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NUTRITION AND HEALTH IN A COHORT REPRESENTATIVE OF THE GENERAL COMMUNITY-DWELLING POPULATION OF LAUSANNE AGED 65 AND OVER

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NUTRITION AND HEALTH IN A COHORT REPRESENTATIVE OF THE GENERAL COMMUNITY-DWELLING POPULATION OF LAUSANNE AGED 65 AND OVER

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par

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Prof. Pierre-Alexander Bart

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SUMMARY OF PROJECTS AND PUBLICATIONS

COMPLETED PROJECTS: OBJECTIVES	CORRESPONDING PUBLICATION
Project 1: To describe the links between individual frailty criteria and specific chronic diseases in the Lc65+ cohort	**Danon-Hersch N**, Rodondi N, Spagnoli J, Santos-Eggimann B. Pre-frailty and chronic morbidity in the youngest old: An insight from the Lausanne cohort Lc65+. *J Am Geriatr Soc.* 2012; 60(9):1687-94. **(APPENDIX I)**
Project 2: To describe 1) eating habits, daily physical activity, and sports frequency in community-dwelling adults aged 65-70, 2) the links of these behaviors with socioeconomic factors, and 3) with adiposity.	**Danon-Hersch N**, Santos-Eggimann B. Using stairs in daily life is associated with lower adiposity values than doing weekly sports in Lc65+ cohort at baseline. *BMC Public Health.* 2013;13:1175. **(APPENDIX II)**
Project 3: To examine the association between body mass index (BMI) and waist circumference (WC) with mortality and autonomy in basic activities of daily living (BADL) in Lc65+ cohort after 8 years of follow-up.	**Danon-Hersch N**, Fustinoni S, Bovet P, Spagnoli J, Santos-Eggimann B. Association between adiposity and disability in the Lc65+ cohort. *JNHA, in press* **(APPENDIX III)**

ABSTRACT

The objective was to study the links between health characteristics, frailty criteria, lifestyles, adiposity and disability in a population-based cohort of non-institutionalized adults aged 65 to 70 years at baseline (N= 1,260 to 1,293). At baseline, frailty was rare (2%), while pre-frailty was common (26%). Pre-frail participants had significantly more comorbidity and disability (defined as help received for activities of daily living, ADL) than non-frail participants. Weakness was the most frequent frailty criterion and was associated with cardio-vascular diseases (CVD). The prevalence of overweight (body mass index (BMI) 25.0-29.9 kg/m^2), obesity (BMI ≥30.0 kg/m^2), and abdominal obesity (waist circumference (WC) ≥102 cm in men, WC ≥88 cm in women) was 53%, 24%, and 45% in men; 35%, 23%, and 45% in women. Walking and using stairs in daily life was associated with lower adiposity values than doing sports at least once/week. Eating fruit and vegetables at least twice/day, walking and using stairs in daily life, and doing sports ≥once/week were significantly negatively associated with financial difficulties and positively with educational level. In longitudinal analyses, 130 persons died over a median follow-up of 8.47 years. In fully adjusted Cox models, mortality was significantly associated with neither BMI nor WC, but there were trends toward non-significant J curves across both BMI and WC quintiles. Disability (defined as difficulty with BADL or institutionalization, 231 cases) tended to increase monotonically across both BMI and WC quintiles and was significantly associated with BMI quintile 5 (HR=2.44, 95% CI [1.65-3.63]), and WC quintiles 4 (HR=1.81 [1.15-2.85]) and 5 (HR=2.58, [1.67-4.00]). Almost half of the population had a substantially increased HR of disability, as compared to the reference BMI/WC categories. In conclusion, studies with larger sample sizes and longer follow-up should assess the roles of BMI and WC trajectories since midlife and further clarify the shapes of their associations with disability. These findings, together with the literature review, emphasize the need for life-long strategies aimed at preventing excess weight, muscle loss and functional decline through adequate nutrition and regular physical activity, starting at early age and extending throughout life.

RÉSUMÉ

Nutrition et santé à l'âge de 65 ans et plus : une étude dans la population de Lausanne ne vivant pas en institution

L'objectif de ce doctorat était d'étudier les liens entre l'état de santé, le degré de fragilité, le style de vie, le surpoids et le développement d'une dépendance dans les activités de la vie quotidienne en analysant les données fournies par environ 1300 adultes initialement âgés de 65 à 70 ans. Ces personnes ont été suivies sur une durée de plus de 8 ans; elles ont rempli des questionnaires et passé des tests régulièrement. La fragilité a été définie sur la base de 5 critères (perte de poids involontaire, vitesse de marche lente, force de préhension au niveau de la main faible, fatigue ressentie et activité physique basse) dont 3 au moins doivent être remplis pour être considéré comme fragile.

Au démarrage de l'étude, la fragilité était rare (2% des participants), mais la pré-fragilité (1 ou 2 critères remplis) fréquente (26%). Les participants pré-fragiles avaient plus souvent des maladies chroniques ou recevaient de l'aide pour effectuer les activités de la vie quotidienne (s'habiller, manger, se doucher, etc.) que les personnes n'ayant aucun des 5 critères de fragilité. La faiblesse de la préhension au niveau de la main était le signe de fragilité le plus fréquent et il était plus souvent observé parmi les personnes souffrant de maladies cardio-vasculaires.

L'indice de masse corporelle (IMC) est une mesure de la corpulence. Il s'agit du poids (en kg) divisé par la taille au carré (en m^2). La fréquence du surpoids (IMC entre 25.0 et 29.9 kg/m^2) était de 53% chez les hommes et de 35% chez les femmes. Celle de l'obésité (IMC ≥30.0 kg/m^2) était de 24% chez les hommes et de 23% chez les femmes. L'obésité abdominale (définie par un tour de taille supérieur ou égal à 102 cm chez les hommes, 88 cm chez les femmes) touchait 45% des hommes et des femmes. Les personnes marchant au quotidien et prenant les escaliers étaient plus minces que celles qui évitaient les escaliers mais faisaient du sport au moins 1x/semaine. Les habitudes nutritionnelles favorables à la santé étaient par ailleurs liées aux facteurs socio-économiques: les personnes mangeant des fruits et légumes au moins 2x/jour, utilisant les escaliers au quotidien et faisant du sport au moins une fois par semaine ont moins souvent rapporté des difficultés financières et bénéficiaient d'un niveau d'éducation plus élevé.

Lors du suivi de 8 ans, 130 personnes sont décédées. En tenant compte de certains facteurs dans les analyses (sexe, âge, difficultés financières, éducation, tabagisme, perte de poids), il n'y avait pas de lien statistiquement significatif entre l'IMC ou le tour de taille et le risque de décès; cependant la mortalité tendait à être plus élevée aux deux extrêmes, parmi les personnes de très faible corpulence ainsi que parmi les personnes obèses. Au cours du suivi, 231 personnes ont développé des difficultés durables dans les activités de la vie quotidienne. Leur nombre augmentait progressivement dans les catégories d'IMC ou de tour de taille plus élevé. En particulier, parmi les 20% des personnes ayant l'IMC le plus élevé, ou les 40% des personnes ayant le tour de taille le plus élevé, la survenue de ces difficultés était significativement plus fréquente.

En conclusion, il faudrait effectuer des études avec plus de participants et un suivi plus long pour mieux connaître le rôle de l'IMC et du tour de taille depuis l'âge de 40-50 ans, et clarifier leurs liens avec les difficultés dans les activités de la vie quotidienne. La littérature suggère qu'il faut prévenir le surpoids, la perte de masse musculaire et le déclin fonctionnel depuis un jeune âge et tout au long de la vie par le biais d'une alimentation équilibrée et d'une activité physique régulière.

LIST OF ABBREVIATIONS

ADL: activities of daily living (BADL: basic; IADL: instrumental)

BMI: body mass index

CHD: coronary heart disease

CHS: Cardiovascular health study

CI: confidence intervals

CVD: cardio-vascular disease

DEXA: dual-energy X-ray absorptiometry

EWGSOP: European working group on sarcopenia in older people

FV: fruits or vegetables

HR: hazard ratio

IWL: involuntary weight loss

MNA: Mini nutritional assessment

MONICA: Monitoring of trends and determinants in cardiovascular disease study

OR: odds ratio

PA: physical activity

SES: socio-economic status

SHS: Swiss health survey

SISF: supra-iliac skin-fold

TSF: triceps skin-fold

WC: waist circumference

WHO: World health organization

WHR: waist-to-hip ratio

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INTRODUCTION

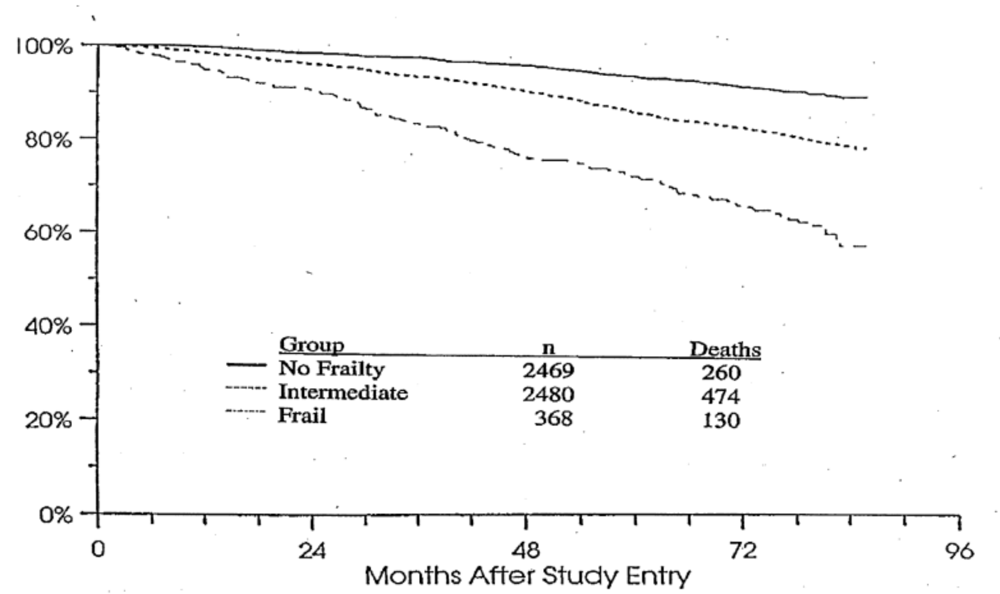
I. Background

Life expectancy has increased in Western populations and the age distribution of these populations is shifting to the right. Public health authorities will have to appropriately plan health services in order to suit the needs of the growing part of the population aged 65 and over. In view of its high prevalence, excess weight is another major health concern in Switzerland [4, 5] and in Western populations [6, 7]. In Switzerland, the prevalence of overweight and obesity has increased in all age groups between 1992 and 2007 [4]; in the city of Lausanne, it was the highest in age group 65-75 years in 2005, compared to younger age categories, reaching a total prevalence of 73% among men, 53% among women [8]. This difference by age was also observed in the Swiss Health Survey 2007, a nationwide study using self-reported height and weight: the prevalence with body mass index (BMI) ≥25 kg/m^2 reached 52% at age 65-74 years. According to Zamboni's review [9], obesity prevalence increases up to 60-69 years, and then declines. It increased in older ages, comparing the period 1999-2000 with 1988-94.

II. Frailty (Project 1)

The concept of frailty has appeared in geriatrics during the last decades in order to define a state of increased vulnerability and loss of adaptation to stress [10] [11]. Linda Fried [1] proposed a standardized definition for frailty. She used data from the Cardiovascular Health Study (involving community-dwelling older adults), with a follow-up of 7 years. Five criteria are at the basis of her definition (**Table 1**): unintentional weight loss (at least 10 lbs in past year), self-reported exhaustion, weakness (grip strength), slow walking speed, and low physical activity; at least three criteria are needed for the definition of frailty, and one or two are needed for the definition of the intermediate state (also called pre-frailty). The frailty phenotype predicts adverse health outcomes such as recurrent falls, worsening mobility, disability [12], fractures [13], death [1] [12] [14], as well as hospitalizations and admissions to nursing homes [12] [15]. In the Cardiovascular Health Study [1], intermediate frailty status showed intermediate risk of these outcomes (**Figure 1**) and increased risk of becoming frail over 3–4 years of follow-up compared to non-frail participants.

Figure 1. Survival curve estimates (unadjusted) over 72 months of follow-up by frailty status at baseline: Frail (3 or more criteria present); Intermediate (1 or 2 criteria present); Not frail (0 criteria present). Source of the Figure: [1]



While the risk of adverse outcomes such as the first hospitalization, the first fall, worsening disability and death seems to increase linearly from the state of non-frailty, to pre-frailty and frailty [1], little is known on the state of pre-frailty. Although this state is predictive of adverse health outcomes, it has been poorly characterized until today. Likewise, to our knowledge, the health state of the “youngest old” has not been described with a detailed and systematic method with respect to the distribution of frailty, disability and chronic morbidity. The frailty syndrome might be partly reversible, at least during its first stages [16]. Although frailty is sometimes associated with disability and with co-morbidity, these three entities are distinct [10]. Co-morbidity and frailty are independent risk factors for disability, but decreased activity due to disability could increase the risk of specific diseases or frailty [10]. In the same way, a systematic review [17] suggests that frailty may lead to cardio-vascular disease (CVD), just as CVD may lead to frailty. The presence of a chronic disease can contribute to the development of frailty. Frailty has been associated with several chronic diseases [18]: CVD [17, 19], diabetes [20] and hyperglycemia [21], obesity [22], chronic kidney disease, among others. To our knowledge, few studies [22] have described the relationship between frailty and obesity. Since involuntary weight loss is one of the frailty criteria, the description of the association between frailty and obesity can be distorted by several potential biases including reverse causality and selection bias.

III. Adiposity, diet, and physical activity (Project 2)

Overweight and obesity are important risk factors for chronic diseases and disability [23] [24]. In this context, it is important to have a more precise picture of how the young old eat and expend energy, and how these behaviors are affected by socioeconomic factors.
The youngest old experience a substantial risk of both obesity and frailty [1, 22]. It appears that both obesity and frailty have links with chronic diseases and disability. Improving dietary habits [25, 26] and increasing PA seem to be the most effective ways to decrease body weight and improve mobility and survival [23]. PA is helpful for reducing the consequences of both obesity [27] and frailty [28]. A positive association between PA and socio-economic status (SES) has often been described [29, 30]. As regards eating habits, a Swiss study in Lausanne (CoLaus, age range 40-82 years) [31] has reported low levels of compliance to the dietary recommendations. Only 39% and 7% complied with the Swiss recommendations for fruit ($\geq$ 2/day) and vegetables ($\geq$ 3/day). Positive links have been observed between dietary

knowledge and compliance, and marital status [32], SES [29], female sex, and higher fast-food prices [33]. In Switzerland, a study has reported a consistent association between the prevalence of overweight and educational level over 4 cross-sectional national health surveys [4]; but the financial situation was not recorded.

Body composition changes [34], and abdominal fat increases with advancing age, especially among women [35], reflecting a decline in PA-related energy expenditure (rather than resting energy expenditure). Whenever accurate measures of body composition (DEXA…) are lacking, BMI is not reliable enough for describing body composition; waist circumference (WC) is often used as a surrogate measure of fat mass distribution, both intra-abdominal and overall body fat [36] [37]. Increases in fat mass might not be reflected in proportional increases in anthropometric indicators. However, according to Flegal et al. [38], BMI and WC may be inaccurate measures of percentage body fat for an individual, but they correspond well overall with percentage body fat within sex-age groups and distinguish categories of percentage body fat. BMI calculated from self-reported height and weight is underestimated [39, 40].

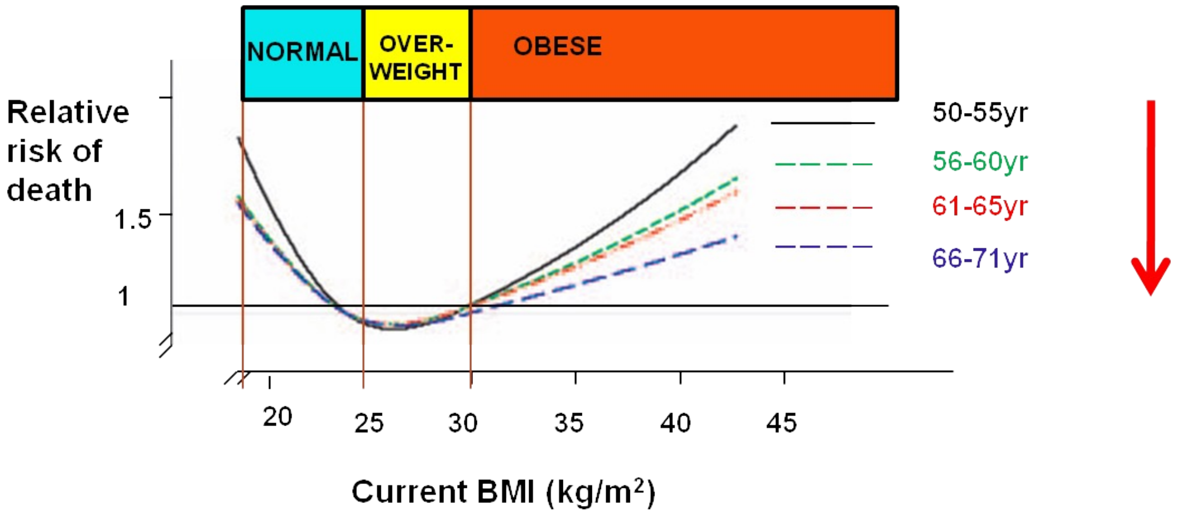
The Mini Nutritional Assessment (MNA) is a widely used tool to assess the risk of malnutrition in older persons [41]. Abdominal obesity is often defined if WC exceeds ≥102 cm for men and ≥88 cm for women [42]. Risk factor associations change with increasing age [43]. Eating habits, PA and adiposity differ between men and women [44, 45].

A large European cross-sectional study found a strong association between low levels of PA during work and leisure time and obesity, while adjusting for education and total energy intake [46]. However, low PA can lead to obesity [47], and obesity can lead to low PA [48]. Several studies have described associations between low SES and suboptimal diet [29] and PA [49], as well as the links of these behaviors with odds for being overweight or obese [50].

IV. Obesity, body composition, and mortality (Project 3)

The relationship between BMI and mortality has been suggested to be U or J-shaped in several prospective studies [3, 51]. The relative risk of mortality in the overweight category was often below 1 (compared with normal BMI) in the US nationally representative National Health and Nutrition Examination Surveys [6]. When patients consult their general practitioner, it seems that the same reference norm (BMI between 18.5 and 24.9 kg/m^2) is recommended for adults of all age groups (website: UpToDate: http://www.uptodate.com/online/, key word: Obesity). This classification has been proposed by the World Health Organization, and has many advantages (for example, for comparisons between studies or countries). However, the relative risk of mortality by BMI category differs across age groups (among other characteristics, such as ethnic groups): while obesity is associated with an increased risk of mortality, this relationship seems to be much weaker after age 65 years [3, 6, 52-54]. The U-shape BMI-mortality relationship is even flattening after age 60 years, and its nadir seems to increase from around 23 to 27 kg/m^2 [55-58]. After age 60 years, it seems unfavourable to have a low BMI [54, 59-62], and authors suggest that the BMI threshold for defining underweight should be raised from 18.5 to 20 kg/m^2 [63]. In the large National Institutes of Health–AARP cohort, the elevated risks associated with both extremely high and extremely low values of BMI declined slightly with increasing age in both men and women [3] (**Figure 2**).

Figure 2. Association between current BMI and relative risk of death, adapted from Adams *et al*. [3]



In her meta-analysis [7], involving more than 2.88 million individuals and more than 270 000 deaths, Flegal reported that overweight was associated with significantly lower all-cause mortality (both in studies with participants of all ages and in studies with participants ≥65 years). In studies including only participants aged ≥65 years, BMI ≥35 kg/m^2 was not significantly associated with increased mortality (but there was significant heterogeneity). She considers that using predefined standard BMI groupings has the advantage of facilitating between-study comparisons. A meta-analysis in community-based adults aged ≥65 years (197,940 individuals) found that for older populations, being overweight was not associated with an increased risk of mortality (the reference was a BMI (in kg/m^2) of 23.0–23.9); however, the risk of mortality increased with a BMI <23.0. [64] Mortality risk began to increase for BMI >33.0. They concluded that the WHO healthy weight range may not be suitable for older adults and the interpretation of BMI for this group should be in the context of other existing co-morbidities and functional capacity. They also indicated that monitoring weight status in those individuals with a BMI <23.0 would seem appropriate to detect weight loss promptly and address modifiable causes.

A longitudinal study of more than 12 millions Korean adults [65] observed that the optimal BMI increased with age. Among men, the age-specific optimal BMI was 23.0–25.9 (kg/m^2) at 18–34 years, 24.0–27.9 at 45–54 year, and 25.0–28.9 at 65–74 years. Among women, it was 15.5–24.9 at 18–34 years, 21.0–26.9 at 45–54 years and 24.0–28.9 at 65–74 years (with adjustment for age, smoking status and known pre-existing illness). The study reported a reverse J-curve (increased risks above and below optimal BMI ranges). Sex-age-specific optimums were generally higher than the WHO normal weight (BMI of 18.5–24.9). A Swiss study [5] involving 9,853 participants aged 25-74 years (MONICA participants) reported that after adjustment for age and sex the association between BMI and all-cause mortality was J-shaped (in non-smokers) or U-shaped (in smokers). Obesity, but not overweight was associated with excess mortality, mainly because of an increased risk of death from CVD and cancer.

After age 65 years, adults with BMI <25 kg/m^2 might be of a lower SES and/or suffer from malnutrition or disease. Low BMI seems to be associated with increased mortality in old age [66] through mechanisms including weight loss, chronic diseases, frailty, and cachexia [67]. Low BMI and high body fat percentage were independently associated with increased mortality in a large cohort [67]; according to its authors, BMI is often used as a proxy for adiposity even though it more closely reflects lean mass than fat mass. The loss of muscle mass probably plays an important role in the flattening of the U-shape BMI-mortality relationship. According to Zamboni [9], central fat and relative loss of fat-free mass may be more important than BMI in assessing the risks of obesity in older persons. Indicators of fat distribution such as WC seem more important than BMI. With increasing age, fat mass increases, while muscle mass decreases [68-70]. This loss of muscle mass is associated with functional impairment and physical disability, [71] affects quality of life, and has important financial consequences for the health care system [72]. According to the European Working

Group on Sarcopenia in Older People (EWGSOP), sarcopenia is a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death [73]. The shape of the relationship between muscle mass and function is still debated: the age-related changes in muscle mass and strength might not be exactly parallel. According to the EWGSOP, sarcopenia diagnosis requires the presence of both low muscle function (strength or performance) and low muscle mass [73]. Authors studying interactions between obesity and sarcopenia suggest that obesity and muscle strength should be considered jointly (rather than obesity and muscle mass) when estimating the risk of functional limitation and mortality.[74]

In a study with 33 years of mortality follow-up, Stenholm *et al.* observed that among participants aged 70 years and older at baseline, obesity was inversely associated with mortality and low handgrip strength positively associated with mortality. (In the old age group (70 years and older), overweight and obese participants with high handgrip strength had significantly lower mortality than normal-weight participants with high handgrip strength). They proposed several explanations for the inverse association between obesity and mortality in older adults, including selection bias, pre-existing chronic diseases, weight history, fat redistribution and protective role of extra caloric stores [75]. Sarcopenic obesity should be further studied in future research [9].

Increasing BMI might reflect higher fitness levels and greater metabolic reserve, leading to higher survival. Overweight persons might therefore represent healthy individuals. In the Nurses' Health Study, a large cohort with 16 years of follow-up, high WC was strongly and positively associated with cardio-vascular disease mortality, independently of BMI [76]. Yet, a systematic review (including mainly cross-sectional studies) [77] compared the discriminatory power of BMI, WC, and WHR in terms of cardiovascular risk and concluded that no adiposity measure had superior discriminatory capability. Price [66] *et al.* compared the associations of BMI, WC, and WHR with mortality and cause-specific mortality in a longitudinal study of persons aged ≥75 years. They concluded that, unlike BMI, increased WHR, indicating abdominal obesity, was associated with increased mortality HRs in men and women. Likewise, the “healthiest” WC category is not clearly identified in the population aged 65 and over [78]. According to studies comparing the predictive value of WC, WHR and BMI, there is still controversy about the indicator with the highest predictive value for the risk of myocardial infarction [79] and death [66].

The literature [80] suggests that it is important to record past weight loss in studies about the relationship between adiposity and mortality, and it is crucial to know if it was intentional [9]. Unintentional weight loss might reflect existing disease. Small amounts (5-10% of initial weight) of voluntary weight loss seem beneficial in older adults [9]. Therefore, studies on the association between obesity and mortality often exclude mortality in the first few years of follow-up [81, 82] in order to reduce a reverse causation effect due to pre-existing disease.

As discussed in the previous paragraphs, uncertainties remain on the shape of the relationship between BMI and risk of death, and on the possible variations of this relationship with age. The BMI-mortality association is difficult to study because of three main types of bias: reverse causation, selective survival bias, and selection bias [83]. These biases might be amplified when the sample under study is restricted to individuals with severe diseases or with diseases caused by obesity. “If subjects have experienced disease-induced weight loss before measurement of body weight (the exposure), this leads to reverse causation. If the disease caused both weight loss and increased mortality, weight loss can give the wrong impression that normal or underweight individuals are more likely to die than those with higher BMI.“ [83, 84] Selective survival is more likely to affect studies of older persons, since susceptible individuals are already deceased [9, 85]. It biases the BMI-mortality relationship if obese individuals with a disease were less likely to survive to participate in a study than normal weight individuals. So the study includes obese subjects who are less susceptible to die from the disease under study.

According to Stevens *et al*., these issues should be evaluated carefully before concluding that obesity is protective. These types of biases are very difficult to study, which is why the literature on the field has controversies. According to Stevens *et al*. [83], the obesity paradox should not interfere with public health efforts: the obesity paradox applies in the main to individuals who have a disease [83] [86]. In general, obesity should be prevented and treated. Obesity has consistent effects on the incidence of diabetes, CVD, certain types of cancer, sleep apnea, osteoarthritis of the knee, and disability [83].

It has been suggested that adiposity status at midlife [87] or maximum lifetime BMI [84] may be better mortality predictors, as they are less prone to the aforementioned biases [84]. Ideally, the lifetime duration of exposure to obesity should be recorded. Several studies [88] [84] [87] [3] [89] support consideration of life-course trajectory of BMI. A study with 12-years mortality follow-up, taking into account life-course BMI trajectory (BMI had been measured twice, in 1974 and 2000) did not support the existence of an obesity paradox in late life [88]. Men who were either constantly overweight or who changed from overweight in midlife to normal weight in late life had poorer prognosis (higher mortality rates) and more frailty and disability in late life than men with constantly normal weight over the life course. The authors concluded that a healthy lifestyle, including weight control, is worthwhile to maintain throughout life. However, this study did not record whether weight loss was intentional. Strandberg *et al.* [88] suggest that frailty may be an intervening mechanism between weight loss after midlife and higher mortality risk in later life.

Stokes *et al.* [84] observed that studies of the relationship between obesity and mortality are usually based on weight recorded at a single point in time. Therefore, there is no distinction between non-obese individuals who were never obese and non-obese individuals who were previously obese and lost weight. They compared four models representing different combinations of weight at survey and lifetime maximum weight. They found that the most successful models used data on maximum weight, and the worst-performing model used only data on weight at survey. Those who have lost weight have exceptionally high mortality, and this distortion (mainly in the normal weight group) makes overweight and obesity appear less harmful. They suggest that the effects of weight excess on US mortality have been consistently underestimated because most studies are based on BMI at survey.

Janssen and Bacon [87] also compared the effect of current and midlife obesity on mortality. They analyzed data from 3,238 participants from the original Framingham Heart Study cohort who lived to at least 70 years of age and who had BMI measures from when they were in their 50s. "Compared to 70-year olds who were non-obese at both 50 and 70 years of age, mortality risk was increased by 47% ($P < 0.001$) in those who were obese at both 50 and 70 years of age, increased by 56% ($P < 0.001$) in those who were obese at 50 years of age and non-obese at 70 years of age, and not significantly different ($P > 0.9$) in those who were non-obese at 50 years of age and obese at 70 years of age (newly obese older adults)." They concluded that midlife and current BMI had independent effects on mortality risk. "Although mortality risk was increased in obese older adults who were already obese at midlife, this was not the case for newly obese older adults. Conversely, non-obese older adults who were obese at midlife had an increased mortality risk." Therefore, BMI at midlife should not be overlooked when considering an older adult's BMI.

Adams *et al*. [3] observed similar findings: when they analyzed recalled BMI at the age of 50 years in relation to the risk of death, the results were stronger than those based on the current BMI after excluding participants who had died during the early years of follow-up. They reported an increased risk of death of 20 to 40 percent among persons who were overweight (BMI between 25.0 and 29.9 kg/m^2) at the age of 50 (compared with normal BMI). They suggested that within the 10-year time frame of their study, using weight at a younger age was more effective in accounting for preexisting disease than using current BMI and excluding participants who died during the initial years of follow-up. Adams et al. confirmed this observation in a more recent cohort study of men and women aged 50-71 years at entry in 1995-1996 [90]. They estimated HRs of total and cause-specific mortality for recalled BMI at ages 18, 35, and 50 years, weight change across 3 adult age intervals. "Weight gain was positively related to mortality, with stronger associations for gain between ages 18 and 35 years and ages 35 and 50 years than between ages 50 and 69 years. Mortality risks were higher in persons who attained or exceeded a BMI of 25.0 at a younger age than in persons who reached that threshold later in adulthood, and risks were lowest in persons who maintained a BMI below 25.0. Heavier initial BMI and weight gain in early to middle adulthood strongly predicted mortality risk in persons aged 50–69 years."

V. Obesity and disability (Project 3)

Many definitions of disability exist [91, 92]. Linda Fried defines disability as "difficulty or dependency in carrying out activities essential to independent living, including essential roles, tasks needed for self-care and living independently in a home, and desired activities important to one's quality of life"[10]. In project 3, difficulty with the basic activities of daily living defined by Katz [93] will be used for assessing disability. Disability is a dynamic process which can be in part reversible [94] [95, 96].

While life expectancy is increasing in developed countries, the evolution of disability-free life expectancy differs across developed countries [97, 98]. Since overweight and obesity are risk factors for disability rather than mortality, many studies suggest that years spent with disability will increase because of the obesity pandemic [36, 91, 99-103]. Majer et al. [91] compared life expectancy and life expectancy with disability among normal weight, overweight, and obese smokers and nonsmokers in Western Europe, using data from the European Community Household Panel. They concluded that daily smoking was associated with mortality more than with disability, while obesity was associated with disability more than with mortality. They suggested that tobacco control would improve life expectancy, while "tackling the obesity epidemic is necessary to prevent an expansion of disability." Some studies have shown no effects of overweight on disability, or a moderate effect [101] [104]. Whether weight loss can improve mobility without increasing mortality in overweight older persons remains unclear. In this context, it would be interesting to compare the links of both BMI and WC with disability.

It has long been shown that smoking, BMI, and exercise patterns predict future disability. Not only do persons with better health habits survive longer, but in such persons, disability is postponed and compressed into fewer years at the end of life [105]. Wong *et al.* [106] observed that obesity, diabetes and smoking had independent, cumulative effects on future disability, mortality and survival free of disability; they developed an algorithm which led to the observation that "a 45-year-old man/woman with the combined risk factors of obesity, diabetes and smoking has similar likelihood of surviving free of disability to a 65-year-old man/woman without any of the same risk factors." Wong *et al.* [100] also calculated that disability prevalence among Australians aged 55-74 would have been 10% less than observed if the rates of obesity and diabetes observed in 2000 had been as low as the levels observed in 1980; disability prevalence would have been an additional 13% if instead the prevalence of obesity and diabetes had been as high as the levels expected in 2025. They estimated that in Australian adults by 2025, around 26% of disability cases would have been avoidable if there had been no change in obesity and diabetes prevalence since 1980. According to them, the significant lifestyle predictors in mid-life for disability in old age include obesity, diabetes, smoking and hypertension.

