical research is to verify mutual characteristics at a population level. Health trends in very old age are not invariable over time, and the changes can have a major impact on planning for local health care, allocating and prioritizing resources, and geriatric practice. It remains to be evaluated whether the characteristics mentioned above contribute to a similar extent longitudinally. A renewed interest in stratified target groups (e.g. homebound individuals, public service users, individuals with specific patterns of multimorbidity, etc.) among the very old is also a topic for future research.

CONCLUSIONS

The ELSA 85 population showed a fairly positive image of healthy perception, good functional ability as well as low use of health care among the majority of participants.

- In-patient care users required more medical resources, social assistance and had lower self-rated health. The factors associated with in-patient care included not only medical aspects but also living conditions (e.g. greater use of assistive technology and community assistance).

- Patterns of cardiac and pulmonary conditions were better associated than any single morbidity with hospitalization. Heart failure as a single morbidity was better associated than multimorbidity patterns with emergency room visits.

- Being obese, as opposed to being overweight, was associated with self-reported activity limitations and comorbidities. Overweight elderly living in their own homes in this population had similar well-being to those of normal weight.

- Obese 88-year-old women had high waist circumference and their handgrip strength was relatively low in relation to their body weight and fat-free mass. These parameters are better than body mass index for predicting physical function and independent daily living.

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