A longitudinal study on the risk of periretirement age disability compared the associations of five different anthropometric measures of body mass and shape (weight, BMI, WC, hip circumference, and WHR) with disability after 5 years. WC best predicted risk for most disability outcomes (among measured gait speed, self-reported mobility problems, instrumental and ordinary activities of daily living (I/ADLs)) in men and women [107]. Another study [108] with a follow-up of 14 years (using logistic regression) reported that BMI and WC predicted disability (BADL and walking 200-300 meters) well in men and women. A review [109] concluded that BMI and WC are emerging as the more consistent predictors of the onset or worsening of mobility disability, and it also included studies assessing difficulty with ADL.

Al Snih *et al*.[110] examined the relationship between BMI and ADL limitation in cross-sectional data from 6 Latin American cities (6,166 participants). Compared to the reference category (BMI 18.5-24.9 kg/m^2), the lowest OR for ADL limitation was BMI 25.0-29.9 (OR 1.10, 95% CI 0.93-1.30), and the highest OR for ADL limitation was for a BMI of 35.0 or higher (OR 1.63, 95% CI 1.26-2.11). They concluded that obesity is an independent factor contributing to ADL disability in this population and should be included in future planning to reduce the impact of disability on global health.

Backholer et al. [111] carried out a meta-analysis of cross-sectional and longitudinal studies and observed that body weight increases the risk of disability (defined as impairment in ADL) in a graded manner. They stressed that additional longitudinal studies are needed with measured height and weight, incident ADL questions, a range of ages, and large numbers of obese class III individuals. Using data from the Melbourne Collaborative Cohort Study, they also observed a graded relationship between BMI at middle age and disability in old age [112]. In this study, Backholer *et al*. reported a significant association between overweight and disability in women but not in men.

According to Al Snih *et al*., [113] "the link between obesity and subsequent disability is probably established through multiple pathways. Obesity is associated with several conditions that, in turn, are risk factors for subsequent disability, including osteoarthritis of the weight-bearing joints, diabetes mellitus, and cardiovascular disease. In addition, while muscle mass increases along with fat mass in obese individuals, muscle strength per gram of muscle tissue actually declines with increasing adiposity." In the longitudinal Osteoarthritis Initiative [114], participants (aged ≥60 years) in the highest WC quartile experienced a lower quality of life, a decline in physical function, and a slightly increased risk of disability over 6 years (using the Late-life Disability Index). IWL has also been associated with decline in ADL function [115]. A review [94] concludes that the relationship between BMI and disability is clearly non-linear. Being underweight is a risk of disability as well as being excessively obese. Other studies have described a J-shape association between adiposity and disability [116, 117]. According to Rejeski *et al*., [94], "obesity at age 30 years constitutes a greater risk for disability later in life than when obesity develops at age 50 years or later. But PA may buffer the adverse effects obesity has on late life disability."

AIM AND OBJECTIVES

Purpose of the PhD research project

To study in detail health characteristics related to the development of frailty criteria, lifestyles, adiposity and their links with disability in the general population of Lausanne aged 65-70 years at baseline:

Project 1: to describe the links between individual frailty criteria and specific chronic diseases (cross-sectional analysis)

Project 2: to describe eating habits, daily physical activity, and sports frequency, the links of these behaviours with socioeconomic factors, and with adiposity (cross-sectional analysis)

Project 3: to examine the association between BMI and WC with mortality and autonomy in basic activities of daily living after up to 8 years of follow-up (longitudinal analysis) and to identify optimal BMI/WC categories in terms of disability risk.

General methodology: presentation of Lc65+ cohort study

I. Design

The Lausanne cohort Lc65+ [2] has been carried out in order to study the determinants, the manifestations and outcomes of frailty from its earliest stage in the general population of Lausanne aged 65 and over. It is a longitudinal, observational study started and carried out by the Institute of Social and Preventive Medicine at the University of Lausanne Hospital Centre (Switzerland), in collaboration with clinical partners from the University of Lausanne Hospital Centre (CHUV) and Department of Community Medicine and Health [2]. Three consecutive samples of about 1,500 individuals each, representative of the general community-dwelling population, are followed up from age 65 to death.

II. Recruitment process and inclusion criteria

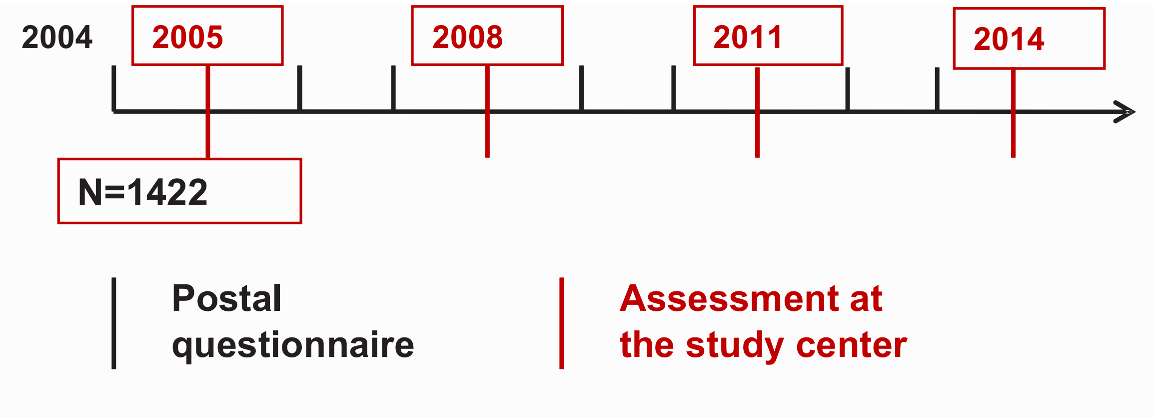
The first stage of sampling and recruitment into the study took place in 2004. The successive samples were recruited in 2009 and 2014 with the same procedure. In order to be included in the first wave, all subjects had to be residents of Lausanne and to be 65 to 70 years old in 2004. Exclusion criteria were defined by being institutionalized or being unable to respond due to advanced dementia. A list of 4,879 residents born between 1934 and 1938 was provided in 2003 by the Population Office of Lausanne. They were randomly allocated to either a study of cardio-vascular diseases [8] (N=1,643, 33.7%) or the Lausanne cohort Lc65+ study (N=3,236, 66.3%). The selection for both studies was made by simple random sampling. Of the 3,236 residents allocated to the Lc65+ study, 36 (1.1%) individuals living in an institution were excluded. 144 (4.5%) persons were further excluded after an update of the list by the Population Office in 2004 (dead or moved away). In 2004, all 3,056 eligible residents received an invitation letter together with an initial self-administered questionnaire.

The response rate was 68.6% (2,096/3,056 mailed questionnaires). 1,567 (74.8%) persons agreed to participate and 529 (25.2%) refused. There was no significant difference in gender nor in birth year distribution [2] between the participants and the non-participants. Participants' socio-economic characteristics were similar to those of the general population of Lausanne of the same age category (aggregate statistics from the Population Office or 2000 Swiss national population census). Among the multiple possible proposed reasons, refusals were mostly motivated by a general unwillingness to participate in any survey (57.8%) or to agree to follow-up contacts (53.9%). Of the 1,567 respondents to the initial questionnaire, 3 subjects were later considered ineligible, leaving 1,564 valid observations. In 2005, all participants were invited to undergo the baseline assessment; 1,524 (97.4%) were still alive and eligible and 1,422 participated.

III. Assessment process

Baseline data were collected using a self-administered questionnaire sent to the subjects' home at recruitment, followed by an in-person interview at the study centre with anthropometric measurements and performance tests performed by trained medical assistants. The Lc65+ follow-up includes an annual self-administered questionnaire, and every third year, all participants undergo an interview and a physical examination at the study centre (**Figure 3**).

Figure 3. Design of Lc65+ cohort, first wave recruited in 2004



IV. Initial self-administered questionnaire at home (2004)

In order to allow comparison with other major population-based health surveys in Switzerland and Europe, the questionnaire included items used in the Swiss health surveys (Federal Office for Statistics), the MONICA study [118] [119] and the SHARE European survey [120]. The questionnaire contained, among others, questions on self-reported chronic medical diagnoses.

V. Specific Methodology

A. Project 1

Cross-sectional analysis of data collected at baseline in the first Lc65+ study sample. In 2005, 1,422 participants (93.3%) underwent the frailty assessment (59% women) and 1,416 could be classified as non-frail, pre-frail or frail according to an adaptation of Fried's phenotype, [1] based on the five criteria (shrinking, weakness, exhaustion, slowness and low activity, **Table 1**). [1] Disability in basic or instrumental activities of daily living (BADLs or IADLs) was assessed according to two questions: *"During the last four weeks, did you have difficulty with performing the following activities: taking a shower or a bath, getting dressed, eating, getting in/out of bed or of arm-chair, using the toilets?"* (BADLs) [93], and *"During* *the last four weeks, did you have difficulty shopping or performing your usual tasks at home?"* (IADLs). There were three possible answers: *No, I have had no difficulty at all; I have had difficulties with one or more of these activities, but I didn't get help;* and *I have received help with one or more of these activities*. Participants who had received help were considered to have disability.

All chronic diseases were self-reported medical diagnoses. Items on self-reported medical diagnoses of diseases ("Has a doctor ever told you that you had…?") assessed coronary heart disease (CHD), other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, osteoporosis, arthritis, cancer, gastrointestinal ulcer, depression, and hypercholesterolemia. In accordance with the lists of medical diagnoses used in SHARE [121, 122] and the Cardiovascular Health Study (CHS) [1], only eight of these diagnoses were included in the variable "number of chronic diseases": CHD, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, arthritis, and cancer. "Other heart diseases" included congestive heart failure, cardiac valvular disease, and heart muscle disease.

Table 1. Operationalization of frailty characteristics in the Cardiovascular Health Study (CHS) [1] and the Lausanne cohort Lc65+ study, reproduced from Santos-Eggimann *et al.*[2]

Frailty	Criteria	
	Cardiovascular Health Study	Lausanne cohort Lc65+ Study
Characteristic		
Shrinking	Unintentional weight loss >10 pounds in prior year	Any reported unintentional weight loss in prior year
Weakness	Grip strength: lowest 20% (according to sex and body mass index)	Grip strength: application of CHS sex- and body mass index–specific cut-off values[a]
Poor endurance, exhaustion	Exhaustion self-report (CES-D Depression Scale): responds “a moderate amount of the time (3–4 days) or most of the time” to either statement “I felt that everything I did was an effort” or “I could not get going” in the last week.	Exhaustion self-report: responds “much” to the question: “Did you have feelings of generalized weakness, weariness, lack of energy in the last four weeks?”
Slowness	Walking time/15 feet: slowest 20% (by gender, height)	Walking time/20 meters: application of CHS gender- and height-specific cut-off values
Low activity	Physical activity self-report: lowest 20% kcal/week expenditure, according to sex, estimated from the short version of the Minnesota Leisure Time Activity questionnaire	Physical activity self-report: 1) doing <20 minutes of sports per week, 2) walking <90 minutes per week, and 3) avoidance of climbing stairs or carrying light loads in daily activities[b]
Classification		
Nonfrail or robust	0 criterion present	0 criterion present
Intermediate, possibly prefrail	1–2 criteria present	1–2 criteria present
Frail	3–5 criteria present	3–5 criteria present

[a]The grip strength test was performed on the right hand (Baseline [R] hydraulic dynamometer, using the best of three measurements).

[b]Low activity was defined when all three statements were fulfilled. This measurement of physical activity based on three questions has been adapted from the Monitoring of Trends and Determinants in Cardiovascular Disease Physical Activity Questionnaire [118] to suit activity patterns of individuals aged 65–70.

For additional information on methods, see Appendix I.

B. Project 2

Cross-sectional analysis of Lc65+ cohort at baseline, including 1,260 adults from the general population of Lausanne aged 65-70 years. Eating habits and PA were assessed by questionnaires. Questions on eating habits stemmed from the Mini Nutritional Assessment [41]. The variable “Daily PA and sports” is a combination of a 4-category variable (A) daily PA, further dichotomized around use, versus avoidance of stairs and loads) and a binary variable (B) sports frequency): A) Daily PA: “*Which statement best describes your current daily physical activity? 1) I am sitting or lying most of the time and I am not moving much*; *2) I often walk, but I avoid taking stairs and carrying loads; 3) I often walk and I take stairs, I carry light loads; and 4) I make an important physical effort, I often carry heavy loads.”* In **Figure 5**, categories 1) and 2) of daily PA are aggregated and labeled “No stairs”; categories 3) and 4) are aggregated and labeled “Stairs”. B) Sports frequency*: “How often do you play sports for at least 20 minutes (for example, gymnastics, tennis, running, football, biking…)? <1x/week; versus ≥1/week.”*. “No sport” is the label for sports frequency <1x/week in **Figure 5.** Body mass index (BMI), supra-iliac (SISF), triceps skin-folds (TSF), waist circumference (WC), and WHR were measured.

For additional information on methods, see Appendix II.

C. Project 3

Longitudinal analysis of Lc65+ data collected from baseline (2004-2005) to 2013 in the first study sample.

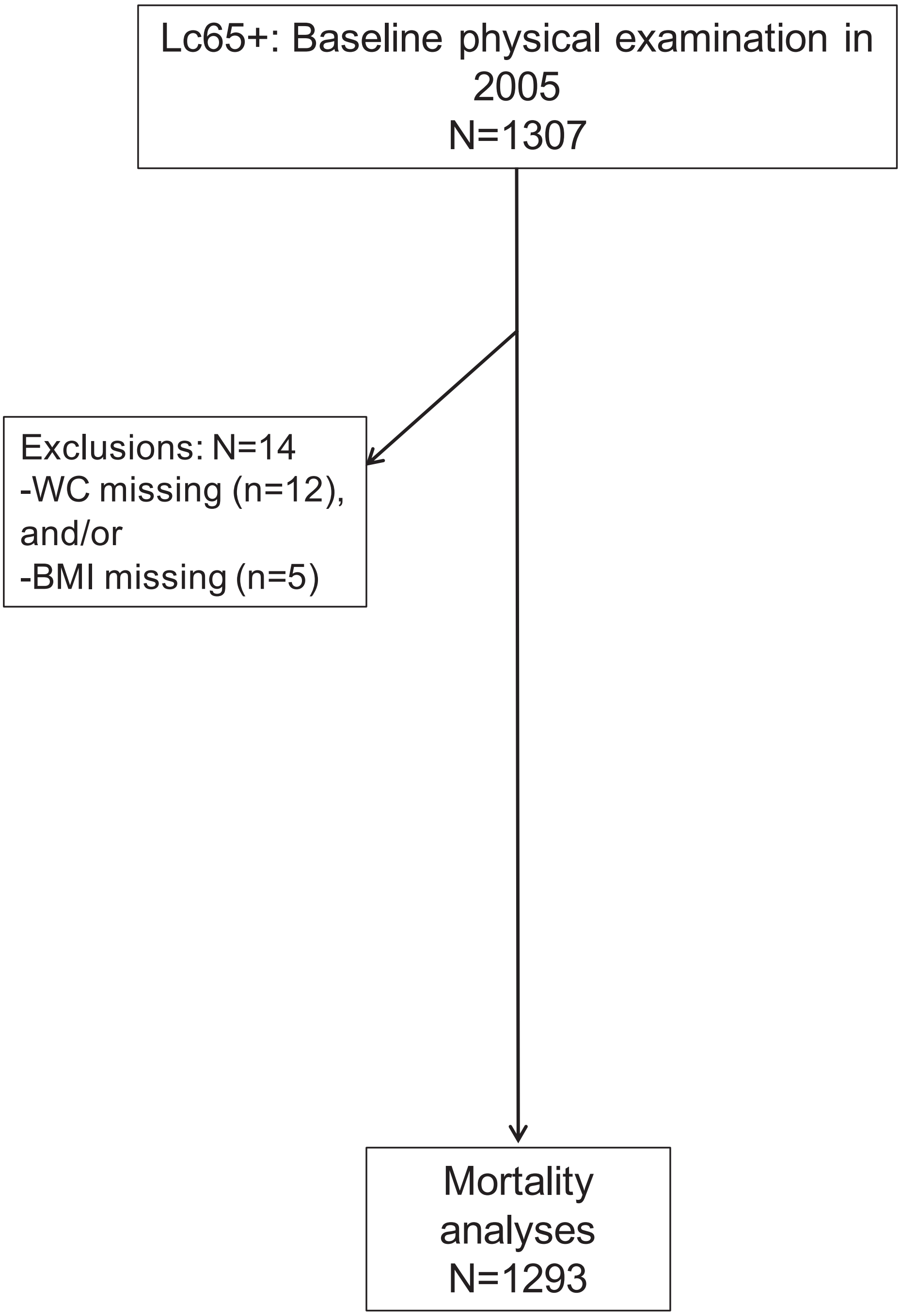
The **Figure 4** shows the flow charts of the analyses about mortality and disability. BMI, WC and covariates were measured at baseline in 2004-2005. Vital status was obtained up to the 31st December 2013 and difficulty with basic activities of daily living (BADL) was reported in a self-administered questionnaire sent to participants every year. The 5 questions assessing difficulty with BADL were based on Katz’ definition [93]: “*Do you have difficulty,* *or do you usually receive help with performing the following activities?: a) getting dressed, including putting on socks and shoes, b) taking a bath or a shower, c) eating, including cutting foodstuffs, d) getting in/out of bed, e) getting on and off toilet?* Each question allowed for three answers: "*No difficulty at all; difficulties but no help; and I receive help".* Participants who reported any difficulty or received help for ≥ one of the five items were considered to have difficulty with BADL. Difficulty with BADL is reversible from year to year. Therefore, in the statistical analysis, the outcome "difficulty with BADL" was considered to have occurred if it had been reported for at least 2 consecutive years. Time at risk for this outcome was considered from baseline until the first year of occurrence of either difficulties with BADL or institutionalization or until the last year with information on the status of the participant. Since this outcome had to last at least 2 consecutive years, the follow-up for disability ended on the 31st December 2012, hence a maximal follow up of 7 years. Primary outcomes were total mortality and disability, defined as difficulty with BADL for ≥2 years or institutionalization. Cox regression was used with BMI/WC quintiles 2 as the reference. Unadjusted Kaplan-Meyer survival curves were produced and differences in univariate comparisons of survival distributions were tested with the log rank test. The assumption of proportional hazards was verified and confirmed for all exposure and adjustment variables with a test of Schoenfeld residuals and with graphical validation. The number of cases of deaths (130) was lower than the number of cases of disability (231); therefore the power to detect differences was higher for the analyses of disability than mortality. BMI and WC were highly correlated and were therefore analyzed in distinct Cox models.

The sample of the Lc65+ study used in project 3 is too small to precisely describe the shape between BMI or WC and mortality. In particular, the number of cases is too small. In order to study the shape of the relationship between adiposity and mortality, large study samples are needed (>4'000 participants), with many deaths. "Approximately 400 events in each age group are required to detect a ratio of relative risks of 1.5, with BMI analyzed as a dichotomous variable divided at the median (with an alpha level of 0.05 and 80 percent power). For example, if the relative risk of death above the median BMI value as compared with that below the median was 1.33 in one age group and 2.0 in another, approximately 400 deaths would be required in each age group for the study to detect this difference" [58]. Therefore, the main outcome of the PhD will not be mortality, but disability.

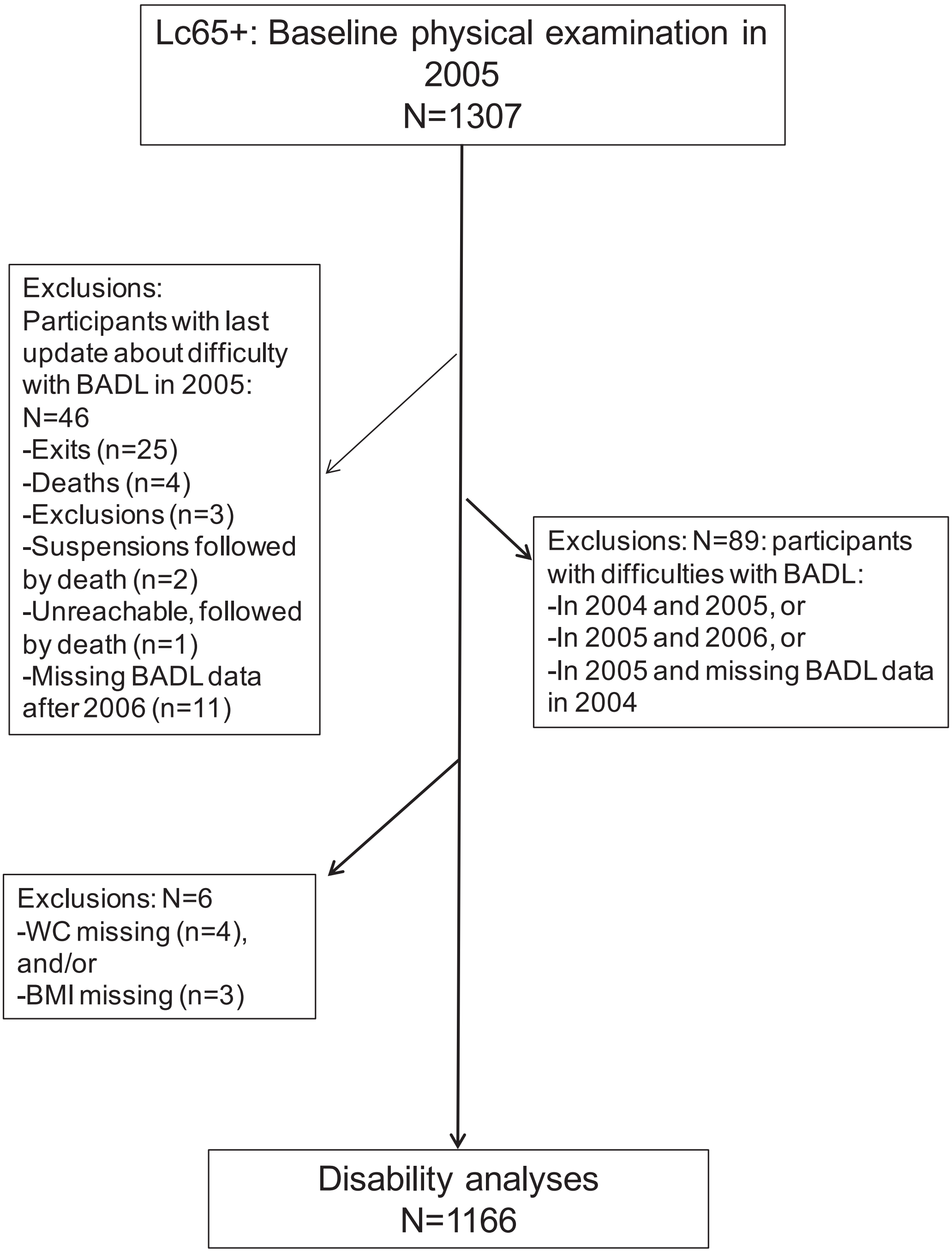
Because obesity requires many years to result in harmful effects on health [9, 85] and many chronic conditions are associated with weight loss [9], studies on the association between obesity and obesity-related outcomes generally exclude subjects with weight loss [9] or pre-existing diseases and/or mortality in the first few years [81]. To minimize potential bias and/or a reverse causation effect related to preexisting disease [82], we adjusted i) for IWL in all analyses [80] and ii) we also ran analyses after exclusion of participants who died within the first 3 years of follow-up [82]. IWL has also been associated with rapid functional decline [115] [104]. Cox models for disability included the same adjustment variables as models for mortality.

Figure 4. Flow chart of the participants included in the mortality analysis (a) and in the disability analysis (b).

a)



b)


Lc65+: Baseline physical examination in 2005
N=1307
Exclusions:
Participants with last update about difficulty with BADL in 2005:
N=46
-Exits (n=25)
-Deaths (n=4)
-Exclusions (n=3)
-Suspensions followed by death (n=2)
-Unreachable, followed by death (n=1)
-Missing BADL data after 2006 (n=11)
Exclusions: N=89: participants with difficulties with BADL:
-In 2004 and 2005, or
-In 2005 and 2006, or
-In 2005 and missing BADL data in 2004
Exclusions: N=6
-WC missing (n=4), and/or
-BMI missing (n=3)
Disability analyses
N=1166

RESULTS

Project 1 (cf. Appendix I)

Status: Published in the Journal of the American Geriatrics Society

Main findings:

At baseline, of 1,283 participants, 71.1% were classified as nonfrail, 26.4% as prefrail, and 2.5% as frail. The proportion of women increased across these three groups (56.5%, 62.8%, and 71.9%, respectively; P=.01), as did the proportion of individuals with one or more chronic diseases (68.0%, 82.8%, and 90.6%, respectively; P<.001) and the proportion with basic or instrumental ADL disability (1.6%, 10.3%, and 59.4%, respectively; P<.001). Weakness (low grip strength) was the most frequent criterion (14.3%). Prefrail participants had significantly more comorbidity and ADL disability than nonfrail participants (P<.001). When present in isolation, weakness was associated with two to three times greater prevalence of coronary heart disease, other heart diseases, diabetes mellitus, and arthritis. Similarly, a significant association was identified between exhaustion and depression (**Table 2**).

Conclusions:

The main contribution of this article to the research field is that prefrailty was common in the youngest old; weakness was the most prevalent frailty criterion and was associated with cardiovascular diseases.

Table 2. Comparison of the prevalence of chronic diseases and disability in non-frail participants (n=912) and in participants experiencing a single frailty criterion (Total n=252)

	Non-frail N=912	**Single frailty criterion**									
		Weakness (Grip), n=102		Weight loss, n=73		Low Activity, n=43		Exhaustion, n=29		Slowness (Gait Speed), n=5	
	n (%)	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value
Help needed with BADLs and IADLs			<.001[a]		.67[a]		.22[a]		.04[a]		<.001[a]
None	897 (98.4)	92 (90.2)		73 (100.0)		41 (95.3)		27 (93.1)		3 (60.0)	
IADLs only	13 (1.4)	6 (5.9)		0 (0.0)		2 (4.7)		1 (3.4)		0 (0.0)	
BADLs	2 (0.2)	4 (3.9)		0 (0.0)		0 (0.0)		1 (3.4)		2 (40.0)	
Number of chronic diseases[b]			<.001		.007		.16		.43		.74[a]
0	292 (32.0)	21 (20.6)		12 (16.7)		10 (23.3)		6 (20.7)		1 (20.0)	
1	359 (39.4)	32 (31.4)		29 (40.3)		15 (34.9)		13 (44.8)		3 (60.0)	
≥2	261 (28.6)	49 (48.0)		31 (43.1)		18 (41.9)		10 (34.5)		1 (20.0)	
Self-reported medical diagnoses											
Coronary heart disease	72 (7.9)	17 (16.7)	.003	5 (6.9)	.77	3 (7.0)	1.00[a]	1 (3.4)	.72[a]	0 (0.0)	1.00[a]
Other heart diseases [c]	45 (4.9)	13 (12.7)	.001	7 (9.7)	.10[a]	5 (11.6)	.07[a]	2 (6.9)	.65[a]	1 (20.0)	.23[a]
Stroke	11 (1.2)	2 (2.0)	.38[a]	0 (0.0)	1.00[a]	2 (4.7)	.11[a]	1 (3.4)	.32[a]	0 (0.0)	1.00[a]
Diabetes mellitus	71 (7.8)	14 (13.7)	.040	10 (13.9)	.07	7 (16.3)	.08[a]	2 (6.9)	1.00[a]	1 (20.0)	.34[a]
Hypertension	334 (36.6)	43 (42.2)	.27	34 (47.2)	.07	19 (44.2)	.32	11 (37.9)	.89	3 (60.0)	.36[a]
Hypercholesterolemia	320 (35.1)	37 (36.3)	.81	30 (41.7)	.26	16 (37.2)	.78	13 (44.8)	.28	1 (20.0)	.66[a]

	Non-frail N=912					**Single frailty criterion**					
		Weakness (Grip), n=102		Weight loss, n=73		Low Activity, n=43		Exhaustion, n=29		Slowness (Gait Speed), n=5	
	n (%)	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value	n (%)	*P*-Value
Chronic respiratory disease	62 (6.8)	9 (8.8)	.45	8 (11.1)	.17	3 (7.0)	1.00[a]	4 (13.8)	.14[a]	1 (20.0)	.30[a]
Osteoporosis	90 (9.9)	12 (11.8)	.55	10 (13.9)	.28	4 (9.3)	1.00[a]	4 (13.8)	.52[a]	3 (60.0)	.009[a]
Arthritis	291 (31.9)	49 (48.0)	.001	28 (38.9)	.22	13 (30.2)	.82	14 (48.3)	.06	1 (20.0)	1.00[a]
Cancer	104 (11.4)	6 (5.9)	.09	12 (16.7)	.18	8 (18.6)	.15	2 (6.9)	.76[a]	0 (0.0)	1.00[a]
Gastrointestinal ulcer	51 (5.6)	9 (8.8)	.19	6 (8.3)	.30[a]	3 (7.0)	.73[a]	0 (0.0)	.40[a]	1 (20.0)	.25[a]
Depression	101 (11.1)	16 (15.7)	.17	10 (13.9)	.47	6 (14.0)	.62[a]	8 (27.6)	.013[a]	1 (20.0)	.45[a]

P-values are from the chi-square test for comparison of proportions with nonfrail participants.

[a]Fisher exact two-tailed test (if expected frequency <5 in any of the cells).

[b]All chronic diseases are self-reported medical diagnoses. The number of chronic diseases included coronary heart disease, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, arthritis, and cancer (maximum number = 8).

[c]Congestive heart failure, cardiac valvular disease, and heart muscle disease.

Project 2 (cf. Appendix II)

Status: published in BMC Public Health

Main findings:

Prevalence of overweight (BMI 25.0-29.9 kg/m^2), obesity (BMI ≥30.0 kg/m^2), and abdominal obesity (WC ≥102 cm in men, WC ≥88 cm in women) was 53%, 24%, and 45% in men; 35%, 23%, and 45% in women. Intake of fruits or vegetables (FV) at least twice/day was negatively associated with male sex (prevalence of 81% versus 90%, chi-square $P<0.001$). Concerning PA in daily life, the proportion avoiding stairs was higher among women (25%) than among men (20%, chi-square $P=0.003$).

In multivariate analyses among both sexes, eating FV (**Table 3**), using stairs in daily life (“stairs”), and doing sports ≥once/week were significantly negatively associated with financial difficulties (stairs: OR=0.54, 95% CI=0.40-0.72) and positively with educational level (stairs: OR=1.68, 95% CI=1.17-2.43 for high school). Living alone was associated with eating less FV among men (OR=0.53, 95% CI=0.31–0.91), and less meat, fish, or poultry among women (OR=0.49, 95% CI=0.36–0.67, **Table 3**).

Adiposity was significantly negatively associated with PA and education. In both sexes and for all five adiposity indicators (except TSF in men), a gradual decrease in adiposity was observed from category “no stairs, sports <once/week”, to “no stairs, sports ≥once/week”, to “stairs, sports <once/week”, and “stairs, sports ≥once/week” (**Figure 5**). The prevalence of obesity (BMI ≥ 30.0 kg/m^2) was respectively 45.6%, 41.4%, 19.3%, and 17.6% in men, respectively 44.8%, 41.2%, 21.6%, and 11.0% in women in categories “no stairs, sports < once/week”, “no stairs, sports ≥ once/week”, “stairs, sports < once/week”, and “stairs, sports ≥ once/week” (chi-square and univariate test for trend P-values <0.001 in both sexes). Corresponding prevalence estimates for abdominal obesity were 69.7%, 62.1%, 44.0%, and

34.2% in men, respectively 69.0%, 68.6%, 42.3%, and 32.7% in women (chi-square and univariate test for trend P-values <0.001 in both sexes).

For all five log-transformed adiposity indicators in women, and for all indicators except SISF and TSF in men, a gradual decrease in adiposity was observed from category “no stairs, sports <once/week” (reference), to “no stairs, sports ≥once/week”, to “stairs, sports <once/week”, and “stairs, sports ≥once/week” and it was confirmed with multiple adjustment in both sexes (for example: WC in men, respectively: β = -0.03, 95% CI= -0.07-0.02; β = -0.06, 95% CI= -0.09--0.03; β = -0.10, 95% CI= -0.12--0.07; and in women, respectively: β = -0.02, 95% CI= -0.07-0.02; β = -0.08, 95% CI= -0.11--0.05; β = -0.12, 95% CI= -0.15--0.09).

Conclusion: The main contribution of this article is that in this cross-sectional study of community-based adults aged 65-70 years, using stairs in daily life was more strongly negatively associated with adiposity than doing sports ≥ once/week.

Table 3. Cross-sectional associations of eating behaviors with age, living arrangement, financial difficulties, depression, and education

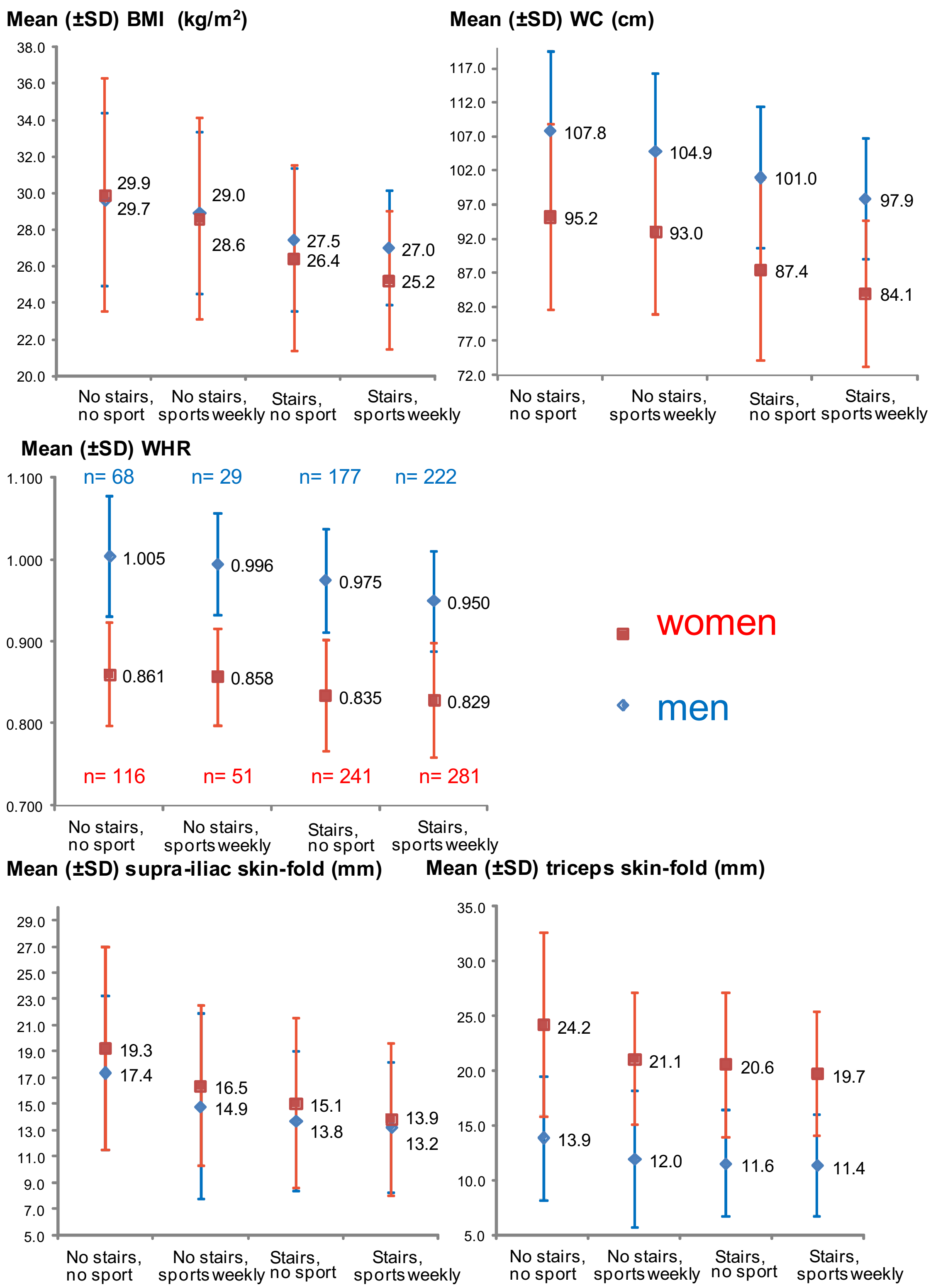
Multivariate logistic regression analysis; one separate model for each sex; approximate N=507 for men, 724 for women

	3 meals/day (versus 1 or 2) OR [95%CI]	**Dairy products ≥ once a day (yes versus no)** OR [95%CI]	**Eggs or leguminous plants ≥ twice/week (yes versus no)** OR [95%CI]	**Meat, fish or poultry everyday (yes versus no)** OR [95%CI]	**Fruit or vegetables ≥twice/day (yes versus no)** OR [95%CI]	**> 5 glasses /day (versus ≤5 drinks/day)** OR [95%CI]	**Loss of appetite (yes versus not at all)** OR [95%CI]	**Self-perception: moderate malnutrition or doesn't know (versus no problems)** OR [95%CI]
MEN								
Age (per 1-birth year)	1.0[0.9-1.1]	0.8[0.7-1.0]*	1.1[0.9-1.2]	1.1[0.9-1.2]	1.0[0.9-1.2]	1.1[0.9-1.2]	1.0[0.8-1.4]	1.0[0.7-1.5]
Living alone (0/1)	0.7[0.5-1.2]	0.7[0.4-1.2]	0.8[0.5-1.3]	0.9[0.6-1.5]	0.5[0.3-0.9]*	1.0[0.6-1.6]	2.2[0.9-5.4]	5.0[1.9-13.6]**
Financial difficulties (0/1) †	0.6[0.4-0.9]*	0.7[0.4-1.1]	0.9[0.6-1.4]	0.8[0.5-1.2]	0.6[0.4-1.0]*	1.0[0.7-1.6]	1.1[0.4-2.8]	3.2[1.2-8.7]*
Current depression (0/1)	0.7[0.4-1.1]	1.0[0.5-1.8]	0.9[0.6-1.4]	1.0[0.6-1.6]	0.7[0.4-1.3]	0.9[0.6-1.4]	2.5[1.1-6.1]*	1.6[0.5-4.5]
Education								
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	1.0[0.6-1.7]	2.0[1.1-3.7]*	1.6[1.0-2.8]	1.6[0.9-2.7]	1.2[0.7-2.2]	0.6[0.4-1.0]	1.7[0.5-6.5]	1.6[0.4-6.4]
≥ High school	1.4[0.8-2.3]	2.6[1.4-4.9]**	1.6[1.0-2.8]	1.2[0.7-2.0]	2.4[1.2-4.5]*	0.6[0.4-1.0]	1.0[0.3-4.1]	0.8[0.2-3.5]
WOMEN								
Age (per 1-birth year)	1.0[0.9-1.1]	0.9[0.8-1.1]	0.9[0.8-1.0]	1.1[1.0-1.2]*	1.0[0.9-1.2]	1.2[1.0-1.3]*	1.0[0.8-1.3]	1.1[0.8-1.5]
Living alone (0/1)	0.9[0.7-1.2]	0.8[0.5-1.2]	0.7[0.6-1.0]	0.5[0.4-0.7]***	0.8[0.5-1.4]	0.8[0.6-1.1]	1.1[0.6-2.1]	2.5[1.1-5.9]*

	3 meals/day (versus 1 or 2) OR [95%CI]	**Dairy products ≥ once a day (yes versus no)** OR [95%CI]	**Eggs or leguminous plants ≥ twice/week (yes versus no)** OR [95%CI]	**Meat, fish or poultry everyday (yes versus no)** OR [95%CI]	**Fruit or vegetables ≥twice/day (yes versus no)** OR [95%CI]	**> 5 glasses /day (versus ≤5 drinks/day)** OR [95%CI]	**Loss of appetite (yes versus not at all)** OR [95%CI]	**Self-perception: moderate malnutrition or doesn't know (versus no problems)** OR [95%CI]
Financial difficulties (0/1) †	0.8[0.5-1.1]	1.1[0.7-1.9]	0.9[0.6-1.2]	1.0[0.7-1.3]	0.5[0.3-0.9]*	1.2[0.8-1.7]	1.2[0.6-2.5]	1.4[0.6-3.3]
Current depression (0/1)	0.7[0.5-1.0]	0.8[0.5-1.3]	1.2[0.9-1.7]	1.3[0.9-1.8]	1.2[0.7-2.0]	1.1[0.8-1.5]	3.4[1.7-6.6]***	3.8[1.7-8.5]**
Education								
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	0.9[0.6-1.3]	1.4[0.8-2.5]	1.2[0.9-1.8]	1.0[0.7-1.4]	1.2[0.7-2.2]	1.2[0.8-1.7]	1.0[0.4-2.3]	1.0[0.3-2.7]
≥ High school	1.2[0.8-1.8]	1.0[0.6-1.7]	1.1[0.7-1.6]	0.8[0.6-1.2]	1.8[0.9-3.4]	1.0[0.7-1.5]	1.9[0.9-4.4]	1.6[0.6-4.2]

*P<0.05; **P<0.01; ***P<0.001. † Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).

Figure 5. Mean adiposity indicators according to category of physical activity (unadjusted), 2005



Project 3 (cf. Appendix III)

Status: manuscript accepted by the JNHA, in press.

Main findings:

The prevalence of overweight and obesity at baseline was 53.3% and 24.1% in men, respectively 35.3% and 23.5% in women. In 2006, in cross-sectional analyses, there were important differences in the distribution of difficulties in mobility and ADLs according to baseline BMI and WC categories (univariate analyses, **Table 4**). In men, BMI and WC were significantly associated with difficulties walking 100 meters, climbing one or several floors by stairs, bending; except for getting dressed and doing heavy household chores, (which were related to WC), difficulties in ADLs were not associated with BMI or WC. In women, all mobility difficulties were associated with BMI and WC, and almost all ADLs were associated with either or both adiposity indicators (except using toilets, **Table 4**).

130 persons died over a median follow-up of 8.47 years (crude mortality rate, men: 16.5/1,000 person-years, women: 9.7/1,000 person-years, **Table 5.)** In Cox regression adjusted for age, sex, education, financial situation, smoking and involuntary weight loss (IWL) at baseline, mortality was significantly associated with neither BMI nor WC, but there were trends toward non-significant J curves across both BMI and WC quintiles (**Figure 6** (Kaplan-Meyer survival curves) and **Figure 7**). Disability (231 cases) tended to increase monotonically across both BMI and WC quintiles and was significantly associated with BMI quintile 5 (HR=2.44, 95% CI [1.65-3.63]), and WC quintiles 4 (HR=1.81 [1.15-2.85]) and 5 (HR=2.58, [1.67-4.00], **Figure 6** (Kaplan-Meyer survival curves) and **Figure 7**). Although the 95% CI included 1, BMI quintile 4 and WC quintile 3 also had increased HR for disability (HR = 1.22[0.78-1.90] and 1.16 [0.71-1.88]), respectively).

Conclusions: The main contribution of this article is that BMI and WC tended to be associated along a J curve with mortality, but monotonically with disability. Almost half of the study population had a substantially increased HR of disability, as compared to the reference BMI/WC categories. This observation emphasizes the need for life-long strategies aimed at preventing excess weight, muscle loss and functional decline through adequate nutrition and regular physical activity. The literature suggests that prevention should start at early age and extend throughout life.

Table 4. Percentage with mobility difficulty and difficulty in specific ADLs in 2006 according to baseline body mass index and waist circumference

	BMI (kg/m^2)				WC (cm)				
	0<25	**25-29**	**≥30**	**Between BMI groups**	**<25%**	**25-75%**	**>75%**	**Between WC groups**	**All**
	N (%)	**N (%)**	**N (%)**	**Chi2 P-value**	**N (%)**	**N (%)**	**N (%)**	**Chi2 P-value**	**N (%)**
MEN	N=108	N=263	N=118		N=121	N=246	N=122		N=489
Mobility difficulty in 2006:									
a. Walking 100 meters	3 (2.8)	10 (3.8)	15 (12.7)	0.001	3 (2.5)	9 (3.7)	16 (13.1)	<0.001	28 (5.7)
b. Getting up from a chair	20 (18.5)	53 (20.2)	31 (27.2)	0.218	18 (15.0)	54 (21.9)	32 (27.1)	0.073	104 (21.4)
c. Climbing several floors by stairs*	26 (23.9)	72 (27.4)	55 (45.8)	<0.001	28 (23.3)	68 (27.3)	57 (46.3)	<0.001	153 (31.1)
d. Climbing one floor by stairs*	1 (0.9)	6 (2.3)	18 (14.9)	<0.001	1 (0.8)	7 (2.9)	17 (13.6)	<0.001	25 (5.1)
e. Bending, kneeling, or squatting	27 (24.6)	97 (36.9)	61 (51.3)	<0.001	20 (16.5)	103 (41.4)	62 (50.8)	<0.001	185 (37.6)
f. Catching something higher than shoulders	11 (10.0)	22 (8.3)	13 (10.8)	0.708	8 (6.6)	23 (9.2)	15 (12.1)	0.335	46 (9.3)
g. Pushing a sofa	11 (10.0)	32 (12.1)	17 (14.2)	0.627	10 (8.3)	30 (12.1)	20 (16.1)	0.169	60 (12.2)
h. Lifting or carrying ≥5 kgs	17 (15.5)	30 (11.3)	19 (15.7)	0.378	16 (13.1)	28 (11.2)	22 (17.6)	0.232	66 (13.3)

	BMI (kg/m²) 0<25	25-29	≥30	Between BMI groups	WC (cm) <25%	25-75%	>75%	Between WC groups	All
	N (%)	N (%)	N (%)	Chi2 P-value	N (%)	N (%)	N (%)	Chi2 P-value	N (%)
Difficulty in specific ADLs in 2006:	N=110	N=267	N=121		N=122	N=251	N=125		N=498
a. Getting dressed	5 (4.6)	24 (9.0)	16 (13.2)	0.071	4 (3.3)	27 (10.8)	14 (11.2)	0.038	45 (9.0)
b. Walking across a room	2 (1.8)	1 (0.4)	4 (3.3)	0.069	2 (1.6)	0 (0.0)	5 (4.0)	0.008	7 (1.4)
c. Bathing or showering	3 (2.7)	5 (1.9)	5 (4.2)	0.416	3 (2.5)	5 (2.0)	5 (4.0)	0.507	13 (2.6)
d. Eating	2 (1.8)	3 (1.1)	2 (1.7)	0.839	1 (0.8)	4 (1.6)	2 (1.6)	0.818	7 (1.4)
e. Getting in/out of bed	4 (3.7)	13 (4.9)	5 (4.2)	0.867	3 (2.5)	13 (5.2)	6 (4.8)	0.490	22 (4.5)
f. Using toilets	2 (1.8)	3 (1.1)	2 (1.7)	0.845	2 (1.7)	2 (0.8)	3 (2.4)	0.446	7 (1.4)
Instrumental ADLs:									
g. Doing light house chores	3 (2.8)	4 (1.5)	7 (5.8)	0.061	2 (1.7)	5 (2.0)	7 (5.6)	0.093	14 (2.8)
h. Doing heavy house chores	19 (17.6)	46 (17.7)	32 (27.1)	0.082	17 (14.3)	46 (18.8)	34 (27.9)	0.025	97 (20.0)
i. Preparing meals	5 (4.8)	11 (4.3)	5 (4.2)	0.975	4 (3.5)	12 (5.0)	5 (4.1)	0.791	21 (4.4)
j. Buying food	3 (2.8)	9 (3.4)	7 (5.8)	0.426	2 (1.7)	10 (4.0)	7 (5.7)	0.261	19 (3.9)
WOMEN	N=265	N=222	N=140	N=627	N=170	N=309	N=148		N=627
Mobility difficulty in 2006:									
a. Walking 100 meters	11 (4.2)	15 (6.8)	20 (14.3)	0.001	6 (3.5)	20 (6.5)	20 (13.5)	0.002	46 (7.3)
b. Getting up from a chair	62 (23.5)	84 (37.5)	82 (56.2)	<0.001	41 (24.0)	103 (32.8)	84 (56.4)	<0.001	228 (36.0)
c. Climbing several floors by stairs *	106 (39.3)	136 (59.9)	121 (79.1)	<0.001	66 (37.9)	173 (54.1)	124 (79.5)	<0.001	363 (55.9)
d. Climbing one floor by stairs *	16 (6.0)	22 (9.6)	38 (25.9)	<0.001	7 (4.1)	30 (9.5)	39 (25.0)	<0.001	76 (11.8)
e. Bending, kneeling, or squatting	95 (35.6)	108 (48.0)	107 (72.8)	<0.001	53 (30.8)	151 (47.9)	106 (69.7)	<0.001	310 (48.5)

	BMI (kg/m²) 0<25 N (%)	25-29 N (%)	≥30 N (%)	Between BMI groups Chi2 P-value	WC (cm) <25% N (%)	25-75% N (%)	>75% N (%)	Between WC groups Chi2 P-value	All N (%)
f. Catching something higher than shoulders	37 (13.8)	36 (15.8)	43 (27.9)	0.001	22 (12.8)	45 (14.1)	49 (30.6)	<0.001	116 (17.8)
g. Pushing a sofa	73 (26.8)	69 (29.4)	60 (39.0)	0.029	42 (24.0)	100 (30.7)	60 (37.5)	0.028	202 (30.6)
h. Lifting or carrying ≥5 kgs	108 (39.3)	108 (45.8)	83 (53.9)	0.013	68 (38.2)	141 (43.3)	90 (55.9)	0.003	299 (45.0)
Difficulty in specific ADLs in 2006:	N=274	N=235	N=159		N=178	N=327	N=163		N=668
a. Getting dressed	8 (2.9)	12 (5.1)	28 (17.6)	<0.001	4 (2.3)	16 (4.9)	28 (17.2)	<0.001	48 (7.2)
b. Walking across a room	1 (0.4)	3 (1.3)	8 (5.1)	0.001	2 (1.1)	5 (1.5)	5 (3.1)	0.343	12 (1.8)
c. Bathing or showering	7 (2.6)	8 (3.4)	20 (12.7)	<0.001	5 (2.8)	7 (2.2)	23 (14.4)	<0.001	35 (5.3)
d. Eating	2 (0.7)	1 (0.4)	5 (3.2)	0.032	2 (1.1)	4 (1.2)	2 (1.2)	0.994	8 (1.2)
e. Getting in/out of bed	10 (3.7)	6 (2.6)	11 (7.1)	0.078	6 (3.4)	9 (2.8)	12 (7.6)	0.036	27 (4.1)
f. Using toilets	7 (2.6)	2 (0.9)	5 (3.2)	0.230	5 (2.8)	3 (0.9)	6 (3.8)	0.090	14 (2.1)
Instrumental ADLs:									
g. Doing light house chores	8 (2.9)	5 (2.1)	13 (8.2)	0.005	4 (2.3)	11 (3.4)	11 (6.8)	0.080	26 (3.9)
h. Doing heavy house chores	102 (37.2)	100 (43.1)	89 (57.1)	<0.001	56 (31.8)	143 (43.5)	92 (58.6)	<0.001	291 (44.0)
i. Preparing meals	2 (0.7)	2 (0.8)	9 (5.7)	<0.001	2 (1.1)	3 (0.9)	8 (4.9)	0.007	13 (1.9)
j. Buying food	11 (4.0)	12 (5.1)	19 (12.0)	0.003	4 (2.3)	21 (6.4)	17 (10.4)	0.008	42 (6.3)

* stairs: without stopping

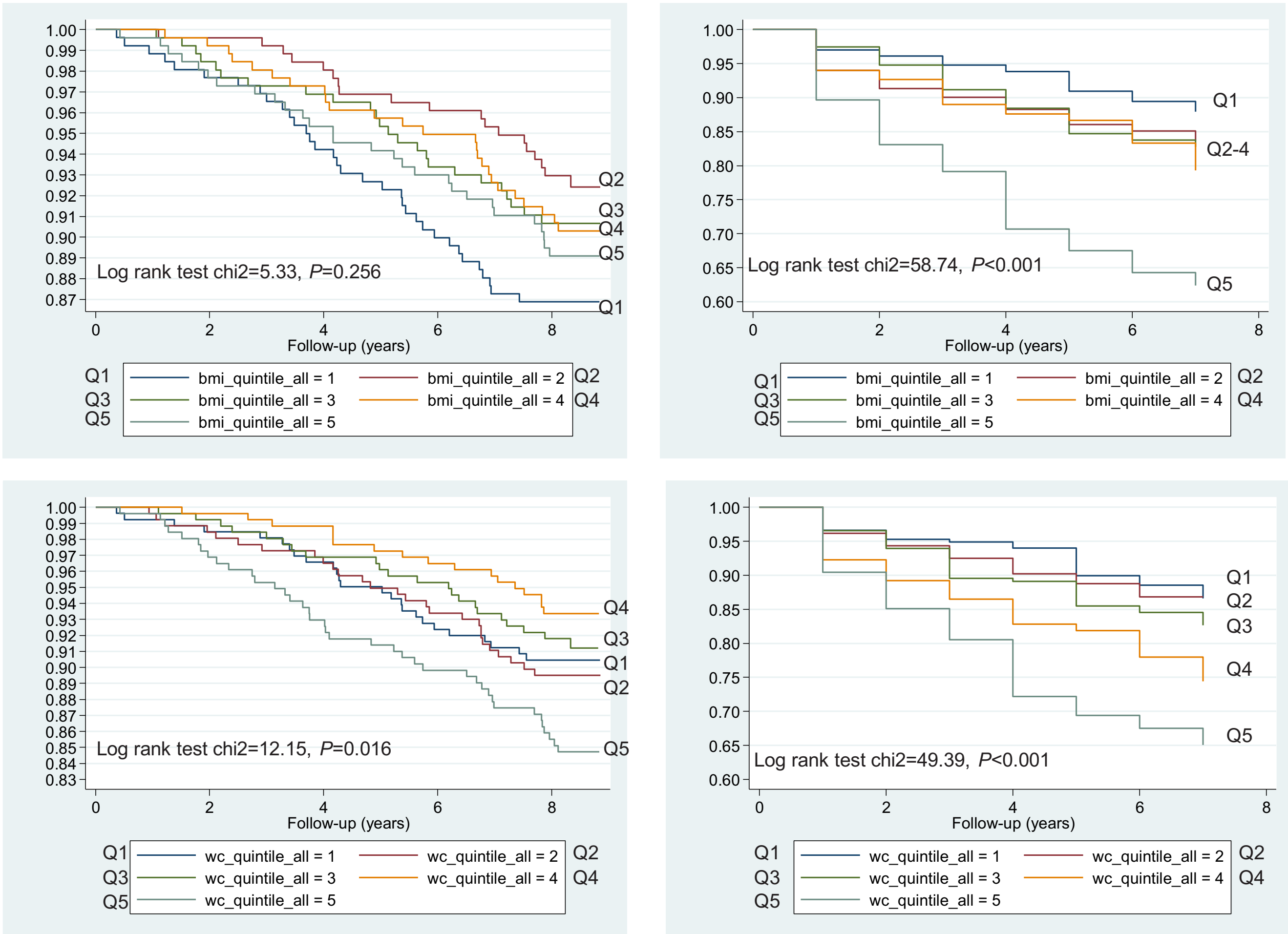
The chi2 test is used because this analysis is considered cross-sectional (BMI and WC measured in 2005; mobility and ADL difficulty assessed in 2006).

Table 5. Numbers of incident cases for each outcome

Outcomes	**MEN** **N**	**WOMEN** **N**	**ALL** **N**	**Total N**	**Specific exclusion criteria**
N	**531**	**762**	**1,293**		Starting with N=1,307, then exclusion of 14 persons with missing BMI/WC **=Sample included for mortality analyses**
Mortality (until 31 December 2013)					
Number of deaths	70	60	130	1,293	
Time at risk (p*y)	4,244	6,202	10,447		
Mortality rate (per 1000 p*y)	16.49	9.67	12.44		
Mean follow-up (y)			8.1		
Median follow-up (y)			8.5		
Maximum follow-up (y)			8.9		
N	**489**	**677**	**1,166**		Starting with N=1,172, then exclusion of 6 persons with missing BMI/WC **=Sample included for analyses of disability**
Disability* (until 31 December 2012)					
Number of incident cases	96	135	231	1,166	
Time at risk (p*y)	2,830	4,028	6,858		
Incidence rate (per 1000 p*y)	33.92	33.52	33.68		
Mean follow-up (y)			5.9		
Median follow-up (y)			7.0		
Maximum follow-up (y)			7.0		

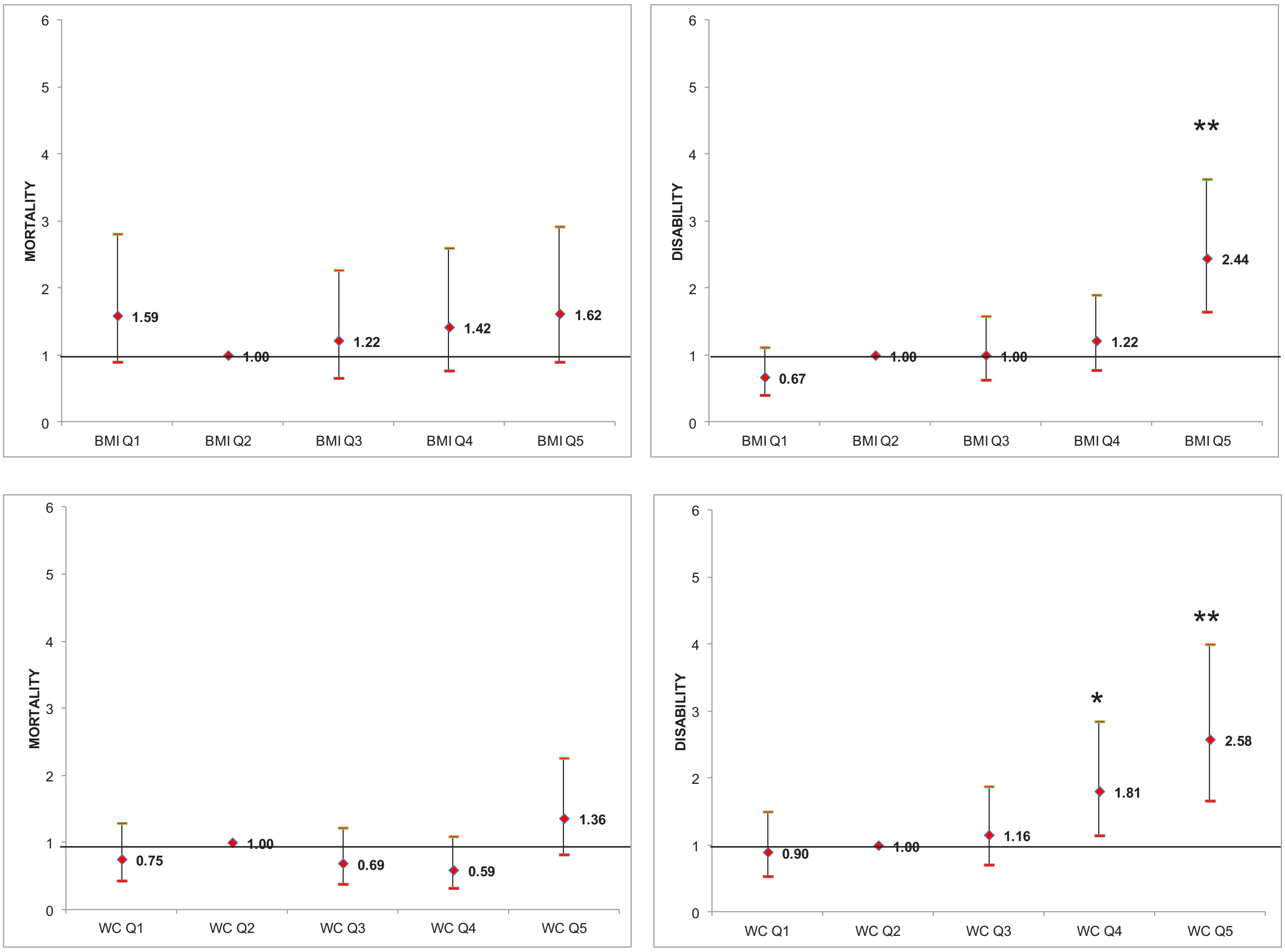
* Difficulty with BADL for ≥2 years or institutionalization

Figure 6. Kaplan-Meyer survival curves for mortality (1st column, N=1,293) and disability incidence (2nd column, N=1,166) by BMI quintiles (upper graphs) and WC quintiles (lower graphs).



"Disability-free survival" is the label indicating survival with neither difficulty with BADL for ≥2 years nor institutionalization. Sex-specific BMI and WC quintiles have been aggregated.

Figure 7. Association between mortality and disability with BMI and WC quintiles. Hazard ratios and 95% CI are adjusted for age, sex, education, financial situation, involuntary weight loss, and smoking status. N=1,270 and median follow-up=8.5 years for mortality; N=1,147 and median follow-up=7.0 years for disability.



**P*<0.01

***P*<0.001

Sex-specific BMI and WC quintiles have been aggregated.

General discussion

I. Main findings

In this community-dwelling population aged 65-70 at baseline, frailty was rare (2%), whereas one-quarter were prefrail. Prefrail individuals had significantly more comorbidity and BADL and IADL disability than nonfrail participants. Weakness was the most frequent frailty criterion, and when present in isolation, it was associated with two to three times greater prevalence of CHD, other heart diseases, diabetes mellitus, and arthritis. Similarly, a significant association was identified between exhaustion and depression.

Overweight and obesity affected more than three quarters of men, and between half and two thirds of women. A gradual decrease in adiposity was almost consistently observed across categories of increasing PA. Adiposity values were higher among participants taking no stairs in daily life, but doing sports ≥1x/week, than among persons taking stairs, but doing sports <1x/week. A rough suggestion stemming from this observation is that daily PA seems more important than weekly PA for keeping satisfying adiposity levels, however, no causal relation can be deducted from this cross-sectional analysis and this hypothesis should be confirmed in longitudinal analyses.

In both sexes, eating FV ≥2x/day, taking stairs every day, and doing sports ≥ once a week were strongly negatively associated with financial difficulties, and positively with education. The independent and significant negative association of adiposity with PA and education in Lc65+ might be explained by higher fat and total energy intake among less educated persons [123]; these nutritional items were not assessed [46]. While the prevalence of abdominal obesity was 45% in both sexes, indicating an important risk of cardio-vascular disease [76], 20% of men and 25% of women avoided using stairs or carrying loads.

In Lc65+, BMI and WC had a non-significant J-shaped association with mortality after 8 years of follow-up. Disability increased monotonically with both BMI and WC and a statistical difference was found when comparing the fifth BMI and WC quintiles 4 and 5 vs. quintile 2. The study lacked sufficient power to describe more precisely the shape of the association. Still, almost half of the study population had increased HR for disability. The finding of a non-significant association between adiposity and mortality was expected in view of the limited study power. As mentioned in the introduction, several potential biases (survival bias [85], selection bias, reverse causation [84]…) can obscure or distort the relationship between adiposity and mortality in older persons. These phenomena might contribute to explain why the higher BMI and WC quintiles were not significantly associated with mortality in our analyses. As discussed in the introduction, adiposity status at midlife [87] or maximum lifetime BMI [84] may better predict mortality, at least as far as causation is concerned, as they are less prone to the aforementioned biases [84]. In our study, we adjusted for involuntary weight loss but this issue is inherently difficult to account for because weight loss related to disease can be insidious and take place over many years. Ideally, the lifetime duration of exposure to obesity should be recorded.

II. Comparisons with previous research and interpretation

Any attempt to compare prevalence estimates across studies or countries should be conducted with caution, because the definitions of the exposures (definition of frailty criteria, measurement versus self-reports of weight and height) [124], the distribution of confounders (e.g., age, sex, race…), and exclusion criteria differ between studies. In addition, the participation rates might differ.

Prefrailty prevalence in Lc65+ appeared to be lower than in other studies, which reported a prevalence ranging from 43% to 54% [1, 15, 125-127]. In SHARE, prefrailty prevalence after age 65 ranged from 35% in Germany to 51% in Spain, with a north–south gradient,[120] but these studies included older individuals [120, 125] [15, 126, 127]. Increasing trends in the prevalence of comorbidity and disability across frailty categories confirm previous results [1, 18, 128]. In Lc65+, the most frequent frailty criterion was weakness, followed by shrinking, low activity, exhaustion, and slowness. Weakness prevalence appeared lower in Lc65+ (14%) than in the 10 countries of SHARE (26%) but similar to Switzerland alone (17%) [120]. Despite the younger age of Lc65+ participants, weakness prevalence seemed slightly higher in Lc65+ participants than in the men of MrOS (13%) [14], possibly because weakness is more frequent in women [129]. The prevalence of exhaustion (6%) and slowness (3%) in Lc65+ appeared to be similar to various studies [130] [129] [14] [131].

Although several articles have identified the most frequent criterion in specific age groups [1, 14, 120, 130, 131], to our knowledge, not many studies have identified the first frailty criterion. In the Women's Health and Aging Study II (WHAS II) [128], a longitudinal study with a 7.5-year follow-up period that included 420 nonfrail women aged 70 to 79 at baseline, weakness was the most common initial manifestation. Although weakness had the highest prevalence in Lc65+, the cross-sectional design precludes the conclusion that it is the first criterion to appear. This hypothesis must be evaluated in the follow-up data. Grip strength has already been identified as a powerful independent predictor of disability [132] and of cause-specific and total mortality [133].

Previous studies have reported associations between chronic diseases [1, 19, 128, 131, 134] and prefrailty but not with individual frailty criteria. In Lc65+, low grip strength was associated with a significantly greater prevalence of CHD, other heart diseases, diabetes mellitus, and arthritis. The link between frailty and mortality has often been described as being mediated through the cardiovascular system (subclinical disease) [19]. Of the pathways suggested to explain this association, atherosclerosis, a state of chronic inflammation resulting in a loss of lean mass (among others), has been proposed [19] [135]. In addition, the association between diabetes mellitus and low grip strength has long been reported [136] [20]. Exhaustion as a single frailty criterion was significantly associated with depression, an association previously observed [131]. A Taiwanese survey also reported a high prevalence of depressive symptoms in frail (89%) and prefrail (32%) older adults [18]. In Lc65+, 19% of prefrail participants reported depression (vs 11% of nonfrail participants, *P* <.001). Although the cause of its association with frailty remains unknown, depression has a recognized prognostic value [137].

Lc65+ obesity prevalence estimates are slightly higher than those observed in the same city in CoLaus study [8], which reported a prevalence of overweight, obesity, and abdominal obesity of 50%, 23%, and 40% in men aged 65-75 years, and respectively 35%, 17% and 45% in women. In the Swiss Health Survey (SHS) 2012 [138], the prevalence of overweight and obesity (self-reported) was 49% and 17% in men, respectively 34% and 14% in women aged 65-74 years at a national level. However, BMI calculated from self-reported height and weight is underestimated [39, 40]. Despite the methodological limitations in any attempt to compare prevalence estimates across countries, several reports suggest that overweight and obesity prevalence among Swiss adults is lower than in other European countries [39, 40, 124]. Several studies have described associations between low SES and suboptimal diet [29] and PA [30, 49], as well as the links of these behaviors with odds for being overweight or obese [50]. Pedestrians in lower socioeconomic areas are less likely to climb stairs and more often choose escalators than pedestrians in high socioeconomic areas [49]. Still, a stair climbing intervention was equally effective in both areas [49].

In Lc65+, living alone was associated with eating less FV among men, but less meat among women, a finding already observed in the SHS, and in England [139]. Lc65+ women living alone were also leaner; in a Swedish cohort [140], women “co-habitating” experienced a higher increase in weight and body fat since age 20. The negative association between current smoking and adiposity in Lc65+ women was also observed in CoLaus [8].

In spite of the limited sample size of our study, the observation of an apparent J-shape association between BMI and mortality is consistent with results of larger studies [141] [142]. The observation of different nadirs for BMI (2nd quintile) and WC (4th quintile) might reflect the different significance of BMI and WC at this age: e.g. different links with the nutritional state, SES, life-course lifestyles, and local adiposity standard and customs. We found a monotonous association between adiposity and disability, which may be consistent with either a linear relationship or a slightly J-curved association. Both shapes have been described in the literature for the association between adiposity (BMI or WC) and disability: linear [112] and (mostly) J-shaped [113, 116] [117] [94]. An underlying explanation for the graded relation is that increasing body weight can decrease a person's functional autonomy and mobility because of increased weight to carry (**Table 4**) [111]. Whether subcutaneous or abdominal, excess weight is also likely to have a negative impact on the osteoarticular system, e.g. arthrosis of the backbone, knees, hips, and feet.

III. Limitations

The sample size was relatively small, thus limiting the generalizability of the findings. These analyses should be replicated in larger samples. Of all 3,056 individuals contacted, 1,422 (47%) completed the baseline frailty assessment. This final participation rate was comparable with other surveys involving community-dwelling individuals [143-145]; for example, in CHS [143], 31% of those contacted in the randomly selected sample were enrolled. Studies looking for systematic differences in health status between participants and nonparticipants yielded inconsistent results [144, 146-148]. The nonparticipation rate seems to be higher in lower socioeconomic groups [148]. In Lc65+, only 8% of those refusing to participate attributed their refusal to poor health [2]. The prevalence of frailty, comorbidity, and disability may have been underestimated if affected individuals had lower participation rates than healthy persons. Although Lc65+ frailty criteria differed partly from the criteria that Fried and colleagues proposed [1], different operationalizations of the phenotype's dimensions reflect the same underlying mechanisms (e.g., weight loss…). The consistency of observations across diverse studies with various measurement instruments supports the plausibility of the findings. The methodological limitations (e.g., potential selection bias and different definitions of frailty criteria) might have affected prevalence estimates for prefrailty but are unlikely to explain the existence of associations between individual frailty criteria and specific chronic diseases. Weakness was involved in most of the associations observed in Lc65+, and it was measured using Fried's exact definition. Assessment of comorbidity was based on self-reporting of medical diagnoses. Self-reported diseases are often used in population-based studies [18, 121, 122] and seem to be accurate [149-151] for specific diagnoses. Studies have observed substantial [151-153] agreement between self-reporting and medical reporting of medical conditions, particularly for life-threatening, acute-onset diseases (e.g., myocardial infarction and stroke) and chronic symptomatic disorders requiring ongoing management (e.g., diabetes mellitus) [149, 154, 155]. When compared with general practitioners' information, the accuracy of patient self-reporting is substantial for cancer but poor for arthritis [149]. Nonetheless, errors in disease measurement due to self-reporting are unlikely to have a differential distribution across frailty categories.

The limitations of Project 2 include the lack of data on total energy intake, fat intake, and sugar intake (the MNA does not include any question on dessert or sugar); the lack of information on total energy intake limited the interpretation of the results, in particular for the multivariate linear analyses of the associations between eating habits, PA, and adiposity indicators. MNA items are categorical and do not allow any quantitative estimation of food intake. Therefore, the report only presents a few items about eating habits, and does not provide a complete dietary assessment. Daily PA and sports frequency were self-reported; a measurement bias could have occurred if participants with higher adiposity values had over-reported their sports frequency, but not their daily PA. To our knowledge, no such a systematic differential bias has previously been described. These analyses could be replicated in studies objectively measuring daily PA and sports frequency. The number of stairs was not specified in the question asked to the participants, nor the number of minutes spent on each of the sports (at least 20 minutes). Therefore, it is not precise enough to clearly establish that there is a dose-response relationship. In addition, the specific benefits of walking and using stairs could not be precisely separated and compared, since a single question addressed both activities. The analysis was cross-sectional: low PA could lead to adiposity [47, 156], in the same way as adiposity could lead to low PA [48, 157]. The relationship between PA and adiposity should be studied longitudinally. A Swiss study observed that encouraging hospital employees to use stairs instead of elevators during their daily work routine significantly improved cardio-vascular disease risk factors (including WC, body weight, and fat mass) and increased cardiorespiratory fitness after 12 weeks [156]. On the other hand, a small study (involving adults younger than 65 years) reported that experimental weight gain (with overfeeding) reduced objectively measured daily walking distance [48]. In another longitudinal study [157], weight, BMI, fat mass, and WC predicted sedentary time after 5.6 years of follow-up, whereas sedentary time did not predict obesity.

Overall, the aim of this PhD was to study adiposity indicators, while Lc65+ cohort study has been designed for exploring frailty, with a focus on weight loss and loss of muscle mass. There is no measurement of fat percentage, and no measurement of blood cholesterol or triglycerides.

Project 3 has some limitations. First, our study lacked statistical power to demonstrate a statistically significant relationship between BMI/WC and mortality and to assess whether the graded relationship with disability was linear or J-curved. However, the consistency of our results in both univariate and multivariate analyses suggests that the J-shape association between adiposity and mortality and a graded association between adiposity and disability in our study are true. The limited study power explains why only extreme quintiles showed statistically significant associations with disability. Further studies aiming at clarifying the relation between BMI/WC and disability will need to include larger sample sizes [104] and longer follow-ups. In addition, cause-specific mortality is not available in the Lc65+ cohort study. Neither midlife BMI /WC measures nor lifetime maximal BMI/WC measures were available for the analyses. Over-adjustment for SES might have occurred because it seems that the link between SES and obesity is bi-directional [158]. If SES is an intermediary between the exposure (obesity) and the outcome (mortality, disability), it should not be adjusted for. For the same reason, the Cox models were not adjusted for an indicator of muscle strength (such as chair rise time). However, a study advocates that obesity and muscle strength should be considered jointly [74] when studying interactions between obesity and sarcopenia and the risk of functional limitation and mortality.

IV. Strengths

Strengths of Lc65+ include the randomly selected sample, which is representative of the general community-dwelling population of Lausanne aged 65 to 70. Unlike other studies [1, 125-127], this study population has a narrow age range (65−70), which limits the potential for age-related confounders or biases, such as selection bias due to differential participation rates across age groups [143]. Except for institutionalization and advanced dementia, this study did not exclude individuals with specific diseases [18] [131] [1]. The limited number of exclusion criteria led to a study sample that was more representative of the source population.

This cohort study offers a detailed description of the socio-economic circumstances of this age group, which deserves careful attention for planning health services for the next decade. Moreover, five anthropometric adiposity indicators were measured using a standardized procedure, allowing examining the consistency of associations.

The longitudinal design is another strength. The follow-up rate (1,311/1,422, i.e. 92% in 2008**)** was high in comparison with other population-based cohort studies. The vital status of all inhabitants of Lausanne is available (confirmation of deaths by the Population's Office). Another important strength [80] is our explicit adjustment for involuntary loss of weight at baseline, while most other similar studies reported weight loss with no distinction of participants' intention [9] [104]. In addition, precise assessment of disability in Lc65+ has not been often performed in large studies so that our results are informative.

V. Implication of findings

These cross-sectional associations between individual frailty criteria and distinct chronic diseases deserve additional study in longitudinal analyses. Arthritis may be a local and straightforward explanation for weakness, and this frailty criterion may not be specific. The independent prognostic significance of weakness as a sole frailty criterion should be evaluated before weakness alone can be considered a target for prevention. Efforts to prevent the apparition of frailty by encouraging regular PA and ensuring adequate nutrition since a young age should be done. Whereas obese older persons should be encouraged to practice sports more than once a week [27], the importance of keeping a high level of mobility in daily life should not be overlooked [156]. In this population, eating habits and PA had strong links with socioeconomic factors, which could be the target of public health interventions [49]. Research studies assessing the effect of total PA should include daily PA (e.g. use of stairs, pedometers). The American College of Sports Medicine and American Heart Association recommend that older adults engage in at least 30 min/d of moderate PA on most days of the week, 75 to 150 min/wk of vigorous intensity PA, or an equivalent combination of both [159]. In the Cardiovascular Health Study, [160] greater PA (assessed at multiple visits and cumulatively updated) was inversely associated with coronary heart disease, stroke, and total CVD, confirming the importance of walking for the reduction of the incidence of CVD among older adults.

Our study suggests that overweight and obesity may result in a substantial morbidity related to disability. Almost half of our study population had a substantially increased HR of disability, as compared to the reference category. This has implications on health care of older persons who either stay at home or need to be institutionalized. This emphasizes the need for preventive measures aimed at preventing overweight with a life-course perspective (i.e. starting at early age and extending throughout a person’s life). Yet, the potentially negative impact of excess weight with regards to disability must be weighed against the apparent survival advantage of high vs. low body weight at an old age. To further address this issue, one should also be able to distinguish leanness due to disease in older persons from leanness maintained during a whole life-course among fully healthy persons, which would incur the use of more complex measurements (e.g. dual-energy X-ray absorptiometry or abdominal CT scan) that often exceed what is acceptable and/or feasible in epidemiological studies. Nonetheless, our findings, consistent with evidence in the literature, stress the need to prevent functional decline and muscle loss in older adults through adequate nutrition (e.g. a number of older person tend to lessen their intake of protein and other important nutrients) and encourage them to sustain regular physical activity, including resistance training at all ages [85] [75]. Another practical issue applicable for all older adults, but likely even more for older persons with overweight, is to adapt the living environment to facilitate daily life movements and activities, including for the prevention of falls, e.g. by installing chairs in the shower, anti-slide mats, electronic devices for seeking help in case of fall, medical walkers. The findings and the literature emphasize the need for life-long strategies to maintain a healthy weight during the entire life course and, specifically, the need for supportive tools for older persons with excess weight to reduce their functional limitations and improve quality of life.

VI. Perspectives

The existence of associations between individual frailty criteria and specific chronic diseases suggests that they could result from common pathophysiological changes. Additional exploration of these processes in longitudinal studies may contribute to understanding the natural history of frailty. In particular, the link between frailty and CVD should be further investigated.

Future studies with large samples and longitudinal designs should consider BMI or WC trajectory throughout life in order to precisely define the optimal lifestyle and weight trajectory. The development of frailty deserves additional study since it could be a mediator between overweight, weight loss and mortality or disability [88]. Strandberg *et al.* suggested that the development of frailty may be an intervening mechanism between weight loss after midlife and higher mortality risk in later life [88]. In their study, “men who were either constantly overweight or who changed from overweight in midlife to normal weight in late life had poorer prognosis and more frailty and disability in late life.”

We found that adiposity markers tended to show a J-shaped relation with mortality and a graded relation with disability in adults aged 65 to 70 years at baseline. Studies with larger sample sizes and longer follow-up should further clarify the exact shapes of these associations, including by assessing the role of exposures (adiposity) measured at different ages [104] on later health outcomes and the potentially different predictive values of different adiposity markers (BMI, WC), which may represent different phenotypes (e.g. overall adiposity versus abdominal adiposity).

The findings of this PhD (together with the literature review) emphasize the need for life-long strategies aimed at preventing excess weight, muscle loss and functional decline through adequate nutrition and regular physical activity, starting at early age and extending throughout life. Socio-economic differences should be addressed in prevention programs in order to target in priority specific risk groups and mitigate the health effects of social determinants.

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Appendix I

Prefrailty and Chronic Morbidity in the Youngest Old: An Insight from the Lausanne Cohort Lc65+

Nadia Danon-Hersch, MD, MSc, Nicolas Rodondi, MD, MAS,† Jacques Spagnoli, MSc,* and Brigitte Santos-Eggimann, MD, DrPH, MPH**

OBJECTIVES: To estimate the prevalence of prefrailty, frailty, comorbidity, and disability in the youngest old and to identify chronic diseases associated with individual frailty criteria.

DESIGN: Population-based cohort study of noninstitutionalized elderly adults at baseline; cross-sectional analysis.

SETTING: Lausanne, Switzerland.

PARTICIPANTS: One thousand two hundred eighty-three individuals with complete data on frailty, aged 65 to 70 (58.5% women).

MEASUREMENTS: Frailty was assessed according to an adaptation of Fried's criteria (shrinking, weakness, exhaustion, slowness, and low activity, three criteria needed for the diagnosis of frailty, 1 to 2 for prefrailty). Other outcomes were diseases diagnosed by a doctor (≥ 2 chronic diseases: comorbidity) and limitations in activities of daily living (ADLs, basic and instrumental).

RESULTS: At baseline, of 1,283 participants 71.1% were classified as nonfrail, 26.4% as prefrail, and 2.5% as frail. The proportion of women increased across these three groups (56.5%, 62.8%, and 71.9%, respectively; $P = .01$), as did the proportion of individuals with one or more chronic diseases (68.0%, 82.8%, and 90.6%, respectively; $P < .001$) and the proportion with basic or instrumental ADL disability (1.6%, 10.3%, and 59.4%, respectively; $P < .001$). Weakness (low grip strength) was the most frequent criterion (14.3%). Prefrail participants had significantly more comorbidity and ADL disability than nonfrail participants ($P < .001$). When present in isolation, weakness was associated with two to three times greater prevalence of coronary heart disease, other heart diseases, diabetes mellitus, and arthritis. Similarly, a significant association was identified between exhaustion and depression.

CONCLUSION: Prefrailty is common in the youngest old. The most prevalent frailty criterion is weakness, which is associated with cardiovascular diseases. Longitudinal studies of the evolution of prefrailty should explore the role of potential interactions between individual frailty criteria and specific chronic diseases. **J Am Geriatr Soc 60:1687–1694, 2012.**

Key words: prefrailty; frailty; disability; chronic disease; youngest old; Switzerland

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The concept of frailty has been developed in geriatrics during past decades[1] to define a state of vulnerability and loss of adaptation to stress.[2–4] Different models[1] have been used to explain the development of frailty. Fried and colleagues, considering frailty as a biological syndrome, suggested the occurrence of a pathophysiological "cycle of frailty associated with declining energetics and reserve"[2] and proposed an operational definition for a frailty phenotype that relies on five criteria: slowness, weakness, weight loss, low level of physical activity, and self-reported exhaustion.[2] Individuals with at least three of the five criteria are classified as frail, and those fulfilling one or two criteria are considered prefrail or intermediate. The frailty phenotype independently predicts recurrent falls,[5] disability,[2,6,7] hip fracture,[5,6] hospitalization,[2] nursing home admission,[7] and death.[2,5–9]

Nevertheless, many gaps remain in the understanding of the physiopathology of frailty. Although the risk of adverse outcomes seems to increase gradually from the state of nonfrailty to prefrailty and frailty,[2] little is known about the significance of prefrailty. This intermediate stage may provide insights into the mechanisms involved. The stage of prefrailty also deserves special interest because frailty is a continuous process that may be partly reversible, especially in its initial phases.[10]

Whereas the association between cardiovascular disease and frailty has been demonstrated,[11,12] the current

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study aimed to identify which frailty criteria were more specifically linked with cardiovascular disease. Likewise, although the association between other chronic diseases (e.g., arthritis, diabetes mellitus, chronic obstructive pulmonary disease) and frailty has been established,[2,13–15] it was hypothesized that specific chronic diseases might be more tightly linked with one or another frailty criterion. These associations might be involved in different parts of the frailty cycle and could provide indications regarding the physiopathology of frailty.

In this report, it was hypothesized that prefrailty would not be rare in the community-dwelling population aged 65 to 70; the prevalence of chronic diseases and disability would differ significantly between prefrail and nonfrail populations; and the distribution of chronic diseases and disability would differ between individuals with different frailty criteria, even among prefrail individuals experiencing a single frailty criterion. To test these hypotheses, the data from the population-based Lausanne cohort Lc65+ were analyzed.[16]

METHODS

Design

The Lausanne cohort Lc65+ is a longitudinal, observational study started in 2004 at the University of Lausanne Hospital Center (Switzerland).[16] It aims to investigate the determinants, manifestations, and outcomes of frailty from its earliest stage in the general population. A sample of 1,564 individuals representative of the general community-dwelling population has been enrolled and is currently being followed from age 65 to death. The ethics committee of the Faculty of Biology and Medicine of the University of Lausanne has approved the study protocol.

Recruitment Process and Inclusion Criteria

Individuals were enrolled at the age of 65 to 70 and provided written informed consent to participate.[16] To be included in 2004, participants had to be residents of Lausanne (city of 125,000 inhabitants) born between 1934 and 1938. Exclusion criteria at enrollment were being institutionalized or unable to respond because of advanced dementia. Enrollment has been previously described.[16] Of the 3,056 people who were initially mailed questionnaires, 2,096 (69%) replied, of whom 1,564 (75%) agreed to participate.[16] Overall, nonparticipants had demographic characteristics similar to those of participants;[16] only 8% of those refusing to participate attributed their refusal to poor health,[16] and 58% had "a general reluctance to participate in any survey." Of the 1,564 respondents to the initial questionnaire, 1,524 (97.4%) were still eligible,[16] and 1,422 (93.3%) participated in the baseline assessment in 2005.

The present analysis, which focused on prefrailty, included all participants with complete data for frailty classification (nonfrail, prefrail, or frail; n = 1,283).

Assessment Process

Baseline data were collected in 2004 using a self-administered questionnaire sent to participants' homes, followed by an interview at the study center with measurements and performance tests conducted by trained medical assistants in 2005. The questionnaire included items used in the Swiss health surveys, Monitoring of Trends and Determinants in Cardiovascular Disease[17] and the Survey of Health, Aging and Retirement in Europe (SHARE).[18] Items on self-reported medical diagnoses of diseases ("Has a doctor ever told you that you had…?") assessed coronary heart disease (CHD), other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, osteoporosis, arthritis, cancer, gastrointestinal ulcer, depression, and hypercholesterolemia. In accordance with the lists of medical diagnoses used in SHARE[19,20] and the Cardiovascular Health Study (CHS),[2] only eight of these diagnoses were included in the variable "number of chronic diseases": CHD, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, arthritis, and cancer.

Disability in basic or instrumental activities of daily living (ADLs or IADLs) was assessed according to two questions: "During the last four weeks, did you have difficulty with performing the following activities: taking a shower or a bath, getting dressed, eating, getting in/out of bed or an arm-chair, using the toilets?" (ADLs), and "During the last four weeks, did you have difficulty shopping or performing your usual tasks at home?" (IADLs). There were three possible answers: No, I have had no difficulty at all; I have had difficulties with one or more of these activities, but I didn't get help; and I have received help with one or more of these activities. Participants who had received help were considered to have disability.

Frailty Assessment

The clinical assessment was conducted following a standardized protocol.[16] Frailty was assessed at baseline according to the five dimensions of the phenotype described by Fried,[2] although these dimensions were operationalized with partly different criteria; Table 1, reproduced from a previous publication about Lc65+,[16] details how frailty characteristics were measured in CHS[2] and in Lc65+. Participants with three to five frailty criteria in Lc65+ were categorized as frail, and those with one or two criteria were categorized as prefrail.

Statistical Analysis

Statistical analyses were performed using Stata 12 software (Stata Corp, College Station, TX). Results were expressed as absolute numbers and percentages. Bivariate comparisons were performed using the chi-square test or Fisher exact test for categorical variables. Multivariate odds ratios (ORs) and 95% confidence intervals (CIs) of the prevalence of self-reported chronic diseases were calculated in participants with zero or one frailty criterion using multivariate logistic regression analysis adjusted for sex and all five frailty criteria.

RESULTS

Characteristics of the Sample

The study sample initially included all participants who participated at baseline in the Lc65+ cohort in 2004/05

Table 1. Operationalization of Frailty Characteristics in the Cardiovascular Health Study (CHS)[2] and the Lausanne cohort Lc65+ Study, Reproduced from Santos-Eggimann et al.[16]

	Criteria	
Frailty	**Cardiovascular Health Study**	**Lausanne Cohort Lc65+ Study**
Characteristic		
Shrinking	Unintentional weight loss > 10 pounds in prior year	Any reported unintentional weight loss in prior year
Weakness	Grip strength: lowest 20% (according to sex and body mass index)	Grip strength: application of CHS sex- and body mass index–specific cutoff values[a]
Poor endurance, exhaustion	Exhaustion self-report (CES-D Depression Scale): responds "a moderate amount of the time (3–4 days) or most of the time" to either statement "I felt that everything I did was an effort" or "I could not get going" in the last week.	Exhaustion self-report: responds "much" to the question: "Did you have feelings of generalized weakness, weariness, lack of energy in the last four weeks?"
Slowness	Walking time/15 feet: slowest 20% (by gender, height)	Walking time/20 m: application of CHS gender- and height-specific cutoff values
Low activity	Physical activity self-report: lowest 20% kcal/week expenditure, according to sex, estimated from the short version of the Minnesota Leisure Time Activity questionnaire	Physical activity self-report: (i) doing <20 minutes of sports per week, (ii) walking <90 minutes per week, and (iii) avoidance of climbing stairs or carrying light loads in daily activities[b]
Classification		
Nonfrail or robust	0 criterion present	0 criterion present
Intermediate, possibly prefrail	1–2 criteria present	1–2 criteria present
Frail	3–5 criteria present	3–5 criteria present

[a] The grip strength test was performed on the right hand[46] (using the best of three measurements).
[b] Low activity was defined when all three statements were fulfilled. This measurement of physical activity based on three questions has been adapted from the Monitoring of Trends and Determinants in Cardiovascular Disease Physical Activity Questionnaire[17,47] to suit activity patterns of individuals aged 65–70.

and were evaluated for frailty (n = 1,283). Birth years were evenly distributed throughout the 1934–1938 period, and 58.5% of participants were women, closely reflecting proportions observed in this age range in the community-dwelling population of Lausanne. Of the 1,283 participants, 71.1% were classified as nonfrail, 26.4% as prefrail, and 2.5% as frail (Table 2). No participant had all five criteria of the frailty phenotype. Weakness was the most frequent criterion and was experienced by 14.3% of Lc65+ participants (n = 183), followed by weight loss (n = 115, 9.0%), low activity (n = 88, 6.9%), exhaustion (n = 81, 6.3%), and slowness (n = 43, 3.4%). One-third (34.9%) reported two or more chronic conditions diagnosed by a physician, and 37.5% reported a single chronic condition. Hypertension, hypercholesterolemia, and arthritis were most often reported. Most participants were independent in their daily life; 3.7% had received help during the four previous weeks for IADLs only and an additional 1.6% for ADLs.

Most prefrail participants also had at least one chronic disease; 27.5% of all participants had none of the eight listed chronic diseases: 32.0% of the nonfrail, 17.2% of the prefrail, and 9.4% of the frail (test for trend $P < .001$, Table 2). Of the 1,282 participants with complete data regarding the three health dimensions, 288 (22.5%) had no frailty criterion, no disability, and no chronic disease. Of the 338 prefrail participants with complete data, 57 (16.9%) had no disability and no chronic disease.

Characteristics of Prefrail Individuals

Prefrail participants differed significantly from nonfrail participants in many respects (Table 2). Prefrail participants were more frequently female and were older. Fewer than 2% of nonfrail participants needed help in IADLs (1.4%) and ADLs (0.2%), more than 10% of prefrail participants did so (IADL, 7.4%; ADLs, 2.9%; $P < .001$). Prefrail individuals also reported comorbidity (≥ 2 chronic diseases) more often. Specific health conditions that were more frequently reported in prefrail participants than in nonfrail participants included CHD ($P = .04$), other heart diseases ($P < .001$), stroke ($P = .01$), diabetes mellitus ($P < .001$), hypertension ($P < .001$), chronic respiratory diseases ($P = .02$), osteoporosis ($P = .01$), arthritis ($P < .001$), and depression ($P < .001$).

The proportion of women increased across the three frailty categories (nonfrail, 56.5%; prefrail, 62.8%; frail, 71.9%; test for trend $P = .01$), as did the proportion of older participants (born in 1934: nonfrail, 16.9%; prefrail, 23.9%; frail, 28.1%; test for trend $P < .001$).

Across frailty categories, there were increasing trends in the prevalence of disability (test for trend $P < .001$), comorbidity (test for trend $P < .001$), CHD (test for trend $P < .001$), other heart diseases (test for trend $P < .001$), stroke (test for trend $P < .001$), diabetes mellitus (test for trend $P < .001$), hypertension (test for trend $P < .001$), chronic respiratory disease (test for trend $P = .001$), osteoporosis (test for trend $P = .006$), arthritis (test for trend $P < .001$), and depression (test for trend $P < .001$; Table 2).

Table 2. Demographic and Health Characteristics at Baseline (2004/5) in Nonfrail, Prefrail (1 or 2 Frailty Criteria), and Frail (3–5 Criteria) Participants

Characteristic	Nonfrail, n = 912 n (%)	Prefrail, n = 339	Frail, n = 32	Total, N = 1,283	χ^2 P-Value (Nonfrail vs Prefrail)	Test for Trend *P*-value (Nonfrail, Prefrail, and Frail)
Female	515 (56.5)	213 (62.8)	23 (71.9)	751 (58.5)	.04	.01
Birth year						
1938	197 (21.6)	52 (15.3)	3 (9.4)	252 (19.6)	.001	<.001
1937	194 (21.3)	51 (15.0)	3 (9.4)	248 (19.3)		
1936	178 (19.5)	76 (22.4)	12 (37.5)	266 (20.7)		
1935	189 (20.7)	79 (23.3)	5 (15.6)	273 (21.3)		
1934	154 (16.9)	81 (23.9)	9 (28.1)	244 (19.0)		
Help received with ADLs or IADLs						
None	897 (98.4)	304 (89.7)	13 (40.6)	1,214 (94.6)	<.001[a]	<.001
With IADLs only	13 (1.4)	25 (7.4)	10 (31.3)	48 (3.7)		
With ADLs	2 (0.2)	10 (2.9)	9 (28.1)	21 (1.6)		
Number of chronic diseases[b]						
0	292 (32.0)	58 (17.2)	3 (9.4)	353 (27.5)	<.001	<.001
1	359 (39.4)	118 (34.9)	4 (12.5)	481 (37.5)		
≥2	261 (28.6)	162 (47.9)	25 (78.1)	448 (34.9)		
Self-reported medical diagnoses						
Coronary heart disease	72 (7.9)	39 (11.5)	10 (31.3)	121 (9.4)	.04	<.001
Other heart diseases[c]	45 (4.9)	41 (12.1)	5 (15.6)	91 (7.1)	<.001	<.001
Stroke	11 (1.2)	11 (3.3)	9 (28.1)	31 (2.4)	.01	<.001
Diabetes mellitus	71 (7.8)	52 (15.4)	6 (18.8)	129 (10.1)	<.001	<.001
Hypertension	334 (36.6)	162 (47.9)	20 (62.5)	516 (40.3)	<.001	<.001
Hypercholesterolemia	320 (35.1)	127 (37.6)	14 (43.8)	461 (36.0)	.41	.24
Chronic respiratory disease	62 (6.8)	37 (10.9)	6 (18.8)	105 (8.2)	.02	.001
Osteoporosis	90 (9.9)	50 (14.8)	6 (18.8)	146 (11.4)	.01	.006
Arthritis	291 (31.9)	154 (45.6)	17 (53.1)	462 (36.0)	<.001	<.001
Cancer	104 (11.4)	45 (13.3)	7 (21.9)	156 (12.2)	.35	.09
Gastrointestinal ulcer	51 (5.6)	25 (7.4)	4 (12.5)	80 (6.2)	.24	.08
Depression	101 (11.1)	63 (18.6)	7 (21.9)	171 (13.3)	<.001	<.001

The chi-square (χ^2) test compares proportions in the group of nonfrail participants with the group of prefrail participants.
[a] Fisher exact two-tailed test (if expected frequency <5 in any of the cells).
[b] All chronic diseases were self-reported medical diagnoses. The number of chronic diseases included coronary heart disease, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, arthritis, and cancer (maximum number = 8).
[c] Congestive heart failure, cardiac valvular disease, and heart muscle disease.
ADL = activity of daily living; IADL = instrumental activity of daily living.

Characteristics of Prefrail Individuals Fulfilling a Single Criterion

When considering the 252 participants with a single frailty criterion, 102 (40.5%) had weakness, 73 (29.0%) had weight loss, 43 (17.1%) had low activity, 29 (11.5%) had exhaustion, and five (2.0%) had slowness. The 102 persons with weakness as the sole frailty criterion differed significantly from nonfrail participants: 66.7% were women (vs 56.5% of nonfrail participants, chi-square $P = .048$), and they were older than nonfrail participants ($P = .01$). Individuals experiencing weakness alone needed help with ADLs and IADLs more frequently (6% for IADLs only, 4% for ADLs, $P < .001$, Table 3). They more frequently reported two or more chronic diseases ($P < .001$). Weakness was significantly associated with CHD ($P = .003$), other heart diseases ($P = .001$), diabetes mellitus ($P = .04$), and arthritis ($P = .001$). Multivariate logistic regression analysis (adjusted for sex and all five frailty criteria, results not shown in Table 3, but available upon request) indicated that low grip strength was associated with two to three times greater prevalence of CHD (multivariate OR = 2.9, 95% CI = 1.6–5.3), other heart diseases (multivariate OR = 2.9, 95% CI = 1.5–5.6), diabetes mellitus (multivariate OR = 2.2, 95% CI = 1.2–4.1), and arthritis (multivariate OR = 1.9, 95% CI = 1.2–2.8). The 29 participants with exhaustion as the single frailty criterion reported depression ($P = .01$) and receiving help with ADLs and IADLs ($P = .04$) significantly more often than nonfrail participants (multivariate OR for the prevalence of depression = 3.0, 95% CI = 1.3–7.0).

DISCUSSION

In this cross-sectional analysis of the Lc65+ cohort study at baseline, 26% of all participants were prefrail, and 2% were frail. Prefrail individuals had significantly more comorbidity and ADL and IADL disability than nonfrail participants. Weakness was the most frequent frailty criterion, and when present in isolation, it was associated with two to three times greater prevalence of CHD, other heart diseases, diabetes mellitus, and arthritis. Similarly, a

Table 3. Comparison of the Prevalence of Chronic Diseases and Disability in Nonfrail Participants (n = 912) and in Participants with a Single Frailty Criterion (n = 252)

		Frailty Criterion									
		Weakness (Grip), n = 102		Weight Loss, n = 73		Low Activity, n = 43		Exhaustion, n = 29		Slowness (Gait Speed), n = 5	
Variable	Nonfrail, n = 912 n (%)	n (%)	*P*-value	n (%)	*P*-value	n (%)	*P*-value	n (%)	*P*-value	n (%)	*P*-value
Help received with ADLs and IADLs			<.001[a]		.67[a]		.22[a]		.04[a]		<.001[a]
None	897 (98.4)	92 (90.2)		73 (100.0)		41 (95.3)		27 (93.1)		3 (60.0)	
IADLs only	13 (1.4)	6 (5.9)		0 (0.0)		2 (4.7)		1 (3.4)		0 (0.0)	
ADLs	2 (0.2)	4 (3.9)		0 (0.0)		0 (0.0)		1 (3.4)		2 (40.0)	
Number of chronic diseases[b]			<.001		.007		.16		.43		.74[a]
0	292 (32.0)	21 (20.6)		12 (16.7)		10 (23.3)		6 (20.7)		1 (20.0)	
1	359 (39.4)	32 (31.4)		29 (40.3)		15 (34.9)		13 (44.8)		3 (60.0)	
≥2	261 (28.6)	49 (48.0)		31 (43.1)		18 (41.9)		10 (34.5)		1 (20.0)	
Self-reported medical diagnoses											
Coronary heart disease	72 (7.9)	17 (16.7)	.003	5 (6.9)	.77	3 (7.0)	1.00[a]	1 (3.4)	.72[a]	0 (0.0)	1.00[a]
Other heart diseases[c]	45 (4.9)	13 (12.7)	.001	7 (9.7)	.10[a]	5 (11.6)	.07[a]	2 (6.9)	.65[a]	1 (20.0)	.23[a]
Stroke	11 (1.2)	2 (2.0)	.38[a]	0 (0.0)	1.00[a]	2 (4.7)	.11[a]	1 (3.4)	.32[a]	0 (0.0)	1.00[a]
Diabetes mellitus	71 (7.8)	14 (13.7)	.040	10 (13.9)	.07	7 (16.3)	.08[a]	2 (6.9)	1.00[a]	1 (20.0)	.34[a]
Hypertension	334 (36.6)	43 (42.2)	.27	34 (47.2)	.07	19 (44.2)	.32	11 (37.9)	.89	3 (60.0)	.36[a]
Hypercholesterolemia	320 (35.1)	37 (36.3)	.81	30 (41.7)	.26	16 (37.2)	.78	13 (44.8)	.28	1 (20.0)	.66[a]
Chronic respiratory disease	62 (6.8)	9 (8.8)	.45	8 (11.1)	.17	3 (7.0)	1.00[a]	4 (13.8)	.14[a]	1 (20.0)	.30[a]
Osteoporosis	90 (9.9)	12 (11.8)	.55	10 (13.9)	.28	4 (9.3)	1.00[a]	4 (13.8)	.52[a]	3 (60.0)	.009[a]
Arthritis	291 (31.9)	49 (48.0)	.001	28 (38.9)	.22	13 (30.2)	.82	14 (48.3)	.06	1 (20.0)	1.00[a]
Cancer	104 (11.4)	6 (5.9)	.09	12 (16.7)	.18	8 (18.6)	.15	2 (6.9)	.76[a]	0 (0.0)	1.00[a]
Gastrointestinal ulcer	51 (5.6)	9 (8.8)	.19	6 (8.3)	.30[a]	3 (7.0)	.73[a]	0 (0.0)	.40[a]	1 (20.0)	.25[a]
Depression	101 (11.1)	16 (15.7)	.17	10 (13.9)	.47	6 (14.0)	.62[a]	8 (27.6)	.013[a]	1 (20.0)	.45[a]

P-values are from the chi-square test for comparison of proportions with nonfrail participants.

[a] Fisher exact two-tailed test (if expected frequency <5 in any of the cells).

[b] All chronic diseases are self-reported medical diagnoses. The number of chronic diseases included coronary heart disease, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, arthritis, and cancer (maximum number = 8).

[c] Congestive heart failure, cardiac valvular disease, and heart muscle disease.

ADL = activity of daily living; IADL = instrumental activity of daily living.

significant association was identified between exhaustion and depression. The existence of associations between individual frailty criteria and specific chronic diseases suggests that they could result from common pathophysiological changes. Further exploration of these processes in longitudinal studies may contribute to understanding the natural history of frailty.

Prevalence of Frailty, Disability, and Comorbidity at Baseline

In this "young old" age group (65–70), frailty was uncommon (2%), whereas one-quarter were prefrail. Any attempt to compare prevalence estimates across studies should be conducted with caution, because the definitions of the frailty criteria, the distribution of confounders (e.g., age and sex), and exclusion criteria differ between studies. Prefrailty prevalence in Lc65+ appeared to be lower than in other studies, which reported a prevalence ranging from 43% to 54%.[2,5,21–23] In SHARE, prefrailty prevalence after age 65 ranged from 35% in Germany to 51% in Spain, with a north–south gradient,[18] but these studies included older individuals (mean age from 74[18,21] to 82[5,22,23]). In the estimation of the authors of the current study, the prevalence of prefrailty among CHS participants aged 65 to 74 should have approximated 44%.[2] This sample included older individuals than in Lc65+, as well as a minority cohort of 687 African American men and women (who have higher frailty prevalence), and the frailty criteria measured in CHS[2] and Lc65+ were different.

In Lc65+, 48% of prefrail and 78% of frail individuals reported at least two chronic diseases; corresponding percentages in CHS were 54% and 68%,[2] although CHS had a somewhat different list of chronic diseases (validated by clinical tests[2]) and other exclusion criteria (Parkinson's disease; Mini-Mental State Examination score less than 18; use of carbidopa-levodopa, donepezil, or antidepressants). In a Taiwanese health survey of elderly adults,[15] 76% of prefrail and 85% of frail individuals had two or more self-reported chronic diseases, although the definition of chronic disease was broader, including osteoporosis and cataracts. Disability prevalence (basic or instrumental) appeared to be lower in Lc65+ prefrail participants (10%) than in CHS (29%),[2] and the prevalence of instrumental disability in Lc65+ (7%) seemed to be lower than in the Osteoporotic Fractures in Men Study[8] (MrOS, 20%) or the MOBILIZE Boston Study[24] (28%), although disability was defined more strictly in Lc65+ (having received help with ADLs in the past 4 weeks) than in CHS[2] or MOBILIZE[24] (difficulty in ≥ 1 ADLs). CHS[2] and MOBILIZE[24] also included older participants. Increasing trends in the prevalence of comorbidity and disability across frailty categories confirm previous results.[2,15]

The Most Frequent Frailty Criterion in Prefrail Participants

In Lc65+, the most frequent frailty criterion (alone and in association with other criteria) was weakness, followed by shrinking, low activity, exhaustion, and slowness. Weakness prevalence appeared lower in Lc65+ (14%) than in the 10 countries of SHARE (26%) but similar to Switzerland alone (17%).[18] Despite the younger age of Lc65+ participants, weakness prevalence seemed slightly higher in Lc65+ participants than in the men of MrOS (13%),[8] possibly because weakness is more frequent in women[25] (a finding also observed in Lc65+). Shrinking seemed slightly more prevalent in Lc65+ (any unintentional weight loss over the past year, 9%) than in MOBILIZE (7%)[24] or the Hertfordshire Cohort Study (4–5%),[25] but these studies defined shrinking as a weight loss of more than 10 pounds during the past year. The prevalence of exhaustion (determined with slightly different sentences) appeared to be similar in Lc65+ (6%), MOBILIZE (9%),[24] the Hertfordshire Cohort Study (6% in men, 10% in women),[25] and MrOS (8%).[8] Slowness was present in 3% of Lc65+ participants, 3% of MrOS participants,[8] and 8% of the participants in a German study on prefrail individuals[26] that included institutionalized participants and had differing exclusion criteria.

Although several articles have identified the most frequent criterion in specific age groups,[2,8,18,24,26] to the knowledge of the authors of the current study, not many studies have identified the first frailty criterion. In the Women's Health and Aging Study II (WHAS II),[27] a longitudinal study with a 7.5-year follow-up period that included 420 nonfrail women aged 70 to 79 at baseline, weakness was the most common initial manifestation. Although weakness had the highest prevalence in Lc65+, the cross-sectional design of the present report precludes the conclusion that it is the first criterion to appear. This hypothesis must be evaluated in the follow-up data. Grip strength has already been identified as a powerful independent predictor of disability[28] and of cause-specific and total mortality.[29]

The Chronic Diseases Most Frequently Associated with Prefrailty in Lc65+

Prefrail Lc65+ participants had a significantly higher prevalence of CHD, other heart diseases, stroke, diabetes mellitus, hypertension, chronic respiratory disease, osteoporosis, arthritis, and depression than nonfrail individuals, findings also observed in CHS[2] and WHAS II.[27] As in CHS[2] and WHAS II,[27] prefrail participants had a significantly higher prevalence of disability than nonfrail participants.

Previous studies have reported associations between chronic diseases[2,12,26,27,30] and prefrailty but not with individual frailty criteria. In Lc65+, low grip strength was associated with a significantly greater prevalence of CHD, other heart diseases, diabetes mellitus, and arthritis. The link between frailty and mortality has often been described as being mediated through the cardiovascular system (subclinical disease).[12] Of the pathways suggested to explain this association, atherosclerosis, a state of chronic inflammation resulting in a loss of lean mass (among other consequences), has been proposed.[12] The association between low grip strength and cardiovascular diseases observed in Lc65+ is consistent with this hypothesis. In addition, the association between diabetes mellitus and low grip strength has long been reported,[31] and individuals with diabetes mellitus develop the conditions necessary for frailty earlier than other individuals as they age.[13]

Exhaustion as a single frailty criterion was significantly associated with depression, an association previously observed.[26] A Taiwanese survey also reported a high prevalence of depressive symptoms in frail (89%) and prefrail (32%) elderly adults.[15] In Lc65+, 19% of prefrail participants reported depression (vs 11% of nonfrail participants, $P < .001$). Although the cause of its association with frailty remains unknown, depression has a recognized prognostic value.[32]

These cross-sectional associations between individual frailty criteria and distinct chronic diseases deserve additional study in longitudinal analyses. Arthritis may be a local and straightforward explanation for weakness, and this frailty criterion may not be specific. The independent prognostic significance of weakness as a sole frailty criterion should be evaluated before weakness alone can be considered a target for prevention.

Limitations

Of all 3,056 individuals contacted, 1,422 (47%) completed the baseline assessment. This final participation rate was comparable with other surveys involving community-dwelling individuals (rather than hospitalized persons) in Western countries;[33–35] for example, in CHS,[33] 31% of those contacted in the randomly selected sample were enrolled. Studies looking for systematic differences in health status between participants and nonparticipants yielded inconsistent results.[34,36–38] The nonparticipation rate seems to be higher in lower socioeconomic groups.[38] There might have been a selection bias due to differential participation rates across frailty categories in Lc65+, although only 8% of those refusing to participate attributed their refusal to poor health.[16] The prevalence of frailty, comorbidity, and disability may have been underestimated if affected individuals had lower participation rates than healthy persons, which could affect the generalizability of the findings.

Although Lc65+ frailty criteria differed partly from the criteria that Fried and colleagues proposed,[2] different operationalizations of the phenotype's dimensions reflect the same underlying mechanisms (e.g., weight loss, sarcopenia, and diminution of the reserve capacity). The consistency of observations across diverse studies with various measurement instruments supports the plausibility of the findings. These limitations (e.g., potential selection bias and different definitions of frailty criteria) might have affected prevalence estimates for prefrailty but are unlikely to explain the existence of associations between individual frailty criteria and specific chronic diseases. Weakness was involved in most of the associations observed in Lc65+, and it was measured using Fried's exact definition.

Assessment of comorbidity was based on self-reporting of medical diagnoses. Self-reported diseases are often used in population-based studies[15,19,20] and seem to be accurate[39–41] for specific diagnoses. Studies have observed substantial[41–43] agreement between self-reporting and medical reporting of medical conditions, particularly for life-threatening, acute-onset diseases (e.g., myocardial infarction and stroke) and chronic symptomatic disorders requiring ongoing management (e.g., diabetes mellitus).[39,44,45] Participants usually underreport hypertension,[45] and agreement on heart failure differs between studies.[40,43] When compared with general practitioners' information, the accuracy of patient self-reporting is substantial for cancer but poor for arthritis.[39] Nonetheless, errors in disease measurement due to self-reporting are unlikely to have a differential distribution across frailty categories; underreporting of some conditions should have led to nondifferential misclassification, attenuating the strength of associations between isolated frailty criteria and specific diseases.

Strengths

Unlike other studies,[2,21–23] this study population had a narrow age range (65–70), which limits the potential for age-related confounders or biases, such as selection bias due to differential participation rates across age groups.[33]

Except for institutionalization and advanced dementia, this study did not exclude individuals with specific diseases, whereas other studies excluded persons with terminal cancer,[15] arthritis, angina pectoris, chronic obstructive pulmonary disease, or depression[26] or those taking antidepressants.[2] The design of the current study allowed associations between individual frailty criteria and chronic diseases to be examined. Furthermore, the limited number of exclusion criteria led to a study sample that was more representative of the source population.

CONCLUSION

Frailty is rare in the youngest old, whereas prefrailty is common. Weakness is the most frequent frailty criterion; when present in isolation, it is significantly associated with CHD, other heart diseases, diabetes mellitus, and arthritis. Likewise, exhaustion is associated with depression. Longitudinal studies regarding the evolution of prefrail persons should explore the role of potential interactions between individual frailty criteria and specific chronic diseases.

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Appendix II

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RESEARCH ARTICLE **Open Access**

Physical activity in daily life is associated with lower adiposity values than doing weekly sports in Lc65+ cohort at baseline

Nadia Danon-Hersch* and Brigitte Santos-Eggimann*

Abstract

Background: Overweight and obesity prevalence is the highest at age 65–75 years in Lausanne (compared with younger classes). We aimed to describe 1) eating habits, daily physical activity (PA), and sports frequency in community-dwelling adults aged 65–70, 2) the links of these behaviors with socio-economic factors, and 3) with adiposity.

Methods: Cross-sectional analysis of Lc65+ cohort at baseline, including 1260 adults from the general population of Lausanne aged 65–70 years. Eating habits (8 items from MNA) and PA (sports frequency and daily PA: walking and using stairs) were assessed by questionnaires. Body mass index (BMI), supra-iliac (SISF), triceps skin-folds (TSF), waist circumference (WC), and WHR were measured.

Results: Prevalence of overweight (BMI 25.0-29.9 kg/m^2), obesity (BMI ≥30.0 kg/m^2), and abdominal obesity was 53%, 24%, and 45% in men; 35%, 23%, and 45% in women.
Intake of fruits or vegetables (FV) ≥ twice/day was negatively associated with male sex (prevalence 81% versus 90%, chi-square $P < 0.001$). The proportion avoiding stairs in daily life was higher among women (25%) than among men (20%, chi-square $P = 0.003$).
In multivariate analyses among both sexes, eating FV, using stairs in daily life ("stairs"), and doing sports ≥ once/week were significantly negatively associated with financial difficulties (stairs: OR = 0.54, 95% CI = 0.40-0.72) and positively with educational level (stairs: OR = 1.68, 95% CI = 1.17-2.43 for high school).
For all five log-transformed adiposity indicators in women, and for all indicators except SISF and TSF in men, a gradual decrease in adiposity was observed from category "no stairs, sports < once/week" (reference), to "no stairs, sports ≥ once/week", to "stairs, sports < once/week", and "stairs, sports ≥ once/week" (for example: WC in men, respectively: ß = −0.03, 95% CI = −0.07-0.02; ß = −0.06, 95% CI = −0.09- -0.03; ß = −0.10, 95% CI = −0.12- -0.07).

Conclusions: In this population with high overweight and obesity prevalence, eating FV and PA were strongly negatively associated with financial difficulties and positively with education. Using stairs in daily life was more strongly negatively associated with adiposity than doing sports ≥ once/week.

Keywords: Obesity, Adiposity, Eating habits, Daily physical activity, Stairs, Sports

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Background

In Switzerland, the prevalence of overweight and obesity has increased in all age groups between 1992 and 2007 [1]; in the city of Lausanne, it was the highest in age group 65–75 years in 2005, compared to younger groups, reaching a total prevalence of 73% among men, 53% among women [2]. This difference by age was also observed in the Swiss Health Survey 2012, a nationwide study using self-reported height and weight: the prevalence with body mass index (BMI) ≥25 kg/m^2 reached 56% at age 65–74 years [3]. Overweight and obesity are important risk factors for chronic diseases and disability [4]. The youngest old deserve special attention because while the risks of obesity, chronic diseases, and disability are still present at this age, this population bears the additional risk of malnutrition, frailty [5], and sarcopenia [6,7]. In obese older adults, improving dietary habits and increasing physical activity (PA) appear to be the most effective strategies in helping to decrease body weight and improve function and survival [4,8,9]. PA has the potential to reduce the risks of both obesity [10] and sarcopenia [11]. To our knowledge, most randomized controlled trials focus on increasing the frequency of sports sessions, while increasing PA in everyday life in the long term is less often the target. In addition, participants are rarely asked in observational studies on PA if they usually climb stairs in their daily life.

In this context, it is important to have a more precise picture of how persons of the general population aged 65 to 70 years eat and expend energy, and how these behaviors are affected by socioeconomic factors. According to our literature review, the associations of eating habits and PA with socioeconomic position and adiposity have not been explored in detail in this age range. A positive link between socioeconomic level and PA has been described [12,13] in older adults. Concerning dietary habits, a Swiss study (CoLaus) in the same city has recently observed that the nutritional recommendations were only slightly followed in the general population (age range 40–82 years at follow-up) [14]: only 39% and 7% complied with the Swiss recommendations for fruit (≥ 2/day) and vegetables (≥ 3/day). Many studies in young adults have observed that nutrition knowledge and compliance with dietary guidelines have positive relationships with female sex, marital situation [15], high socioeconomic position [12], and higher fast food prices [16]. In Switzerland, a link between overweight and obesity and low education status has been observed in four cross-sectional National health surveys using representative samples of the Swiss population aged 18–102 years [1]; however differences in financial resources were not taken into account in this analysis. Changes in body composition are observed with advancing age [8,17], highlighting the need to monitor adiposity trends with several indicators, including BMI and waist circumference (WC) [18]. Although sophisticated methods exist for exploring adiposity, simple measures such as anthropometric indicators are useful for routine clinical practice and public health surveillance.

The present article aims to identify a hierarchy in prevention efforts: diet, versus PA; and daily PA versus sports frequency. We hypothesized that the youngest old with more or less healthy eating habits, daily PA, and sports frequency would have different anthropometric adiposity values. Our aim was to describe 1) eating habits, daily physical activity (PA), and sports frequency in community-dwelling adults aged 65 to 70, 2) the links of each of these behaviors with socioeconomic factors, and 3) with adiposity.

Methods

Study design and participants

The Lausanne cohort Lc65+, a study of the manifestations, determinants and outcomes of frailty [19], recruited individuals aged 65–70 in 2004, stemming from a representative sample of the general non-institutionalized population living in Lausanne (random sample from the list of all inhabitants given by the Population Office). The design of Lc65+ has already been described [19]. The ethics committee of the Faculty of Biology and Medicine of the University of Lausanne has approved the protocol. All participants provided written informed consent. Persons living in institutions or unable to respond because of advanced dementia were excluded. Of the 3,056 people who were initially mailed questionnaires, 2,096 (69%) replied, of whom 1,564 (75%) agreed to participate [19]. Overall, nonparticipants had demographic characteristics similar to those of participants [19]; only 8% of those refusing to participate attributed their refusal to poor health, and 58% had "a general reluctance to participate in any survey". Of the 1,564 respondents to the initial questionnaire, 1,524 (97.4%) were still eligible, and 1,422 (93.3%) participated in the baseline assessment in 2005 [5,19]. This report is based on a cross-sectional analysis of the cohort at baseline (2004–5). Eating habits [20] and PA could be influenced by cognitive impairment. Therefore, 162 persons with Mini-mental State Score <24 [21] (n = 49) or missing (n = 113) were excluded and 1,260 participants remained in this analysis.

In 2004, all participants completed a questionnaire sent at home; in 2005, they underwent the assessment at the study center with an interview, measurements, and performance tests conducted by trained medical assistants.

Eating habits and physical activity

A selection of 8 items stemming from the Mini Nutritional Assessment (MNA) [22], and describing eating habits was asked to the study population. The MNA is a widely used tool for assessing the risk of malnutrition in older adults [22].

The following MNA questions were selected (Tables 1 and 2): A) *How many full meals do you eat daily? 1) 1 meal; 2) 2 meals; and 3) 3 meals. B) Do you consume at least one serving of dairy products per day? 1) yes; 2) no. C) Do you consume at least two servings of legumes or eggs per week? 1) yes; 2) no. D) Do you consume meat, fish or poultry every day? 1) yes; 2) no. E) Do you consume two or more servings of fruits or vegetables per day? 1) yes; 2) no. F) Do you have a loss of appetite? 1) yes, severe; 2) yes, moderate; 3) not at all. G) How many drinks do you consume per day (water, juice, coffee, tea, milk, wine, beer, soup…)? 1) less than 3 glasses (1 glass = 2 dl.); 2) 3 to 5 glasses; 3) more than 5 glasses. H) Do you view yourself as being well fed, as having no nutritional problem? 1) severe malnutrition; 2) does not know or moderate malnutrition; 3) no nutritional problem.* The 8 items' distributions are shown in Table 1.

Since the MNA does not include any quantitative assessment of total energy intake, only three questions entailing indirect (however incomplete) information about energy intake were kept for multivariate analyses of the associations between diet and PA and adiposity indicators. In order to have a simple binary variable summarizing protein intake in these analyses, "sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥ twice/week.

PA was assessed with 2 main questions, described hereafter: daily PA and sports frequency (Table 3). This measurement of PA based on two questions has been adapted from the Monitoring of Trends and Determinants in Cardiovascular Disease Physical Activity Questionnaire [23,24] to suit activity patterns of individuals aged 65–70. In order to compare daily PA and sports frequency with respect to their association with adiposity, a four-category variable named "Daily PA and sports" combining both variables was created: "daily PA and sports" is a combination of a 4-category ordered variable (daily PA, further dichotomized around use, versus avoidance of stairs and loads) and a binary variable (sports frequency): A) Daily PA: "*Which statement best describes your current daily physical activity? 1) I am sitting or lying most of the time and I am not moving much; 2) I often walk, but I avoid taking stairs and carrying loads; 3) I often walk and I take stairs, I carry light loads; and 4) I make an important physical effort, I often carry heavy loads."* In the Figure 1 and in Table 4, categories 1) and 2) of daily PA are aggregated and labeled "No stairs"; categories 3) and 4) are aggregated and labeled "Stairs". B) Sports frequency: *"How often do you play sports for at least 20 minutes (for example, gymnastics, tennis, running, football, biking…)? <1x/week; versus ≥1/week."*. "No sport" is the label for sports frequency <1×/week in the Figure 1 and in Table 4. "Sports weekly" is the label for sports ≥1×/week. Therefore, the 4 categories of variable "Daily PA and sports" are: I) no stairs, no sport, II) no stairs, but sports weekly, III) stairs, but no sport, and IV) stairs and sports weekly.

Adiposity indicators

Height, weight, supra-iliac skin-fold (SISF), triceps skin-fold (TSF), waist (WC), and hip circumferences were measured without shoes. Weight was assessed with a digital SECA scale. The standard procedure recommended in NHANES III [25] was followed. WC was measured at the level midway between the lowest rib and the highest point of the iliac crest. Hip circumference was recorded as the maximum circumference over the buttocks. Skin-folds were measured with a GPM® caliper on the dominant side. Overweight and obesity were defined according to body mass index (BMI = 25.0-29.9 kg/m^2 and ≥30.0 kg/m^2). Abdominal obesity was considered if WC was ≥102 cm for men and ≥88 cm for women [26].

Other Covariates

Potential confounders of the diet-adiposity relationship or the PA-adiposity association are shown in Table 1 and adjusted for in multivariate models (Tables 3 and 4): age, living arrangement (living alone, 0/1), financial difficulties, symptoms of depression, education, and smoking status are known to be associated with eating habits [15,27,28], PA (as independent variables) [12,29], and adiposity (as the dependent variable) [8]. The educational level entitled "high school or more" includes high school, professional school, or university. Living alone was assessed by the question: *"With how many persons are you currently living? 1) I am living alone; 0) I am living with … persons".* Financial difficulties was a variable of interest for objective 2 (the cross-sectional association between eating habits, PA, and socio-economic factors), and a potential confounder for objective 3. It is defined in the footnotes of Tables 1, 2, 3, and 4. Current symptoms of depression were considered for the participants who had answered "yes" to at least one of two screening questions [30]: "*During the past month have you often been bothered by feeling down, depressed, or hopeless?*" and "*During the past month have you often been bothered by little interest or pleasure in doing things?*" Since eating habits, PA, and adiposity indicators differ between men and women [31,32], all analyses are stratified by sex.

Statistical analyses

Results were expressed as absolute numbers and percentages. Bivariate comparisons were performed using the chi-square test or Fisher exact test for categorical variables.

Table 1 Obesity, eating habits and physical exercise in 2004-2005

	Men N = 519 N (%)	Women N = 741 N (%)	χ^2 *P*-value
OBESITY PREVALENCE			
Body mass index category:			<0.001
Underweight (BMI < 18.5 kg/m^2)	0 (0.0)	19 (2.6)	
Normal weight (BMI 18.5-24.9 kg/m^2)	120 (23.3)	290 (39.2)	
Overweight (BMI 25.0-29.9 kg/m^2)	271 (52.6)	260 (35.2)	
Obesity (BMI ≥ 30.0 kg/m^2)	124 (24.1)	170 (23.0)	
Abdominal obesity (waist circumference: WC ≥ 102 cm in men, ≥ 88 cm in women)	228 (44.6)	334 (45.3)	0.823
WC-defined normal weight obesity (BMI < 25 kg/m^2 and WC ≥ 102 cm in men, ≥ 88 cm in women)	0 (0.0)	16 (2.2)	<0.001**
WHR-defined normal weight obesity (BMI < 25 kg/m^2 and WHR ≥ 66th gender-specific percentile)	12 (2.3)	37 (5.0)	0.017 **
EATING HABITS			
Questions from the MNA:			
Number of meals per day*			0.177
1 meal/day	33 (6.4)	60 (8.1)	
2 meals/day	204 (39.4)	257 (34.8)	
3 meals/day	281 (54.3)	422 (57.1)	
Meat, fish or poultry everyday	265 (51.3)	343 (46.4)	0.087
Dairy products ≥ once a day	425 (82.1)	643 (86.8)	0.021
Eggs or leguminous plants ≥ twice/week	254 (49.0)	350 (47.2)	0.529
"Sufficient protein intake"[†]	375 (72.5)	514 (69.5)	0.239
Fruit or vegetables ≥ twice/day	417 (80.5)	666 (90.1)	<0.001
Drinks per day			0.223
<3 glasses (1 glass = 2 dl.)	40 (7.7)	58 (7.8)	
3 to 5 glasses	199 (38.4)	250 (33.7)	
>5 glasses	279 (53.9)	433 (58.4)	
Loss of appetite			0.627
Yes, severe	1 (0.2)	4 (0.5)	
Yes, moderate	25 (4.8)	35 (4.7)	
Not at all	492 (95.0)	701 (94.7)	
Self-perception of nutrition			0.708
Severe malnutrition	0 (0.0)	0 (0.0)	
Doesn't know/moderate malnutrition	21 (4.1)	27 (3.6)	
No nutritional problem	497 (96.0)	714 (96.4)	
PHYSICAL ACTIVITY (PA):			
Daily PA:			0.003
Sitting or lying most of the time	39 (7.5)	37 (5.1)	
Often walking, but avoids stairs and loads	66 (12.8)	144 (19.7)	
Often walking and using stairs, carrying light loads	373 (72.2)	512 (69.9)	
Important physical activity, carries heavy loads	39 (7.5)	40 (5.5)	
Sports (≥20 minutes) frequency:			0.236
Less than once a week	246 (49.3)	359 (51.9)	
Once or twice a week	154 (30.9)	222 (32.1)	
Thrice a week or more	99 (19.8)	111 (16.0)	

Table 1 Obesity, eating habits and physical exercise in 2004-2005 *(Continued)*

ADJUSTMENT VARIABLES:			
Living alone (0/1)	96 (18.5)	346 (46.7)	<0.001
Financial difficulties (0/1)‡	123 (23.7)	207 (27.9)	0.092
Current symptoms of depression	97 (19.0)	201 (27.7)	<0.001
Education			<0.001
Basic compulsory	82 (15.9)	218 (29.5)	
Apprenticeship	225 (43.5)	274 (37.1)	
High school or more	210 (40.6)	246 (33.3)	
Current smoking§	119 (23.2)	143 (19.5)	0.112

Categorical variables are given in numbers (%); the chi-square *P*-value compares proportions across sexes.
**Fisher's exact test.
*Instructions given to interviewers: a breakfast includes a drink and one solid food item. A lunch or dinner meal needs to include a source of proteins, starchy food (feculent), and fruit or vegetables. It can be warm or cold. A sandwich is not considered as a meal.
†In order to have an approximate summary measure for protein intake, "Sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥ twice/week.
‡Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).
§Participants who had stopped smoking before less than one year are considered current smokers in the analyses.

Table 2 shows multivariate logistic regression analyses of the cross-sectional associations between eating habits and age, living arrangement, financial difficulties, symptoms of depression, and education. Table 3 shows multivariate logistic regression analyses of the cross-sectional associations of "daily PA" and "sports weekly" with age, living arrangement, financial difficulties, depressive symptoms, education, and current smoking.

Table 4 shows multivariate linear regressions of the cross-sectional associations of each of five anthropometric adiposity indicators with eating habits and PA. Eating habits and PA are simultaneously included in the same model. Since residuals had skewed distributions, all adiposity indicators were log-transformed. All potential confounders included in the adjustment are shown in Table 4. Statistical analyses were performed using Stata 12 software (Stata Corp, College Station, TX).

Results

Eating habits and PA

The prevalence of underweight (BMI < 18.5 kg/m^2) and normal weight was 0% and 23% among men, respectively 3% and 39% among women. Overweight and obesity prevalence was 53% and 24% among men, 35% and 23% among women. Abdominal obesity prevalence was 45% (both sexes). The prevalence of normal weight central obesity (BMI <25.0 kg/m^2 and WC ≥ 102 cm for men, ≥ 88 cm for women) was 0.0% among men, and 2.2% (16/736) among women. The prevalence with BMI < 25.0 kg/m^2 and WHR ≥ 66th gender-specific percentile was 2.3% in men and 5.0% in women (Table 1).

According to Table 1, 81% of men and 90% of women ate fruit or vegetables (FV) ≥2×/day (chi-square $P < 0.001$). 5% of both men and women reported moderate appetite loss and 4% moderate malnutrition (or unawareness of their own nutritional state).

Concerning physical activity (PA) in daily life, a higher proportion of women (25%) avoided using stairs or carrying loads than men (20%, chi-square $P = 0.003$). About half of men and women played sports <1×/week, without any significant sex difference. Women more frequently lived alone (47% vs. 19%, chi-square $P < 0.001$) and more often experienced symptoms of depression than men (28% vs. 19%, chi-square $P < 0.001$). Financial difficulties (about one quarter) and smoking (about one fifth) were equally distributed among sexes.

Links of eating habits and physical activity with socio-economic factors

According to Table 2, eating FV ≥ twice/day was negatively associated with financial difficulties and positively with education. Among men, eating 3 meals per day was significantly negatively associated with financial difficulties (OR = 0.6, 95% CI = 0.4–0.9). Among women, eating meat, fish, or poultry every day was positively related with being younger (OR = 1.1, 95% CI = 1.0–1.2 for each additional birth year); but very strongly negatively with living alone (OR = 0.5, 95% CI = 0.4–0.7). Men living alone were less likely to eat FV ≥2×/day (OR = 0.5, 95% CI = 0.3–0.9). Self-perception of malnutrition was strongly associated with living alone in both sexes. In men, this perception was also associated with financial difficulties (OR = 3.2, 95% CI = 1.2-8.7). Symptoms of depression were strongly associated with appetite loss in both sexes and with perception of moderate malnutrition in women (OR = 3.8, 95% CI = 1.7-8.5).

Table 3 shows that both daily PA and sports weekly have strong and significant negative links with financial difficulties

Table 2 Associations of eating habits with age, living arrangement, financial difficulties, symptoms of depression, and education

	3 meals/day (versus 1 or 2)	Dairy products ≥ once a day (yes versus no)	Eggs or leguminous plants ≥ twice/week (yes versus no)	Meat, fish or poultry everyday (yes versus no)	"Sufficient protein intake"[‡] (yes versus no)
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
MEN					
Age (per 1-birth year)	1.0 [0.9-1.1]	0.8 [0.7-1.0]*	1.1 [0.9-1.2]	1.1 [0.9-1.2]	1.1 [0.9-1.3]
Living alone (0/1)	0.7 [0.5-1.2]	0.7 [0.4-1.2]	0.8 [0.5-1.3]	0.9 [0.6-1.5]	0.9 [0.5-1.5]
Financial difficulties (0/1)[†]	0.6 [0.4-0.9]*	0.7 [0.4-1.1]	0.9 [0.6-1.4]	0.8 [0.5-1.2]	0.7 [0.5-1.1]
Symptoms of depression (0/1)	0.7 [0.4-1.1]	1.0 [0.5-1.8]	0.9 [0.6-1.4]	1.0 [0.6-1.6]	0.9 [0.6-1.5]
Education					
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	1.0 [0.6-1.7]	2.0 [1.1-3.7]*	1.6 [1.0-2.8]	1.6 [0.9-2.7]	1.9 [1.1-3.4]*
High school or more	1.4 [0.8-2.3]	2.6 [1.4-4.9]**	1.6 [1.0-2.8]	1.2 [0.7-2.0]	1.5 [0.8-2.5]
WOMEN					
Age (per 1-birth year)	1.0 [0.9-1.1]	0.9 [0.8-1.1]	0.9 [0.8-1.0]	1.1 [1.0-1.2]*	1.0 [0.9-1.1]
Living alone (0/1)	0.9 [0.7-1.2]	0.8 [0.5-1.2]	0.7 [0.6-1.0]	0.5 [0.4-0.7]***	0.5 [0.4-0.8]***
Financial difficulties (0/1)[†]	0.8 [0.5-1.1]	1.1 [0.7-1.9]	0.9 [0.6-1.2]	1.0 [0.7-1.3]	0.8 [0.6-1.2]
Symptoms of depression (0/1)	0.7 [0.5-1.0]	0.8 [0.5-1.3]	1.2 [0.9-1.7]	1.3 [0.9-1.8]	1.5[1.0-2.2]
Education					
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	0.9 [0.6-1.3]	1.4 [0.8-2.5]	1.2 [0.9-1.8]	1.0 [0.7-1.4]	1.1 [0.7-1.6]
High school or more	1.2 [0.8-1.8]	1.0 [0.6-1.7]	1.1 [0.7-1.6]	0.8 [0.6-1.2]	0.9 [0.6-1.3]

	Fruit or vegetables ≥ twice/day (yes versus no)	> 5 glasses/day (versus ≤5 drinks/day)	Loss of appetite (yes versus not at all)	Self-perception: moderate malnutrition or doesn't know (versus no nutritional problems)
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
MEN				
Age (per 1-birth year)	1.0 [0.9-1.2]	1.1 [0.9-1.2]	1.0 [0.8-1.4]	1.0 [0.7-1.5]
Living alone (0/1)	0.5 [0.3-0.9]*	1.0 [0.6-1.6]	2.2 [0.9-5.4]	5.0 [1.9-13.6]**
Financial difficulties (0/1)[†]	0.6 [0.4-1.0]*	1.0 [0.7-1.6]	1.1 [0.4-2.8]	3.2 [1.2-8.7]*
Symptoms of depression (0/1)	0.7 [0.4-1.3]	0.9 [0.6-1.4]	2.5 [1.1-6.1]*	1.6 [0.5-4.5]
Education				
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	1.2 [0.7-2.2]	0.6 [0.4-1.0]	1.7 [0.5-6.5]	1.6 [0.4-6.4]
High school or more	2.4 [1.2-4.5]*	0.6 [0.4-1.0]	1.0 [0.3-4.1]	0.8 [0.2-3.5]

Table 2 Associations of eating habits with age, living arrangement, financial difficulties, symptoms of depression, and education *(Continued)*

WOMEN				
Age (per 1-birth year)	1.0 [0.9-1.2]	1.2 [1.0-1.3]*	1.0 [0.8-1.3]	1.1 [0.8-1.5]
Living alone (0/1)	0.8 [0.5-1.4]	0.8 [0.6-1.1]	1.1 [0.6-2.1]	2.5 [1.1-5.9]*
Financial difficulties (0/1)†	0.5 [0.3-0.9]*	1.2 [0.8-1.7]	1.2 [0.6-2.5]	1.4 [0.6-3.3]
Symptoms of depression (0/1)	1.2 [0.7-2.0]	1.1 [0.8-1.5]	3.4 [1.7-6.6]***	3.8 [1.7-8.5]**
Education				
Basic compulsory	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Apprenticeship	1.2 [0.7-2.2]	1.2 [0.8-1.7]	1.0 [0.4-2.3]	1.0 [0.3-2.7]
High school or more	1.8 [0.9-3.4]	1.0 [0.7-1.5]	1.9 [0.9-4.4]	1.6 [0.6-4.2]

Multivariate logistic regression analysis; one separate model for each sex; approximate N = 507 for men, 724 for women.
*P < 0.05; **P < 0.01; ***P < 0.001.
†Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).
‡"Sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥ twice/week.

Table 3 Association of physical activity with socio-economic and lifestyle factors

	Daily PA		Sports weekly	
	OR [95% CI]	***P*-value**	**OR [95% CI]**	***P*-value**
MEN				
N	501		486	
Age (per 1-birth year)	1.0 [0.8-1.1]	0.623	1.0 [0.9-1.1]	0.865
Living alone (0/1)	0.5 [0.3-0.9]	0.013	0.7 [0.4-1.1]	0.094
Financial difficulties (0/1)[†]	0.4 [0.3-0.7]	0.001	0.5 [0.3-0.8]	0.002
Symptoms of depression (0/1)	0.8 [0.4-1.3]	0.367	0.9 [0.5-1.4]	0.635
Education				
Basic compulsory	1 (ref)		1 (ref)	
Apprenticeship	1.1 [0.6-2.1]	0.780	1.0 [0.6-1.7]	0.991
High school or more	1.6 [0.8-3.1]	0.150	1.4 [0.8-2.4]	0.265
Current smoking (0/1)[‡]	0.6 [0.4-1.1]	0.090	0.4 [0.3-0.7]	<0.001
WOMEN				
N	713		677	
Age (per 1-birth year)	1.1 [0.9-1.2]	0.373	1.1 [1.0-1.2]	0.131
Living alone (0/1)	0.8 [0.6-1.1]	0.234	1.0 [0.7-1.4]	0.978
Financial difficulties (0/1)[†]	0.6 [0.4-0.9]	0.008	0.6 [0.4-0.8]	0.002
Symptoms of depression (0/1)	0.6 [0.4-0.9]	0.017	1.0 [0.7-1.4]	0.933
Education				
Basic compulsory	1 (ref)		1 (ref)	
Apprenticeship	1.2 [0.8-1.8]	0.386	1.2 [0.8-1.7]	0.473
High school or more	1.7 [1.1-2.7]	0.018	1.7 [1.1-2.6]	0.010
Current smoking (0/1)[‡]	0.8 [0.6-1.3]	0.458	0.4 [0.3-0.7]	<0.001
ALL				
N	1214		1163	
Age (per 1-birth year)	1.0 [0.9-1.1]	0.675	1.0 [1.0-1.1]	0.290
Male sex	1.3 [0.5-3.2]	0.588	1.5 [0.7-3.3]	0.331
Living alone (0/1)	0.8 [0.6-1.2]	0.289	1.0 [0.7-1.4]	0.985
Financial difficulties (0/1)[†]	0.5 [0.4-0.7]	<0.001	0.5 [0.4-0.7]	<0.001
Symptoms of depression (0/1)	0.6 [0.4-0.9]	0.023	1.0 [0.7-1.4]	0.954
Education				
Basic compulsory	1 (ref)		1 (ref)	
Apprenticeship	1.2 [0.8-1.7]	0.414	1.1 [0.8-1.6]	0.443
High school or more	1.7 [1.1-2.7]	0.021	1.7 [1.1-2.6]	0.009
Current smoking (0/1)[‡]	0.8 [0.5-1.1]	0.102	0.4 [0.3-0.6]	<0.001
Living alone*male sex	0.6 [0.3-1.1]	0.115	0.7 [0.4-1.2]	0.151
Depressive symptoms*male sex	1.1 [0.6-2.2]	0.687	0.9 [0.5-1.6]	0.691
Education*male sex	1.0 [0.7-1.5]	0.951	0.9 [0.6-1.3]	0.528

*Daily physical activity (PA, 0/1):*1) Often walking and using stairs, carrying light loads, and important physical activity, carries heavy loads; 0) sitting or lying most of the time, or often walking, but avoiding stairs and loads. *Sports weekly (0/1):* Sports frequency <1×/week (0), versus ≥1×/week (1). Multivariate logistic regression analysis.

[†]Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).

[‡]Participants who had stopped smoking before less than one year are considered current smokers in the analyses.

*Interaction.

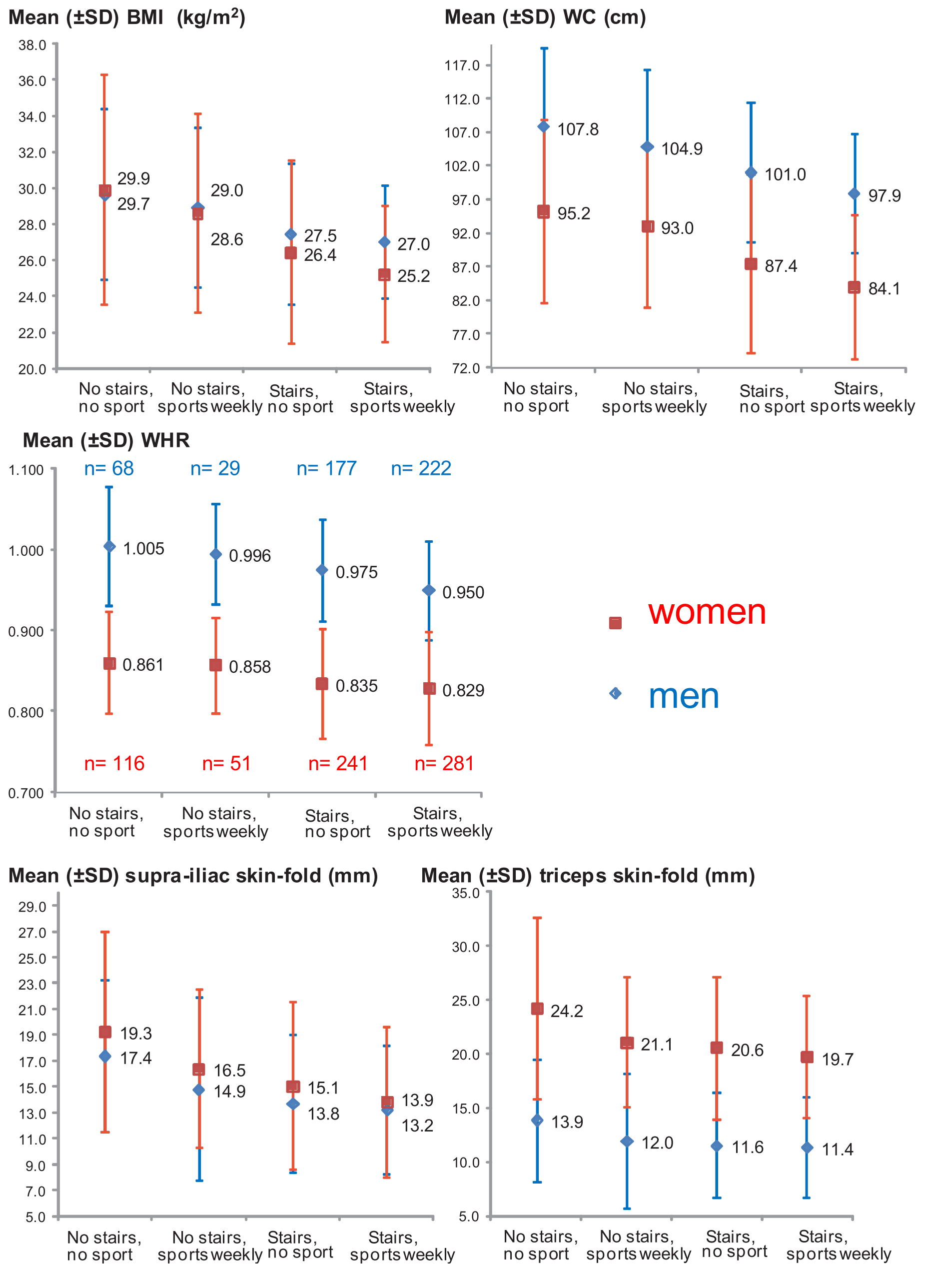

Figure 1 Mean adiposity indicators according to category of physical activity (unadjusted), 2005. Categories of variable "Daily PA and sports": No stairs: sitting or lying most of the time, or often walking, but avoiding stairs and loads (versus often walking and using stairs, carrying light loads, and important physical activity, carries heavy loads). No sport: sports (≥20 minutes) frequency <1×/week (versus ≥1×/week).

in both sexes, and significant positive links with educational level in women only; however the interaction was not statistically significant. Unlike women, men living alone were significantly less likely to use stairs and carry light loads in their daily life than men living with someone (OR = 0.5, 95% CI = 0.3-0.9). No sex interaction reached significance. Sports weekly, but not daily PA, had strong significant negative links with current smoking in both sexes.

Across the 4 categories of variable "Daily PA and sports", there was a gradual decrease in the prevalence of participants living alone, experiencing financial difficulties, depressive symptoms, current smoking, and a gradual increase in educational level. The test for trend *P*-value was statistically significant ($P < 0.05$) for all above mentioned associations (Additional file 1).

Links of eating habits and physical activity with adiposity

The Figure 1 shows univariate associations between each adiposity indicator and variable "Daily PA and sports". Men had higher BMI, WC, and waist-to-hip ratio (WHR)

Table 4 Associations of five log-transformed adiposity indicators with eating habits and physical activity

	Ln (BMI)		Ln (WC)		Ln (WHR)		Ln (SISF)		Ln (TSF)	
	ß [95% CI]	P	ß [95% CI]	P	ß [95% CI]	P	ß [95% CI]	P	ß [95% CI]	P
MEN: (N ≥ 477):										
Eating habits:										
Three meals/day	−0.02 [−0.04-0.01]		−0.01 [−0.02-0.01]		−0.01 [−0.02-0.00]		0.00 [−0.07-0.08]		−0.04 [−0.11-0.03]	
Fruit and veg. ≥twice/day	0.00 [−0.03-0.03]		0.00 [−0.02-0.03]		0.00 [−0.02-0.01]		0.05 [−0.05-0.14]		0.02 [−0.07-0.12]	
Sufficient protein intake$	0.03 [0.00-0.06]	*	0.03 [0.01-0.05]	**	0.02 [0.01-0.03]	**	0.04 [−0.04-0.12]		−0.03 [−0.11-0.04]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1×/wk	−0.03 [−0.08-0.03]		−0.03 [−0.07-0.02]		0.00 [−0.03-0.03]		−0.25 [−0.43- -0.07]	**	−0.22 [−0.40- -0.04]	*
3: Stairs, no sport	−0.07 [−0.11- -0.04]	***	−0.06 [−0.09- -0.03]	***	−0.02 [−0.04- -0.01]	*	−0.24 [−0.35- -0.13]	***	−0.18 [−0.29- -0.07]	**
4: Stairs, sports ≥1×/wk	−0.09 [−0.13- -0.05]	***	−0.10 [−0.12- -0.07]	***	−0.05 [−0.07- -0.03]	***	−0.30 [−0.41- -0.18]	***	−0.20 [−0.31- -0.09]	**
Age (per 1-birth year)	0.01 [0.00-0.01]		0.00 [0.00-0.01]		0.00 [0.00-0.01]		0.02 [0.00-0.05]		0.00 [−0.02-0.03]	
Living alone (0/1)	−0.03 [−0.06-0.00]		−0.01 [−0.04-0.01]		0.01 [−0.01-0.02]		0.03 [−0.07-0.12]		0.02 [−0.08-0.11]	
Financial diff. (0/1)€	−0.01 [−0.03-0.02]		0.00 [−0.02-0.02]		0.00 [−0.01-0.01]		−0.01 [−0.10-0.08]		0.01 [−0.07-0.10]	
Symptoms of depression	0.03 [0.00-0.06]	*	0.02 [−0.01-0.04]		0.00 [−0.01-0.02]		0.06 [−0.04-0.15]		0.04 [−0.06-0.13]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	−0.03 [−0.07-0.00]		−0.02 [−0.05-0.01]		−0.01 [−0.03-0.01]		−0.01 [−0.11-0.10]		−0.03 [−0.13-0.07]	
≥High school	−0.05 [−0.09- -0.02]	**	−0.03 [−0.06- -0.01]	*	−0.02 [−0.04- -0.01]	*	−0.02 [−0.13-0.08]		−0.03 [−0.13-0.08]	
Current smoking (0/1)§	−0.04 [−0.07- -0.01]	*	−0.01 [−0.03-0.01]		0.01 [−0.01-0.02]		−0.11 [−0.20- -0.03]	*	−0.05 [−0.14-0.03]	
WOMEN (N ≥ 657)										
Eating habits:										
Three meals/day	0.00 [−0.03-0.03]		0.01 [−0.02-0.03]		0.00 [−0.01-0.01]		0.06 [−0.02-0.13]		−0.03 [−0.09-0.03]	
Fruit and veg. ≥twice/day	0.05 [0.00-0.10]	*	0.02 [−0.02-0.05]		−0.01 [−0.03-0.01]		0.14 [0.02-0.27]	*	0.14 [0.04-0.23]	**
Sufficient protein intake$	0.03 [0.00-0.06]		0.02 [0.00-0.04]		0.01 [−0.01-0.02]		0.04 [−0.04-0.11]		0.05 [−0.01-0.11]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1×/wk	−0.04 [−0.10-0.01]		−0.02 [−0.07-0.02]		0.00 [−0.03-0.03]		−0.16 [−0.32-0.00]	*	−0.13 [−0.25- -0.01]	*
3: Stairs, no sport	−0.12 [−0.16- -0.08]	***	−0.08 [−0.11- -0.05]	***	−0.03 [−0.04- -0.01]	**	−0.25 [−0.36- -0.14]	***	−0.15 [−0.23- -0.07]	***
4: Stairs, sports ≥1×/wk	−0.16 [−0.20- -0.12]	***	−0.12 [−0.15- -0.09]	***	−0.03 [−0.05- -0.01]	**	−0.34 [−0.45- -0.23]	***	−0.19 [−0.27- -0.11]	***
Age (per 1-birth year)	0.00 [−0.01-0.01]		0.00 [−0.01-0.01]		0.00 [0.00-0.00]		0.01[−0.02-0.03]		0.00 [−0.02-0.02]	
Living alone (0/1)	−0.03 [−0.06-0.00]	*	−0.02 [−0.04-0.00]		−0.01 [−0.02-0.01]		−0.05 [−0.12-0.03]		−0.06 [−0.11-0.00]	*
Financial diff. (0/1)€	0.04 [0.01-0.07]	*	0.02 [−0.01-0.04]		0.00 [−0.01-0.02]		0.08 [−0.01-0.16]		0.05 [−0.01-0.12]	
Symptoms of depression	0.01[−0.02-0.04]		0.01[−0.01-0.04]		0.01[0.00-0.02]		0.06[−0.02-0.14]		0.01[−0.05-0.07]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	−0.02[−0.05-0.01]		−0.01[−0.03-0.02]		−0.01[−0.02-0.01]		−0.04[−0.13-0.05]		−0.02[−0.09-0.05]	
≥High school	−0.06[−0.10- -0.03]	***	−0.04[−0.06- -0.01]	**	−0.02[−0.03-0.00]	*	−0.14[−0.23- -0.05]	**	−0.07[−0.14-0.00]	
Current smoking (0/1)§	−0.07[−0.11- -0.04]	***	−0.04[−0.06- -0.01]	**	0.00[−0.01-0.02]		−0.21[−0.30- -0.12]	***	−0.15[−0.22- -0.08]	***

Multivariate linear regression analysis. The table shows all covariates included in the adjustment.
$"Sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥ twice/week.
€Financial difficulties (diff.) are considered if any of the following criteria is fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).
§Participants who had stopped smoking before less than one year are considered current smokers in the analyses.
*P < 0.05; **P < 0.01; ***P < 0.001.

mean values than women. In contrary, women had higher SISF and TSF mean values than men. For all five adiposity indicators and in both sexes, a progressive decrease in adiposity was observed from category “No stairs, no sport”, to “No stairs, sports weekly”, to “Stairs, no sport”, and finally “Stairs, sports weekly”. This consistent univariate association was statistically significant for all indicators (test for trend *P*-value <0.001 for all indicators, except TSF among men: *P*-value = 0.002). This Figure 1 suggests that adiposity values were higher among participants taking no stairs in daily life, but doing sports ≥1×/week, than among persons taking stairs, but doing sports <1×/week. The same progressive decrease in median adiposity values across categories of PA was observed for all five indicators and in both sexes (Additional file 2). The prevalence of obesity (BMI ≥ 30.0 kg/m^2) was respectively 45.6%, 41.4%, 19.3%, and 17.6% in men, respectively 44.8%, 41.2%, 21.6%, and 11.0% in women in categories “no stairs, sports < once/week”, “no stairs, sports ≥ once/week”, “stairs, sports < once/week”, and “stairs, sports ≥ once/week” (chi-square and univariate test for trend *P*-values <0.001 in both sexes). Corresponding prevalence estimates for abdominal obesity were 69.7%, 62.1%, 44.0%, and 34.2% in men, respectively 69.0%, 68.6%, 42.3%, and 32.7% in women (chi-square and univariate test for trend *P*-values <0.001 in both sexes).

According to Table 4, “sufficient protein intake” was positively linked with BMI, WC, and WHR in men. FV intake was positively related to BMI, SISF, and TSF in women. Except for SISF and TSF in men (with similar *ß* coefficients across PA categories), the gradual decrease in adiposity across categories of increasing PA observed in the Figure 1 was confirmed with multiple adjustment in both sexes (Table 4). Unlike men, women living alone had slightly lower BMI and TSF values than women living with someone. Current smoking was strongly significantly negatively associated with all adiposity indicators but WHR in women. Additional adjustment for number of chronic diseases and self-rated health yielded similar results (Additional file 3).

Discussion

In this community-dwelling population aged 65–70, overweight and obesity affected more than three quarters of men, and between half and two thirds of women. Abdominal obesity almost hit half of both sexes. Normal weight abdominal obesity, defined as BMI < 25 kg/m^2 and WC ≥102 cm in men, 88 cm in women, was absent among men, and very rare among women. A gradual decrease in adiposity was almost consistently observed across categories of increasing PA. Adiposity values were higher among participants taking no stairs in daily life, but doing sports ≥1×/week, than among persons taking stairs, but doing sports <1×/week. In both sexes, eating FV ≥2×/day, taking stairs every day, and doing sports ≥ once a week were strongly negatively associated with financial difficulties, and positively with education. The independent and significant negative association of adiposity with PA and education in Lc65+ might be explained by higher fat and total energy intake among less educated persons [33]; these nutritional items were not assessed. A large European cross-sectional study reported a strong association between low levels of PA (during work and leisure time) and obesity, while adjusting for educational level and total energy intake [34].

The main limitations of the present study include the lack of data on total energy intake, fat intake, and sugar intake (the MNA does not include any question on dessert or sugar); the lack of information on total energy intake limited the interpretation of the results, in particular for Table 4. MNA items are categorical and do not allow any quantitative estimation of food intake. Therefore, the present report only presents a few items about eating habits, and does not provide a real dietary assessment. Daily PA and sports frequency were self-reported; a measurement bias could have occurred if participants with higher adiposity values had over-reported their sports frequency, but not their daily PA. To our knowledge, no such a systematic differential bias has previously been described. These analyses could be replicated in studies objectively measuring daily PA and sports frequency. The number of stairs was not specified in the question asked to the participants, nor the number of minutes spent on each of the sports (except that it was at least 20 minutes per session). Therefore, it is not precise enough to clearly establish that there is a dose–response relationship. In addition, the specific benefits of walking and using stairs could not be precisely separated and compared, since a single question addressed both these activities. The sample size was relatively small, thus limiting the generalizability of the findings. This analysis should be replicated in larger samples. The present analysis was cross-sectional: low PA could lead to adiposity [35,36], in the same way as adiposity could lead to low PA [37,38]. The relationship between PA and adiposity should be studied longitudinally. A Swiss study observed that encouraging hospital employees to use stairs instead of elevators during their daily work routine significantly improved cardio-vascular disease risk factors (including WC, body weight, and fat mass) and increased cardiorespiratory fitness after 12 weeks [35]. On the other hand, a small study (involving adults younger than 65 years) reported that experimental weight gain (with overfeeding) reduced objectively measured daily walking distance [37]. In another longitudinal study [38], weight, BMI, fat mass, and WC predicted sedentary time after 5.6 years of follow-up, whereas sedentary time did not predict obesity. With increasing age, visceral abdominal fat mass increases

[4,8] while subcutaneous fat mass decreases. Increases in fat mass might not be reflected in proportional increases in anthropometric indicators [4]. However, according to Flegal *et al*. [39], BMI and WC may be inaccurate measures of percentage body fat for an individual, but they correspond well overall with percentage body fat within sex-age groups and distinguish categories of percentage body fat.

Strengths of Lc65+ include the randomly selected sample, which is representative of the general community-dwelling population of Lausanne aged 65 to 70. Its age distribution is homogeneous, reducing the potential for age-related biases (e.g. selection bias) or confounders. This cohort study offers a detailed description of the socio-economic circumstances of this age group, which deserves careful attention for planning health services for the next decade. Height and weight were measured. Moreover, five anthropometric adiposity indicators were assessed, allowing examining the consistency of associations.

Lc65+ obesity prevalence estimates are slightly higher than those observed in the same city in CoLaus study [2], with a prevalence of overweight, obesity, and abdominal obesity of 50%, 23%, and 40% in men aged 65–75 years, respectively 35%, 17% and 45% in women (same definitions in CoLaus and Lc65+). In the Swiss Health Survey (SHS) 2012 [3], the prevalence of overweight and obesity (self-reported height and weight) was 49% and 17% in men, respectively 34% and 14% in women aged 65–74 years at a national level. However, BMI calculated from self-reported height and weight is underestimated [40,41]. Studies allowing reliable international comparisons of overweight and obesity prevalence after age 65 years are lacking because of methodological issues (samples not always representative of the general population, differing participation rates, heterogeneous age distributions, measurements versus self-reports of weight and height) [42]. Despite these limitations, several reports suggest that overweight and obesity prevalence among Swiss adults is lower than in other European countries [40-42]. Several studies have described associations between low socioeconomic status and suboptimal diet [12] and PA [13,43], as well as the links of these behaviors with odds for being overweight or obese [44]. In Lc65+, living alone was associated with eating less FV among men, but less meat among women, a finding already observed in the SHS, and in England [45]. Lc65+ women living alone were also leaner; in a Swedish cohort [46], women “co-habitating” experienced a higher increase in weight and body fat since age 20. Current smoking was consistently negatively associated with adiposity among Lc65+ women, a relationship also observed in CoLaus [2]. As regards daily PA, it has already been observed that pedestrians in lower socioeconomic areas are less likely to climb stairs and more often choose escalators than pedestrians in high socioeconomic areas [43]. Still, a stair climbing intervention was equally effective in both areas [43].

Conclusions

While the prevalence of abdominal obesity was 45% in both sexes, indicating an important risk of cardiovascular disease [47], 20% of men and 25% of women avoided using stairs or carrying loads. Whereas obese older persons should be encouraged to practice sports more than once a week [10], the importance of keeping a high level of mobility in daily life should not be overlooked [35]. In this population, eating habits and PA had strong links with socioeconomic factors, which could be the target of public health interventions [43]. Simple measures about use of stairs in everyday life can provide interesting information on health behaviors. In the present study, these measures had consistent cross-sectional associations with adiposity indicators. In conclusion, this study suggests that walking and using stairs in daily life has stronger negative links with adiposity than doing sports at least once a week.

Ethics approval

The ethics committee of the Faculty of Biology and Medicine of the University of Lausanne has approved the study protocol.

Additional files

Additional file 1: Associations between variable “Daily PA and sports” and socio-economic factors and lifestyle factors.

Additional file 2: Median values of the 5 adiposity indicators according to variable “Daily PA and sports”.

Additional file 3: Associations of adiposity with diet and physical activity, adjusted for number of chronic diseases. Associations of adiposity with diet and physical activity, adjusted for self-rated health.

Abbreviations

BMI: Body mass index; CI: Confidence intervals; FV: Fruits or vegetables; MNA: Mini nutritional assessment; OR: Odds ratio; PA: Physical activity; SHS: Swiss Health Survey; SISF: Supra-iliac skin-fold; TSF: Triceps skin-fold; WC: Waist circumference; WHR: Waist-to-hip ratio.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

Study design: SE. Data acquisition: SE. Data analysis and interpretation: DH, SE. Manuscript preparation: DH, SE. Both authors read and approved the final manuscript.

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ADDITIONAL FILE 1. ASSOCIATIONS BETWEEN VARIABLE "DAILY PA AND SPORTS" AND SOCIO-ECONOMIC FACTORS

Univariate associations of the 4 categories of variable "Daily PA and sports" with age, living arrangement, financial difficulties, symptoms of depression, education, and smoking status

	No stairs, no sport N(%)	**No stairs, sports weekly** N(%)	**Stairs, no sport** N(%)	**Stairs, sports weekly** N(%)	χ^2 ***P*-value**	**Univariate test for trend *P*-value**
MEN (Total N=498): N	69	29	177	223		
Birth year					0.724	0.500
1934	12 (17.4)	6 (20.7)	30 (17.0)	38 (17.0)		
1935	12 (17.4)	8 (27.6)	35 (19.8)	51 (22.9)		
1936	15 (21.7)	1 (3.5)	38 (21.5)	47 (21.1)		
1937	13 (18.8)	8 (27.6)	42 (23.7)	43 (19.3)		
1938	17 (24.6)	6 (20.7)	32 (18.1)	44 (19.7)		
Living alone	23 (33.3)	5 (17.2)	32 (18.1)	32 (14.4)	0.005	0.001
Financial difficulties (0/1) ‡	30 (43.5)	8 (27.6)	47 (26.6)	34 (15.3)	<0.001	<0.001
Symptoms of depression (0/1)	22 (32.4)	4 (14.3)	31 (17.7)	36 (16.4)	0.023	0.011
Education					0.281†	0.010
Basic compulsory	13 (18.8)	6 (21.4)	29 (16.5)	29 (13.0)		
Apprenticeship	36 (52.2)	12 (42.9)	76 (43.2)	92 (41.3)		
High school or more	20 (29.0)	10 (35.7)	71 (40.3)	102 (45.7)		
Current smoking (0/1) §	23 (33.8)	6 (21.4)	49 (27.7)	34 (15.4)	0.003	0.001
WOMEN (Total N=690): N	116	51	242	281		
Birth year					0.009	0.178
1934	22 (19.0)	19 (37.3)	56 (23.1)	41 (14.6)		
1935	20 (17.2)	8 (15.7)	52 (21.5)	64 (22.8)		
1936	28 (24.1)	9 (17.7)	54 (22.3)	48 (17.1)		
1937	20 (17.2)	9 (17.7)	34 (14.1)	65 (23.1)		
1938	26 (22.4)	6 (11.8)	46 (19.0)	63 (22.4)		

Continued…

	No stairs, no sport N(%)	**No stairs, sports weekly** N(%)	**Stairs, no sport** N(%)	**Stairs, sports weekly** N(%)	**χ^2 *P*-value**	**Univariate test for trend *P*-value**
Living alone	65 (56.0)	23 (45.1)	109 (45.0)	124 (44.1)	0.163	0.046
Financial difficulties (0/1) ‡	44 (37.9)	19 (37.3)	74 (30.6)	47 (16.7)	<0.001	<0.001
Symptoms of depression (0/1)	45 (39.8)	18 (35.3)	57 (23.8)	64 (23.1)	0.002	<0.001
Education					0.008	<0.001
Basic compulsory	44 (37.9)	16 (31.4)	72 (29.9)	62 (22.2)		
Apprenticeship	47 (40.5)	18 (35.3)	90 (37.3)	103 (36.9)		
High school or more	25 (21.6)	17 (33.3)	79 (32.8)	114 (40.9)		
Current smoking (0/1) §	28 (24.4)	11 (22.0)	63 (26.1)	31 (11.0)	<0.001	0.001

*P<0.05; **P<0.01; ***P<0.001.

† Fisher exact two-tailed test (if expected frequency <5 in any of the cells).

‡ Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).

§ Participants who had stopped smoking before less than one year are considered current smokers in the analyses.

Additional file 2. Median values of the 5 adiposity indicators according to variable "Daily PA and sports"

	No stairs, no sport Median	No stairs, sports weekly Median	Stairs, no sport Median	Stairs, sports weekly Median
Men				
N	66-68	28-29	175-177	222
Body mass index (kg/m^2)	29.1	28.8	27.1	26.7
Waist circumference (cm)	108.0	105.0	100.7	97.8
Waist-to-hip ratio	1.004	0.999	0.971	0.954
Supra-iliac skin-fold (mm)	17.3	13.0	12.6	12.4
Triceps skin-fold (mm)	12.3	10.8	10.6	10.3
Women				
N	110-116	50-51	237-241	278-281
Body mass index (kg/m^2)	29.5	27.8	25.6	24.6
Waist circumference (cm)	95.2	93.8	85.0	82.5
Waist-to-hip ratio	0.860	0.863	0.829	0.825
Supra-iliac skin-fold (mm)	19.4	15.7	15.2	13.0
Triceps skin-fold (mm)	23.6	20.4	20.2	19.8

Definition of variable "Daily PA and sports":

No stairs: sitting or lying most of the time, or often walking, but avoiding stairs and loads (versus often walking and using stairs, carrying light loads, and important physical activity, carries heavy loads)

No sport: sports (≥20 minutes) frequency <1x/week (versus ≥1x/week)

ADDITIONAL FILE 3. TABLE A. ASSOCIATIONS OF ADIPOSITY WITH DIET AND PHYSICAL ACTIVITY, ADJUSTED FOR NUMBER OF CHRONIC DISEASES.

The five adiposity indicators have been log-transformed. Multivariate linear regression analysis. The table shows all covariates included in the adjustment.

	Ln(BMI)		Ln(WC)		Ln(WHR)		Ln(SISF)		Ln(TSF)	
	β [95%CI]	*P*	*β* [95%CI]	*P*	*β* [95%CI]	*P*	*β* [95%CI]	*P*	*β* [95%CI]	*P*
MEN:(N≥477):										
Eating habits:										
Three meals/day	-0.01[-0.04-0.01]		0.00[-0.02-0.02]		-0.01[-0.02-0.00]		0.01[-0.07-0.08]		-0.04[-0.11-0.04]	
Fruit and veg. ≥twice/day	0.00[-0.03-0.03]		0.00[-0.02-0.03]		0.00[-0.02-0.01]		0.05[-0.05-0.14]		0.03[-0.07-0.12]	
Sufficient protein intake$	0.03[0.00-0.06]	*	0.03[0.01-0.05]	**	0.02[0.01-0.03]	**	0.04[-0.04-0.12]		-0.03[-0.11-0.05]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1x/wk	-0.03[-0.08-0.03]		-0.03[-0.07-0.02]		0.00[-0.03-0.03]		-0.25[-0.43--0.06]	**	-0.22[-0.39--0.04]	*
3: Stairs, no sport	-0.07[-0.11--0.03]	***	-0.06[-0.09--0.03]	***	-0.02[-0.04-0.00]	*	-0.24[-0.35--0.12]	***	-0.17[-0.29--0.06]	**
4: Stairs, sports ≥1x/wk	-0.09[-0.13--0.05]	***	-0.09[-0.12--0.06]	***	-0.05[-0.07--0.03]	***	-0.29[-0.41--0.18]	***	-0.20[-0.31--0.08]	**
Age (per 1-birth year)	0.01[0.00-0.01]		0.00[0.00-0.01]		0.00[0.00-0.01]		0.02[0.00-0.05]		0.00[-0.02-0.03]	
Living alone (0/1)	-0.03[-0.06-0.00]		-0.01[-0.04-0.01]		0.00[-0.01-0.02]		0.03[-0.07-0.12]		0.02[-0.08-0.11]	
Financial diff. (0/1)€	-0.01[-0.04-0.02]		0.00[-0.02-0.02]		0.00[-0.02-0.01]		-0.01[-0.10-0.08]		0.01[-0.08-0.09]	
Symptoms of depression	0.03[0.00-0.06]		0.01[-0.01-0.04]		0.00[-0.01-0.02]		0.05[-0.04-0.15]		0.03[-0.06-0.12]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	-0.03[-0.07-0.00]		-0.02[-0.05-0.01]		-0.01[-0.03-0.01]		-0.01[-0.11-0.10]		-0.03[-0.14-0.07]	
≥High school	-0.05[-0.09--0.02]	**	-0.03[-0.06--0.01]	*	-0.02[-0.04--0.01]	*	-0.02[-0.13-0.08]		-0.03[-0.14-0.08]	

Continued…

	Ln(BMI) β [95%CI]	P	Ln(WC) β [95%CI]	P	Ln(WHR) β [95%CI]	P	Ln(SISF) β [95%CI]	P	Ln(TSF) β [95%CI]	P
Current smoking (0/1)§	-0.04[-0.06--0.01]	*	-0.01[-0.03-0.01]		0.01[-0.01-0.02]		-0.11[-0.20--0.02]	*	-0.05[-0.14-0.03]	
Number of chronic diseases #										
0	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
1	0.03[0.00-0.05]		0.02[0.00-0.04]	*	0.01[-0.01-0.02]		-0.01[-0.09-0.07]		0.05[-0.03-0.13]	
≥2	0.02[-0.01-0.05]		0.02[0.00-0.05]		0.01[0.00-0.03]		0.02[-0.08-0.11]		0.03[-0.07-0.12]	
WOMEN (N≥ 657)										
Eating habits:										
Three meals/day	0.00[-0.03-0.03]		0.01[-0.02-0.03]		0.00[-0.01-0.01]		0.06[-0.02-0.13]		-0.03[-0.09-0.03]	
Fruit and veg. ≥twice/day	0.05[0.00-0.10]	*	0.02[-0.02-0.05]		-0.01[-0.03-0.01]		0.14[0.02-0.27]	*	0.14[0.04-0.23]	**
Sufficient protein intake$	0.03[0.00-0.06]	*	0.02[0.00-0.04]		0.01[-0.01-0.02]		0.04[-0.04-0.11]		0.05[-0.01-0.11]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1x/wk	-0.04[-0.10-0.01]		-0.02[-0.07-0.02]		0.00[-0.03-0.03]		-0.16[-0.32-0.00]	*	-0.13[-0.25--0.01]	*
3: Stairs, no sport	-0.12[-0.16--0.08]	***	-0.08[-0.11--0.05]	***	-0.02[-0.04--0.01]	**	-0.25[-0.36--0.14]	***	-0.15[-0.23--0.07]	***
4: Stairs, sports ≥1x/wk	-0.16[-0.20--0.12]	***	-0.12[-0.15--0.09]	***	-0.03[-0.05--0.01]	**	-0.34[-0.45--0.23]	***	-0.19[-0.27--0.11]	***
Age (per 1-birth year)	0.00[-0.01-0.01]		0.00[-0.01-0.01]		0.00[0.00-0.00]		0.01[-0.02-0.03]		0.00[-0.02-0.02]	
Living alone (0/1)	-0.03[-0.06-0.00]	*	-0.02[-0.04-0.00]		-0.01[-0.02-0.01]		-0.05[-0.12-0.03]		-0.06[-0.11-0.00]	*
Financial diff. (0/1)€	0.04[0.01-0.07]	*	0.02[-0.01-0.04]		0.00[-0.01-0.02]		0.08[0.00-0.16]		0.05[-0.01-0.12]	
Symptoms of depression	0.01[-0.02-0.04]		0.01[-0.01-0.04]		0.01[-0.01-0.02]		0.06[-0.02-0.14]		0.01[-0.05-0.07]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	-0.02[-0.06-0.01]		-0.01[-0.04-0.02]		-0.01[-0.02-0.01]		-0.04[-0.13-0.04]		-0.02[-0.09-0.05]	
≥High school	-0.06[-0.10--0.03]	***	-0.04[-0.07--0.01]	**	-0.02[-0.03-0.00]	*	-0.14[-0.23--0.05]	**	-0.07[-0.14-0.00]	

Continued…

	Ln(BMI)		Ln(WC)		Ln(WHR)		Ln(SISF)		Ln(TSF)	
	β [95%CI]	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***
Current smoking (0/1)§	-0.07[-0.11--0.04]	***	-0.04[-0.06--0.01]	**	0.00[-0.01-0.02]		-0.21[-0.30--0.12]	***	-0.15[-0.22--0.08]	***
Number of chronic diseases #										
0	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
1	0.02[-0.01-0.06]		0.02[-0.01-0.04]		0.01[-0.01-0.02]		0.04[-0.04-0.13]		0.03[-0.03-0.10]	
≥2	0.01[-0.03-0.04]		0.02[-0.01-0.05]		0.01[0.00-0.03]		0.00[-0.09-0.09]		0.02[-0.05-0.09]	

$ "Sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥twice/week.

€ Financial difficulties (diff.) are considered if any of the following criteria is fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).

§ Participants who had stopped smoking before less than one year are considered current smokers in the analyses.

*P<0.05; **P<0.01; ***P<0.001.

All chronic diseases are self-reported medical diagnoses ("Has a doctor ever told you that you had…?"). The number of chronic diseases included coronary heart disease, other heart diseases (congestive heart failure, cardiac valvular disease, and heart muscle disease), stroke, diabetes mellitus, chronic respiratory disease, osteoporosis, arthritis, cancer, and depression (maximum number = 9).

TABLE B. ASSOCIATIONS OF ADIPOSITY WITH DIET AND PHYSICAL ACTIVITY, ADJUSTED FOR SELF-RATED HEALTH

The five adiposity indicators have been log-transformed. Multivariate linear regression analysis. The table shows all covariates included in the adjustment.

	Ln(BMI)		Ln(WC)		Ln(WHR)		Ln(SISF)		Ln(TSF)	
	ß [95%CI]	*P*	*ß* [95%CI]	*P*	*ß* [95%CI]	*P*	*ß* [95%CI]	*P*	*ß* [95%CI]	*P*
MEN:(N≥476):										
Eating habits:										
Three meals/day	-0.02[-0.04-0.01]		0.00[-0.02-0.01]		-0.01[-0.02-0.00]		0.00[-0.07-0.08]		-0.04[-0.11-0.03]	
Fruit and veg. ≥twice/day	0.01[-0.03-0.04]		0.01[-0.02-0.03]		0.00[-0.02-0.01]		0.06[-0.04-0.15]		0.04[-0.06-0.13]	
Sufficient protein intake$	0.03[0.00-0.06]	*	0.04[0.02-0.06]	**	0.02[0.01-0.03]	**	0.05[-0.03-0.13]		-0.02[-0.10-0.06]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1x/wk	-0.02[-0.08-0.04]		-0.03[-0.07-0.02]		0.00[-0.03-0.03]		-0.23[-0.41--0.05]	*	-0.20[-0.37--0.02]	*
3: Stairs, no sport	-0.07[-0.11--0.03]	***	-0.05[-0.08--0.03]	***	-0.02[-0.04-0.00]	*	-0.23[-0.35--0.11]	***	-0.15[-0.27--0.04]	*
4: Stairs, sports ≥1x/wk	-0.09[-0.12--0.05]	***	-0.08[-0.11--0.05]	***	-0.05[-0.07--0.03]	***	-0.28[-0.40--0.16]	***	-0.17[-0.29--0.05]	**
Age (per 1-birth year)	0.01[0.00-0.02]		0.00[0.00-0.01]		0.00[0.00-0.01]		0.02[0.00-0.05]		0.00[-0.03-0.02]	
Living alone (0/1)	-0.03[-0.06-0.00]		-0.01[-0.04-0.01]		0.01[-0.01-0.02]		0.03[-0.07-0.12]		0.02[-0.08-0.11]	
Financial diff. (0/1)€	-0.01[-0.04-0.02]		0.00[-0.02-0.02]		0.00[-0.01-0.02]		-0.01[-0.09-0.08]		0.01[-0.08-0.09]	
Symptoms of depression	0.03[0.00-0.06]		0.01[-0.01-0.03]		0.00[-0.01-0.02]		0.05[-0.04-0.15]		0.02[-0.07-0.11]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	-0.03[-0.06-0.01]		-0.02[-0.04-0.01]		-0.01[-0.03-0.01]		0.00[-0.10-0.11]		-0.02[-0.12-0.09]	
≥High school	-0.05[-0.08--0.01]	**	-0.03[-0.06-0.00]	*	-0.02[-0.04-0.00]	*	-0.02[-0.12-0.09]		-0.03[-0.13-0.08]	
Current smoking (0/1)§	-0.04[-0.06--0.01]	*	-0.01[-0.03-0.01]		0.00[-0.01-0.02]		-0.11[-0.20--0.02]	*	-0.06[-0.14-0.03]	

Continued…

	Ln(BMI)		Ln(WC)		Ln(WHR)		Ln(SISF)		Ln(TSF)	
	***β* [95%CI]**	***P***	***β* [95%CI]**	***P***	***β* [95%CI]**	***P***	***β* [95%CI]**	***P***	***β* [95%CI]**	***P***
Self-rated health #										
Clearly better	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Slightly better	-0.01[-0.06-0.03]		-0.01[-0.04-0.02]		-0.01[-0.03-0.02]		0.03[-0.10-0.16]		-0.08[-0.21-0.05]	
In the mean	-0.01[-0.05-0.04]		0.01[-0.02-0.04]		0.01[-0.01-0.03]		0.05[-0.08-0.19]		0.00[-0.13-0.14]	
Slightly poorer	-0.01[-0.08-0.06]		0.03[-0.03-0.08]		0.00[-0.04-0.04]		-0.07[-0.29-0.15]		-0.07[-0.28-0.14]	
Clearly poorer	0.16[0.00-0.31]	*	0.13[0.02-0.25]	*	0.00[-0.08-0.07]		0.63[0.16-1.09]	**	0.38[-0.03-0.79]	
WOMEN (N≥ 657)										
Eating habits:										
Three meals/day	0.00[-0.03-0.03]		0.00[-0.02-0.03]		0.00[-0.01-0.01]		0.05[-0.02-0.13]		-0.03[-0.09-0.02]	
Fruit and veg. ≥twice/day	0.05[0.00-0.10]	*	0.02[-0.02-0.06]		-0.01[-0.03-0.02]		0.14[0.01-0.27]	*	0.13[0.03-0.23]	**
Sufficient protein intake$	0.03[0.00-0.06]		0.02[0.00-0.04]		0.01[-0.01-0.02]		0.03[-0.04-0.11]		0.05[-0.01-0.11]	
Daily PA and sports										
1: No stairs, no sport	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
2: No stairs, sports ≥1x/wk	-0.05[-0.11-0.01]		-0.02[-0.07-0.02]		0.00[-0.03-0.03]		-0.17[-0.33--0.01]	*	-0.14[-0.26--0.02]	*
3: Stairs, no sport	-0.12[-0.16--0.08]	***	-0.08[-0.11--0.05]	***	-0.02[-0.04--0.01]	*	-0.26[-0.37--0.15]	***	-0.16[-0.25--0.08]	***
4: Stairs, sports ≥1x/wk	-0.16[-0.20--0.12]	***	-0.11[-0.15--0.08]	***	-0.03[-0.05--0.01]	**	-0.34[-0.45--0.23]	***	-0.20[-0.29--0.12]	***
Age (per 1-birth year)	0.00[-0.01-0.01]		0.00[-0.01-0.01]		0.00[0.00-0.00]		0.01[-0.02-0.03]		0.00[-0.02-0.02]	
Living alone (0/1)	-0.03[-0.06-0.00]	*	-0.02[-0.04-0.00]		-0.01[-0.02-0.01]		-0.05[-0.12-0.03]		-0.06[-0.11-0.00]	*
Financial diff. (0/1)€	0.04[0.01-0.07]	*	0.02[0.00-0.05]		0.00[-0.01-0.02]		0.08[0.00-0.17]		0.06[-0.01-0.12]	
Symptoms of depression	0.01[-0.02-0.04]		0.01[-0.01-0.03]		0.01[-0.01-0.02]		0.06[-0.02-0.14]		0.02[-0.04-0.08]	
Education										
Basic compulsory	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Apprenticeship	-0.02[-0.05-0.01]		-0.01[-0.03-0.02]		-0.01[-0.02-0.01]		-0.04[-0.13-0.05]		-0.02[-0.09-0.05]	
≥High school	-0.06[-0.10--0.03]	***	-0.04[-0.06--0.01]	**	-0.02[-0.03-0.00]	*	-0.14[-0.23--0.05]	**	-0.07[-0.14-0.00]	

Continued…

	Ln(BMI)		Ln(WC)		Ln(WHR)		Ln(SISF)		Ln(TSF)	
	β [95%CI]	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***	**β [95%CI]**	***P***
Current smoking (0/1)§	-0.07[-0.11--0.04]	***	-0.04[-0.06--0.01]	**	0.01[-0.01-0.02]		-0.21[-0.30--0.12]	***	-0.15[-0.22--0.08]	***
Self-rated health #										
Clearly better	0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)		0 (ref.)	
Slightly better	0.01[-0.04-0.06]		0.01[-0.03-0.05]		0.01[-0.02-0.03]		-0.01[-0.15-0.12]		0.00[-0.10-0.11]	
In the mean	0.02[-0.03-0.07]		0.03[-0.01-0.07]		0.02[0.00-0.04]		0.05[-0.09-0.18]		0.02[-0.08-0.12]	
Slightly poorer	-0.03[-0.10-0.05]		0.02[-0.04-0.08]		0.02[-0.01-0.06]		-0.12[-0.32-0.09]		-0.15[-0.30-0.01]	
Clearly poorer	0.15[-0.01-0.31]		0.11[-0.01-0.24]		0.02[-0.05-0.10]		0.19[-0.23-0.61]		0.16[-0.17-0.48]	

$ "Sufficient protein intake" was defined if the participant reported eating meat, fish or poultry every day, or as an alternative, if he consumed dairy products ≥ once a day and eggs or leguminous plants ≥twice/week.

€ Financial difficulties (diff.) are considered if any of the following criteria is fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance).

§ Participants who had stopped smoking before less than one year are considered current smokers in the analyses.

*P<0.05; **P<0.01; ***P<0.001.

Self-rated health: *If you compare your current health with persons of your age, do you think that you are …? 1) clearly in better health, 2) slightly in better health, 3) in the mean, 4) slightly in poorer health, 5) clearly in poorer health.*

Appendix III

ASSOCIATION BETWEEN ADIPOSITY AND DISABILITY IN THE Lc65+ COHORT

N. DANON-HERSCH, S. FUSTINONI, P. BOVET, J. SPAGNOLI, B. SANTOS-EGGIMANN

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Abstract: *Objectives:* To examine the longitudinal association between body mass index (BMI) and waist circumference (WC) with mortality and incident disability in Lc65+ cohort. *Design:* Population-based cohort of non-institutionalized adults with up to 8.9 years of follow-up. *Setting:* City of Lausanne, Switzerland. *Participants:* 1,293 individuals aged 65 to 70 at baseline (58% women). *Measurements:* BMI, WC and covariates were measured at baseline in 2004-2005. Vital status was obtained up to the 31st December 2013 and difficulty with basic activities of daily living (BADL) was reported in a self-administered questionnaire sent to participants every year. Main outcomes were total mortality and disability, defined as difficulty with BADL for ≥2 years or institutionalization. Cox regression was used with BMI/WC quintiles 2 as the reference. *Results:* 130 persons died over a median follow-up of 8.47 years (crude mortality rate, men: 16.5/1,000 person-years, women: 9.7/1,000 person-years). In Cox regression adjusted for age, sex, education, financial situation, smoking and involuntary weight loss (IWL) at baseline, mortality was significantly associated with neither BMI nor WC, but there were trends towards non-significant J-curves across both BMI and WC quintiles. Disability (231 cases) tended to increase monotonically across both BMI and WC quintiles and was significantly associated with BMI quintile 5 (HR=2.44, 95% CI [1.65-3.63]), and WC quintiles 4 (HR=1.81 [1.15-2.85]) and 5 (HR=2.58, [1.67-4.00]). *Conclusion:* Almost half of the study population had a substantially increased HR of disability, as compared to the reference BMI/WC categories. This observation emphasizes the need for life-long strategies aimed at preventing excess weight, muscle loss and functional decline through adequate nutrition and regular physical activity, starting at early age and extending throughout life.

Key words: Body mass index, waist circumference, adiposity, disability, mortality.

Introduction

In many developed countries, including Switzerland, overweight and obesity prevalence peaks between 60 and 75 years of age (1, 2). Mortality associated with body mass index (BMI) differs according to age and is weaker after age 65 years (3-8). Some studies suggest that mortality is not increased among older persons with high BMI (3, 4). At this age, adults with BMI <25 kg/m^2 might be of a lower socio-economic status and/or suffer from malnutrition or disease. Low BMI seems to be associated with increased mortality in old age (9) through mechanisms including weight loss, chronic diseases, frailty, and cachexia (10). Low BMI and high body fat percentage were independently associated with increased mortality in a large cohort (10); according to its authors, BMI is often used as a proxy for adiposity even though it more closely reflects lean mass than fat mass. Increasing BMI might reflect higher fitness levels and greater metabolic reserve, leading to higher survival. Body composition changes and abdominal fat increases with increasing age, especially among women (11). Waist circumference (WC) is often used as a surrogate measure of fat mass distribution, both intra-abdominal and overall body fat (12). In an important cohort study with 16 years of follow-up, high WC was strongly and positively associated with cardiovascular disease mortality, independently of BMI (13). Yet, a systematic review (including mainly cross-sectional studies) (14) compared the discriminatory power of BMI, WC, and waist:hip ratio in terms of cardiovascular risk and concluded that no adiposity measure had superior discriminatory capability. There is a long-standing controversy on which adiposity indicator performs best in predicting cardiovascular risk (15-18).

Studies aimed at assessing the shape of the association between adiposity and mortality usually require large samples in order to ensure sufficient numbers of persons with very low and very high BMI/WC values (e.g. >4,000 participants) (7, 19-21), and studies relating adiposity with mortality in older persons should ideally also account for adiposity (e.g. BMI) at middle age in order to avoid several potential biases like reverse causation or survival bias (22).

Obesity seems to have a negative impact on a person's independence in basic activities of daily living (BADL) among the young old (i.e. at age 65-70 years), in particular because muscle mass decreases with advancing age (23, 24). While life expectancy is increasing in most populations, disability-free life expectancy evolves differently across developed countries (25, 26), but a common finding is that years spent with disability tend to increase (12, 27-29). Because obesity is likely to be associated with disability, the obesity pandemic (30) might increase the burden of dependent persons in the future. Unlike obesity, the effect of overweight on disability is more controversial: some studies have shown either no (31, 32) or

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moderate effect on disability. Furthermore, several definitions of disability exist in the medical literature (28, 33). According to Linda Fried (34), "disability is defined as difficulty or dependency in carrying out activities essential to independent living, including essential roles, tasks needed for self-care and living independently in a home, and desired activities important to one's quality of life." In this report, difficulty with BADL (35) will be used for assessment of disability.

To which extent overweight is associated with mortality and disability is still uncertain after age 65. This study aims to identify which BMI and WC quintiles are associated with the longest preservation of autonomy in BADL (primary aim) and survival (secondary aim) after a follow-up of up to 8.9 years in a Swiss cohort aged 65-70 years at baseline.

Methods

The Lc65+ cohort has been described previously (36-39). Briefly, a population-based sample of residents of Lausanne aged 65-70 years were invited to be examined and enrolled in the cohort in 2005. Exclusion criteria at baseline included being institutionalized or unable to respond because of advanced dementia. Of the 3,056 persons who were initially mailed a questionnaire, 2,096 (69%) replied, of whom 1,564 (75%) agreed to participate [36]. Overall, nonparticipants had demographic characteristics (sex, birth year) similar to participants (36) and participants' socio-economic characteristics closely reflected the Lausanne general population in the same age category in aggregate statistics from the Population Office or the 2000 Swiss national census (proportions with foreign nationality, marital status, place of birth, living arrangement, professional activity). Of the 1,564 respondents to the initial questionnaire, 1,524 (97.4%) were still eligible and 1,307 (85.8%) participated in the baseline physical examination in 2005 at the study centre.

All participants were asked to complete and return a postal questionnaire every year, and to undergo an interview and a physical examination every 3 years since 2005. Trained medical assistants conducted the performance tests and examination using standardized protocols (36).

Body weight, height, and waist circumference (WC) were measured and body mass index (BMI) was calculated. The participants' financial situation was assessed by the self-report of financial difficulties (construction of the variable: see tables' footnotes).

Mortality

We updated the vital status of the participants by checking every year the electronic records of the office in charge for population registration in the Canton of Vaud. Among all 1,307 participants examined in 2004 and 2005, 14 (1.1%) persons with missing data for BMI (N=5) and/or WC (N=12) were excluded. Therefore, this study includes 1,293 participants examined at baseline (see Flow chart in Figure 1A). In the Kaplan-Meyer survival curves, person-years at risk were calculated from the date of the first examination (in 2005) to date of death or 31 December 2013, whichever came first (time unit: day).

Deaths among all participants continuously residing in the Canton de Vaud could be ascertained by the Population's Office until December 31st, 2013, except for 8 of 1,293 cases (0.6%), who had left the Canton de Vaud and for whom vital status is unknown. For these persons, the date of the last contact was kept as the censoring date.

Disability

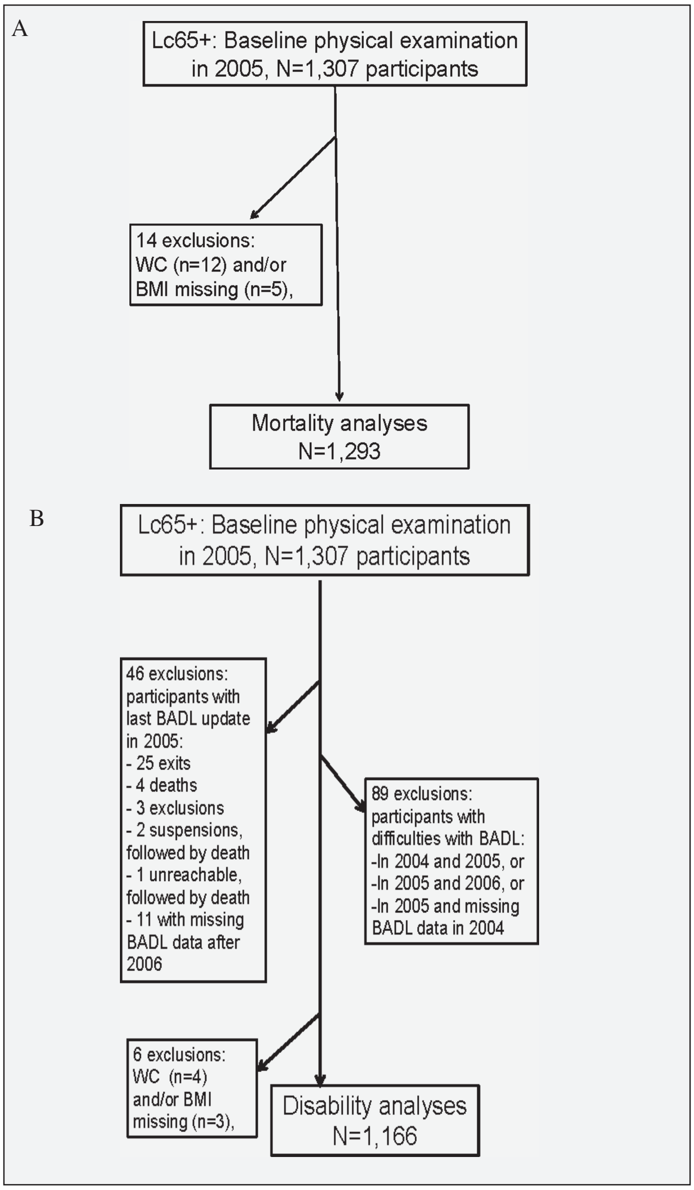
Difficulty with basic activities of daily living (BADL) was reported every year in a self-administered questionnaire sent at home, except in 2011, where the same questions were asked by the interviewer during the visit at the study centre; the following questions where used about five BADLs defined by Katz (35): "Do you have difficulty, or do you usually receive help with performing the following activities?: a) getting dressed, including putting on socks and shoes, b) taking a bath or a shower, c) eating, including cutting foodstuffs, d) getting in/out of bed, e) getting on and off toilet? Each question allowed for three answers: "No difficulty at all; difficulties but no help; and I receive help". Participants who reported any difficulty or received help for ≥ one of the five items were considered to have difficulty with BADL.

Difficulty with BADL is reversible from year to year. Therefore, in the statistical analysis, the outcome "difficulty with BADL" was considered to have occurred if it had been reported for at least 2 consecutive years.

The outcome «disability» was defined as the occurrence of difficulty with ≥1 of 5 BADLs for ≥2 consecutive years or institutionalization (time unit: year). Institutionalization is included in the definition of this outcome because older adults' admission in nursing homes in the study area implies functional limitations. Time at risk for this outcome was considered from baseline until the first year of occurrence of either difficulties with BADL or institutionalization or until the last year with information on the status of the participant. Since this outcome had to last at least 2 consecutive years, the follow-up for disability ended on the 31st December 2012, hence a follow-up of up to 7 years.

Among the 1,307 participants assessed in 2005, information on difficulty with BADL on subsequent years was not available in 46 and these persons were excluded from all analyses about difficulty with BADL (see Flow chart in Figure 1B). In addition, 89 persons were excluded because they already reported difficulty with BADL or had missing information on difficulty with BADL at baseline. Furthermore, 6 participants with missing data on baseline exposures (weight, height, WC) were excluded. As a result, the analysis of the disability outcome is based on data in 1,166 participants. A flow chart about inclusion of participants appears in Figure 1B.

Figure 1
Flow Chart of the Participants Included in the Mortality Analysis (A) and in the Disability Analysis (B)



Statistical analysis

Statistical analyses were performed using Stata 14 (Stata Corp, College Station, TX). Differences in proportions were tested with the Chi-square test. Mortality and disability were compared across baseline BMI and WC quintiles, using Cox regression analysis. Sex-specific BMI and WC quintiles were re-aggregated (Tables 1, 3, 4, and Figures 2 and 3). Unadjusted Kaplan-Meyer survival curves were produced and differences in univariate comparisons of survival distributions were tested with the log rank test. The assumption of proportional hazards was verified and confirmed for all exposure and adjustment variables with a test of Schoenfeld residuals and with graphical validation. The number of cases of deaths (130) was lower than the number of cases of disability (231); therefore the power to detect differences was higher for the analyses of disability than mortality. BMI and WC were highly correlated and were therefore analyzed in distinct Cox models.

Mortality

Confounders were chosen if they were known to be associated with BMI (or WC) and mortality (40). Initial Cox models were adjusted for age and sex only, and sex interactions were tested. Subsequent models were additionally adjusted for education, financial difficulties, involuntary weight loss during the 12 months before baseline (IWL) (41), and smoking status (42). The final model was adjusted for all covariates.

Because obesity requires many years to result in harmful effects on health (8, 43) and many chronic conditions are associated with weight loss (43), studies on the association between obesity and obesity-related outcomes generally exclude subjects with weight loss (43) or pre-existing diseases and/or mortality in the first few years (44). To minimize potential bias and/or a reverse causation effect related to preexisting disease (45), we adjusted i) for IWL in all analyses (41) and ii) we also ran analyses after exclusion of participants who died within the first 3 years of follow-up (45).

Disability

IWL has also been associated with rapid functional decline (46, 31). Models in Table 4 included the same adjustment variables as models in Table 3 (mortality). In addition, all possible interactions involving BMI or WC quintiles were tested.

All participants had given written informed consent and the ethics committee of the Faculty of Biology and Medicine of the University of Lausanne has approved the study protocol.

Results

This study included 531 men and 762 women (total N=1,293). The prevalence of overweight and obesity at baseline was 53.3% and 24.1% in men, respectively 35.3% and 23.5% in women. The prevalence of IWL in 2005, educational level and the financial situation were significantly and linearly negatively associated with BMI and WC quintiles (Table 1). The correlation coefficient between BMI and WC was 0.89 in men and 0.85 in women.

Mortality

Of the 1,293 participants at baseline, 130 persons died over a total follow-up period of 10,447 person-years of observation, a crude mortality rate of 12.4 per 1,000 person-years (16.5 among men, 9.7 among women, Table 2). The mean, median and maximal follow-up durations were respectively 8.1, 8.5 and 8.9 years. In crude analyses (Figure 2, 1st column, upper graph), mortality rates tended to follow a J-curve with highest mortality in the first BMI quintile and lowest mortality rate in the second

Table 1
Baseline Characteristics of Participants according to Baseline BMI (a) and WC (b) Quintiles (N=1,293)

a)	BMI quintiles							
Baseline characteristics	Q 1	Q 2	Q 3	Q 4	Q 5			Total
	N=260	N=258	N=259	N=258	N=258			1,293
BMI range (kg/m²)								
Men	18.7-24.8	24.8-26.4	26.5-28.3	28.3-30.6	30.6-46.7			
Women	15.0-22.5	22.5-24.8	24.8-27.3	27.3-30.7	30.7-53.6			
	N(%)	*N(%)*	*N(%)*	*N(%)*	*N(%)*	*Chi 2 P*	*Test for trend P-value (across quintiles)*	*N(%)*
Women	153 (58.9)	152 (58.9)	153 (59.1)	152 (58.9)	152 (58.9)			762 (58.9)
Age at baseline visit (2005)*	69.1 (1.5)	68.9 (1.4)	69.0 (1.4)	69.2 (1.5)	68.9 (1.5)	0.274		69.0 (1.5)
Education: high school or more	126 (48.5)	97 (37.6)	97 (37.9)	73 (28.6)	65 (25.3)	0.001	<0.001	458 (35.6)
Financial difficulties (0/1)	53 (20.4)	67 (26.0)	63 (24.3)	78 (30.2)	92 (35.7)	0.001	<0.001	353 (27.3)
IWL in 2005 (12 mo.)	44 (16.9)	24 (9.3)	21 (8.1)	9 (3.5)	16 (6.2)	<0.001	<0.001	114 (8.8)
Smoking status								
Never	104 (40.3)	127 (49.8)	116 (45.7)	116 (45.1)	105 (41.5)	0.004	0.222	568 (44.5)
Former	86 (33.3)	69 (27.1)	94 (37.0)	97 (37.7)	107 (42.3)			453 (35.5)
Current	68 (26.4)	59 (23.1)	44 (17.3)	44 (17.1)	41 (16.2)			256 (20.1)

b)	WC quintiles							
Baseline characteristics	Q 1	Q 2	Q 3	Q 4	Q 5			Total
	N=263	N=259	N=256	N=259	N=256			1,293
WC range (cm)								
Men	70.0-91.9	92.0-97.5	97.6-103.0	103.2-109.5	109.6-147.2			
Women	58.8-77.0	77.1-83.0	83.2-90.0	90.2-99.0	99.1-150.0			
	N(%)	*N(%)*	*N(%)*	*N(%)*	*N(%)*	*Chi 2 P*	*Test for trend P-value (across quintiles)*	*N(%)*
Women	156 (59.3)	152 (58.7)	150 (58.6)	153 (59.1)	151 (59.0)			762 (58.9)
Age at baseline visit (2005)*	69.0 (1.5)	68.9 (1.5)	69.1 (1.4)	69.0 (1.4)	69.0 (1.5)	0.451		69.0 (1.5)
Education: high school or more	118 (45.0)	110 (42.5)	78 (30.7)	81 (31.4)	71 (28.1)	<0.001	<0.001	458 (35.6)
Financial difficulties (0/1)	58 (22.1)	54 (20.9)	74 (28.9)	77 (29.7)	90 (35.2)	0.001	<0.001	353(27.3)
IWL in 2005 (12 mo.)	36 (13.7)	26 (10.0)	20 (7.8)	13 (5.0)	19 (7.4)	0.008	0.002	114 (8.8)
Smoking status								
Never	122 (46.6)	131 (51.8)	111 (43.7)	110 (42.6)	94 (37.6)	0.001	0.173	568 (44.5)
Former	79 (30.2)	78 (30.8)	82 (32.3)	98 (38.0)	116 (46.4)			453 (35.5)
Current	61 (23.3)	44 (17.4)	61 (24.0)	50 (19.4)	40 (16.0)			256 (20.1)

Sex-specific BMI and WC quintiles have been re-aggregated; *mean (SD) and Kruskall-Wallis test P-value; Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance). IWL in 2005 was assessed (in the postal questionnaire) by the question: "In the last 12 months, have you involuntarily lost weight?" (yes/no)

BMI quintile. The mortality rates across BMI quintiles were the following: BMI quintile 1) 16.5 per 1,000 person-years (p*y) (95% confidence interval (CI) 11.8-23.1), 2) 9.0 (5.7-14.1), 3) 11.5 (7.7-17.1), 4) 11.9 (8.0-17.6), and 5) 13.5 (9.3-19.6). The differences were not significant according to the log rank test (P=0.256).

The mortality rates across WC quintiles were the following: WC quintile 1) 11.7 per 1,000 p*y (95% CI 7.9-17.4), 2) 12.9 (8.9-18.9), 3) 10.5 (6.9-16.0), 4) 8.0 (5.0-12.8), and 5) 19.4 (14.2-26.6, Figure 2, 1st column, lower graph, log rank test chi2 P=0.016). There was some trend towards a J-curve, with the lowest mortality in fourth quintile and highest mortality in the

Table 2
Numbers of Incident Cases for each Outcome

Outcomes	MEN N	WOMEN N	ALL N	Total N	Specific exclusion criteria
					Starting with N=1,307, then exclusion of 14 persons with missing BMI/WC
N	531	762	1,293		=Sample included for mortality analyses
Mortality (until 31 December 2013)					
Number of deaths	70	60	130	1,293	
Time at risk (p*y)	4,244	6,202	10,447		
Mortality rate (per 1,000 p*y)	16.49	9.67	12.44		
Mean follow-up (years)			8.1		
Median follow-up (years)			8.5		
Maximum follow-up (years)			8.9		
					Starting with N=1,172, then exclusion of 6 persons with missing BMI/WC
N	489	677	1,166		=Sample included for analyses of disability
Disability* (until 31 December 2012)					
Number of incident cases	96	135	231	1,166	
Time at risk (p*y)	2,830	4,028	6,858		
Incidence rate (per 1,000 p*y)	33.92	33.52	33.68		
Mean follow-up (years)			5.9		
Median follow-up (years)			7.0		
Maximum follow-up (years)			7.0		

* Difficulty with BADL for ≥2 years or institutionalization

fifth.

In Cox regression analysis adjusting for age at study entry, sex, education, financial difficulties, IWL, and smoking, there was no statistically significant difference in mortality across both BMI quintiles (Table 3A), and WC quintiles (Table 3B). There were again non-significant trends towards J-curve relations with BMI with highest mortality in the highest quintile and lowest mortality in the second quintile (hazard ratio (HR) 1.59, 1.00, 1.22, 1.42 and 1.62 in the five quintiles, respectively); as well as with WC with highest mortality in the 5th quintile and lowest mortality in the fourth quintile (HR 0.75, 1.00, 0.69, 0.59, and 1.36, Figure 3, first column). Except for the first BMI quintile (HR =0.99 (95% CI 0.45-2.18) in men, HR =3.10 (1.23-7.81) in women), the results were very similar in both sexes. The interaction of BMI with sex was not significant. Whereas absolute mortality rates differed strongly between men and women (Table 2), the associations between adiposity and mortality were similar in both sexes.

The correlations between all adjustment variables were calculated. The highest correlation in absolute value was between sex and smoking status (Cramér's V=0.30).

No significant interactions were found between BMI, WC and the potential confounders included in the models. In the fully adjusted models (Table 3), male sex, IWL in 2005, and current smoking were significantly associated with higher mortality.

The same analyses were carried out after exclusion of 31 participants deceased during the first three years of their follow-up; after this exclusion, mortality rates remained similar across all BMI and WC quintiles.

Disability

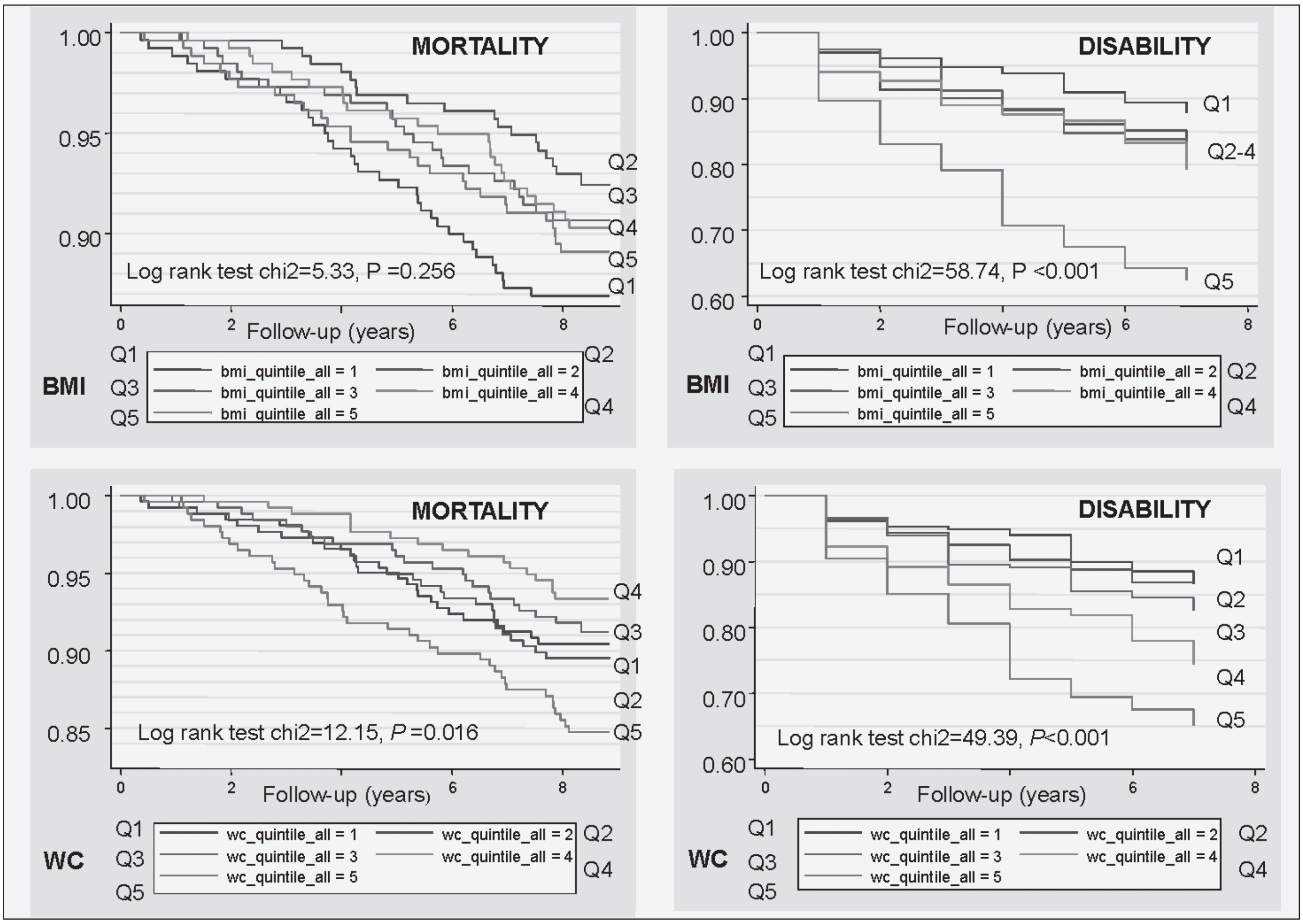
Of 1,166 disability-free participants at baseline (489 men and 677 women), 231 experienced disability. The crude incidence rate of disability was 33.7 per 1,000 p*y (33.9/1,000 p*y in men, 33.5/1,000 p*y in women, Table 2). The mean, median and maximal follow-up durations were respectively 5.9, 7.0 and 7.0 years.

The crude disability incidence rate increased monotonically across BMI baseline quintiles: 18.3/1,000 p*y (95% CI 12.4-26.8), 26.0 (18.8-35.8), 27.2 (19.8-37.4), 32.8 (24.5-43.9), and 68.5 (55.4-84.7, Figure 2, 2nd column, upper graph, log rank test chi2 P<0.001).

The crude disability incidence rate also increased

Figure 2

Kaplan-Meyer Survival Curves for Mortality (1st Column, N=1,293) and Disability Incidence (2nd column, N=1,166) by BMI Quintiles (Upper Graphs) and WC Quintiles (Lower Graphs)



"bmi_quintile_all" is the label indicating that the sex-specific BMI quintiles have been reagreggated to give BMI quintiles including men and women. In the same way, "wc_quintile_all" is the label indicating WC quintiles including men and women. For example, wc_quintile_all=5 indicates the 5th WC quintile. "Disability-free survival" indicates survival with neither difficulty with BADL for ≥2 years nor institutionalization.

monotonically across WC baseline quintiles: 20.3/1,000 p*y (95% CI 14.2-29.0), 20.8 (14.5-30.0), 27.3 (20.0-37.4), 42.2 (32.5-54.9), and 62.4 (49.9-78.1, Figure 2, 2nd column, lower graph, log rank test chi2 P<0.001).

Fully adjusted Cox models also showed that disability tended to increase monotonically across BMI quintiles (HRs: 0.67, 1.00, 1.00, 1.22, and 2.44) and was significantly associated with BMI quintile 5 (HR=2.44, (95% CI 1.65-3.63), p<0.001, Table 4A and Figure 3, 2nd column, upper graph). Disability also tended to increase monotonically across WC quintiles (HRs: 0.90, 1.00, 1.16, 1.81, and 2.58) and was significantly associated with WC quintile 4 (HR=1.81, (1.15-2.85), p=0.011) and quintile 5 (HR=2.58, (1.67-4.00), p<0.001, Table 4B and Figure 3, 2nd column, lower graph). The results were very similar in both sexes.

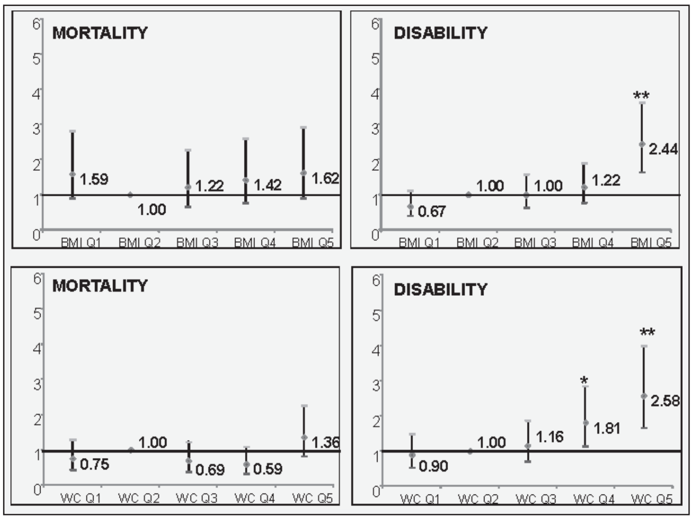
The range of BMI quintile 5 was 30.5-41.8 kg/m^2 in men, and 30.3-47.4 kg/m^2 in women. Therefore, overweight (BMI 25.0-29.9 kg/m^2) was not significantly associated with incident disability although there were, as mentioned above, non-significant trends towards monotonically upward increases in disability across both BMI and WC quintiles.

Older age at baseline, low education, financial difficulties, and IWL were significantly associated with disability. There were no statistically significant interactions involving disability.

Of note, we have also carried out the analyses of Tables 3 and 4 and Figure 3 (results not shown, tables available upon request) while stratifying data by sex. Results stratified by sex were nearly identical to sex-adjusted aggregated results, except that BMI/WC quintiles 4 and 5 were slightly more significantly associated with disability in women than in men in the stratified analyses. In addition, the first BMI quintile was significantly associated with mortality in women (HR=3.10 [1.23-7.81], P=0.017), but not in men, in the sex-stratified analyses.

Figure 3

Association between Mortality (1st Column) and Disability (2nd Column) with BMI (Upper Graphs) and WC quintiles (Lower Graphs)



Hazard ratios and 95% CI are adjusted for age, sex, education, financial situation, involuntary weight loss, and smoking status. In this Figure, hazards ratios and 95% CI stem from the 3rd columns of Tables 3 and 4; N=1,270 and median follow-up=8.5 years for mortality; N=1,147 and median follow-up=7.0 years for disability; *P<0.05; **P<0.001; Sex-specific BMI and WC quintiles have been aggregated.

In summary, the BMI-mortality and the WC-mortality relationships were J-shaped; the optimal values in terms of mortality were unclear because of an insufficient study power. By contrast, disability increased monotonically with both BMI and WC; larger samples would be needed to assess whether this association is linear or curved.

Discussion

In this cohort study of community-dwelling adults aged 65 to 70 years at baseline, BMI and WC had a non-significant J-shaped association with mortality after 8 years of follow-up. Disability increased monotonically with both BMI and WC and a statistical difference was found when comparing the fifth BMI and WC quintiles vs. quintile 2. However, the study lacked sufficient power to assess whether this relationship was linear or curved.

The finding of a non-significant association between adiposity and mortality was expected in view of the limited study power. There are a number of entangled issues that prevent straightforward interpretation of the relationship between adiposity (e.g. BMI, WC) and mortality in older persons, including survival bias (8), collider bias, competing risks, reverse causation (normal weight participants at study entry who had previously been obese have very high mortality rates) (47), the obesity paradox (applying to individuals who have a disease) (10, 19, 48), and differential meaning of BMI versus WC at different ages and in men vs. women. These phenomena might contribute to explain why the higher BMI and WC quintiles were not significantly associated with mortality in our analyses.

It is likely that adiposity status at midlife (22) or maximum lifetime BMI (47) may better predict mortality, at least as far as causation is concerned, as they are less prone to the aforementioned biases (47). In the present study, we adjusted for involuntary weight loss but this issue is inherently difficult to account for because weight loss related to disease can be insidious and take place over many years. Ideally, the lifetime duration of exposure to obesity should be recorded. In spite of the limited sample size of our study, the observation of an apparent J-shape association between BMI and mortality is consistent with results of larger studies (49, 50). The observation of different nadirs for BMI (2nd quintile) and WC (4th quintile) might reflect the different significance of BMI and WC at this age: e.g. different links with the nutritional state, socio-economic status, life-course lifestyles, and local adiposity standard and customs.

In the present study, we observed no gender difference in the disability incidence rates, while in the literature disability prevalence or incidence is usually higher in women than in men (51-53). However, gender differences are usually more marked in instrumental activities than in basic activities of daily living (BADL) (52-54), while the present study focused exclusively on the latter (i.e. BADL). Men might be less inclined to report functional limitations (54), although some studies suggest that they do so with reasonably good reliability (55). Women might truly have a higher frequency of disability or perceive and report that they do. Moreover, in Lc65+ at baseline, the prevalence of overweight was 53% in men, but 35% in women.

We found a monotonous association between adiposity and disability, which may be consistent with either a linear relationship or a slightly J-curved association. Both shapes have been described in the literature for the association between adiposity (BMI or WC) and disability: linear (56) and J-shaped (57-59). An underlying explanation for the graded relation is that increasing body weight can decrease a person's functional autonomy and mobility because of increased weight to carry, and it can increase the risk of disability (60). Whether subcutaneous or abdominal, excess weight is also likely to have a negative impact on the osteoarticular system, e.g. arthrosis of the backbone, knees, hips, and feet.

Our study suggests that overweight and obesity may result in a substantial morbidity related to disability. Almost half of our study population had a substantially increased HR of disability, as compared to the reference category. This finding has implications on health care of older persons who either stay at home or need to be institutionalized. This observation emphasizes the need for preventive measures aimed at preventing overweight with a life-course perspective (i.e. starting at early age and extending throughout a person's life). Yet, the potentially negative impact of excess weight with regards to disability must be weighted against the apparent survival advantage of high vs. low body weight at an old

Table 3
Univariate and Multivariate Associations between Mortality and A) BMI Quintiles and B) WC Quintiles Measured at Baseline, during 8-Year Follow-up

MORTALITY	**Univariate N=1,293 Crude HR (95% CI)**	**P>z**	**Multivariate N=1,293 HR (95% CI)**	**P>z**	**Multivariate N=1,270 HR (95% CI)**	**P>z**	**Multivariate after exclusion of early deaths N=1,240 HR (95% CI)**	**P>z**
A)BMI quintiles								
Q1 (Men: 18.7-24.8; Women: 15.0-22.5)	1.85 [1.06-3.25]	0.031	1.82 [1.04-3.20]	0.036	1.59[0.90-2.81]	0.114	1.30[0.69-2.43]	0.418
Q2 (Men: 24.8-26.4; Women: 22.5-24.8)	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Q3 (Men: 26.5-28.3; Women: 24.8-27.3)	1.28 [0.70-2.34]	0.418	1.26 [0.69-2.30]	0.452	1.22[0.66-2.27]	0.523	0.91[0.46-1.84]	0.803
Q4 (Men: 28.3-30.6; Women: 27.3-30.7)	1.32 [0.73-2.40]	0.356	1.30 [0.72-2.37]	0.385	1.42[0.77-2.60]	0.259	1.24[0.65-2.38]	0.519
Q5 (Men: 30.6-46.7; Women: 30.7-53.6)	1.51 [0.85-2.71]	0.163	1.51 [0.84-2.70]	0.167	1.62[0.90-2.92]	0.108	1.23[0.64-2.36]	0.541
Age at first visit (2005), linear	1.05[0.94-1.18]	0.400	1.05[0.93-1.18]	0.434	1.03[0.91-1.17]	0.610	1.07[0.93-1.23]	0.341
Female sex	0.58[0.41-0.82]	0.002	0.58[0.41-0.82]	0.002	0.69[0.48-0.99]	0.043	0.65[0.43-0.99]	0.047
Education: ≥high school	0.84 [0.58-1.21]	0.354			0.84[0.57-1.22]	0.360	0.73[0.47-1.13]	0.160
Financial difficulties (0/1)	1.50[1.05-2.15]	0.026			1.32[0.91-1.92]	0.147	1.12[0.72-1.74]	0.606
IWL in 2005 (12 mo.)	3.71[2.48-5.56]	<0.001			3.39[2.20-5.22]	<0.001	2.91[1.74-4.87]	<0.001
Smoking status								
Never	1 (ref)				1 (ref)		1 (ref)	
Former	1.78[1.15-2.75]	0.009			1.46[0.93-2.30]	0.102	1.66[0.98-2.80]	0.058
Current smoker	2.98[1.91-4.64]	<0.001			2.58[1.63-4.08]	<0.001	2.90[1.70-4.95]	<0.001

MORTALITY	**Univariate N=1,293 Crude HR (95% CI)**	**P>z**	**Multivariate N=1,293 HR (95% CI)**	**P>z**	**Multivariate N=1,270 HR (95% CI)**	**P>z**	**Multivariate after exclusion of early deaths N=1,240 HR (95% CI)**	**P>z**
B)WC quintiles								
Q1 (Men: 70.0-91.9 cm; Women: 58.8-77.0 cm)	0.91[0.53-1.57]	0.730	0.91[0.53-1.56]	0.724	0.75[0.43-1.29]	0.296	0.79[0.42-1.47]	0.450
Q2 (Men: 92.0-97.5 cm; Women: 77.1-83.0 cm)	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Q3 (Men:97.6-103.0 cm; Women: 83.2-90.0 cm)	0.81[0.46-1.42]	0.461	0.80[0.45-1.40]	0.434	0.69[0.38-1.22]	0.202	0.68[0.35-1.32]	0.256
Q4 (Men: 103.2-109.5 cm; Women: 90.2-99.0 cm)	0.61[0.33-1.13]	0.115	0.61[0.33-1.12]	0.108	0.59[0.32-1.09]	0.093	0.69[0.35-1.35]	0.277
Q5 (Men: 109.6-147.2 cm; Women: 99.1-150.0 cm)	1.50[0.92-2.45]	0.104	1.51[0.92-2.46]	0.102	1.36[0.82-2.26]	0.239	1.19[0.66-2.17]	0.558
Age at first visit (2005), linear*	1.05[0.94-1.18]	0.400	1.06[0.94-1.19]	0.343	1.04[0.92-1.17]	0.532	1.08[0.94-1.24]	0.307
Female sex	0.58[0.41-0.82]	0.002	0.58[0.41-0.81]	0.002	0.69[0.48-1.00]	0.048	0.66[0.43-1.00]	0.051
Education: ≥high school	0.84 [0.58-1.21]	0.354			0.86[0.59-1.25]	0.433	0.74[0.48-1.16]	0.189
Financial difficulties (0/1)	1.50[1.05-2.15]	0.026			1.29[0.89-1.88]	0.184	1.10[0.71-1.71]	0.670
IWL in 2005 (12 mo.)	3.71[2.48-5.56]	<0.001			3.50[2.30-5.34]	<0.001	2.99[1.80-4.96]	<0.001
Smoking status								
Never smoker	1 (ref)				1 (ref)		1 (ref)	
Former smoker	1.78[1.15-2.75]	0.009			1.43[0.91-2.26]	0.125	1.62[0.96-2.75]	0.073
Current smoker	2.98[1.91-4.64]	<0.001			2.66[1.68-4.22]	<0.001	2.98[1.74-5.09]	<0.001

HR: hazard ratio from Cox regression models; N indicated in the first line represents the number of participants included in the model; Sex-specific BMI and WC quintiles have been aggregated; Adjustment variables: sex, age at first visit (linear), education ≥high school (0/1), financial difficulties (0/1), involuntary weight loss during the past 12 months (IWL) in 2005 (0/1); smoking status (never/former/current smoker); Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance); IWL in 2005 was assessed (in the postal questionnaire) by the question: "In the last 12 months, have you involuntarily lost weight?" (yes/no)

Table 4

Univariate and Multivariate Associations between Disability (i.e. Difficulty with BADL for ≥2 Years or Institutionalization) and A) BMI Quintiles and B) WC Quintiles Measured at Baseline, during 7-Year Follow-up

DISABILITY	**Univariate N=1,166 Crude HR (95% CI)**	**P>z**	**Multivariate N=1,166 HR (95% CI)**	**P>z**	**Multivariate N=1,147 HR (95% CI)**	**P>z**
A)BMI quintiles						
Q1 (Men: 18.7-24.8; Women: 15.0-22.4))	0.70[0.43-1.16]	0.167	0.68[0.41-1.13]	0.138	0.67[0.41-1.12]	0.126
Q2 (Men: 24.8-26.4; Women: 22.5-24.6)	1 (ref)		1 (ref)		1 (ref)	
Q3 (Men: 26.4-28.3; Women: 24.6-27.0)	1.04[0.66-1.64]	0.857	1.00[0.64-1.58]	0.996	1.00[0.63-1.58]	0.997
Q4 (Men: 28.3-30.5; Women: 27.0-30.2)	1.26[0.81-1.94]	0.304	1.21[0.78-1.87]	0.401	1.22[0.78-1.90]	0.390
Q5 (Men: 30.5-41.8; Women: 30.3-47.4)	2.58[1.75-3.80]	<0.001	2.53[1.72-3.72]	<0.001	2.44[1.65-3.63]	<0.001
Age at first visit (2005)	1.12[1.02-1.22]	0.015	1.12[1.02-1.22]	0.013	1.12[1.02-1.22]	0.015
Female sex	0.99[0.76-1.29]	0.949	0.98[0.76-1.28]	0.906	0.94[0.71-1.25]	0.662
Education: ≥high school	0.53[0.39-0.71]	<0.001			0.62[0.45-0.84]	0.003
Financial difficulties (0/1)	1.54[1.17-2.03]	0.002			1.35[1.02-1.79]	0.038
IWL in 2005 (12 mo.)	2.02[1.39-2.94]	<0.001			2.49[1.70-3.66]	<0.001
Smoking status						
Never	1 (ref)				1 (ref)	
Former	1.07[0.80-1.44]	0.643			1.00[0.72-1.37]	0.985
Current smoker	1.26[0.89-1.77]	0.187			1.30[0.91-1.85]	0.152
DISABILITY	**Univariate N=1,166 Crude HR (95% CI)**	**P>z**	**Multivariate N=1,166 HR (95% CI)**	**P>z**	**Multivariate N=1,147 HR (95% CI)**	**P>z**
B)WC quintiles						
Q1 (Men: 70.0-91.8 cm; Women: 58.8-76.8 cm)	0.98[0.59-1.63]	0.936	0.97[0.58-1.61]	0.893	0.90[0.54-1.50]	0.687
Q2 (Men: 91.9-97.5 cm; Women: 77.0-82.5 cm)	1 (ref)		1 (ref)		1 (ref)	
Q3 (Men:97.6-103.0 cm; Women: 82.6-89.5 cm)	1.32[0.81-2.13]	0.261	1.28[0.79-2.07]	0.317	1.16[0.71-1.88]	0.560
Q4 (Men: 103.2-109.0 cm; Women: 89.8-97.2 cm)	2.01[1.29-3.15]	0.002	1.98[1.26-3.10]	0.003	1.81[1.15-2.85]	0.011
Q5 (Men: 109.1-138.5 cm; Women: 97.3-150.0 cm)	2.95[1.92-4.52]	<0.001	2.89[1.89-4.43]	<0.001	2.58[1.67-4.00]	<0.001
Age at first visit (2005)	1.12[1.02-1.22]	0.015	1.11[1.01-1.21]	0.022	1.10[1.01-1.20]	0.035
Female sex	0.99[0.76-1.29]	0.949	0.99[0.76-1.29]	0.945	0.92[0.70-1.22]	0.571
Education: ≥High school	0.53[0.39-0.71]	<0.001			0.59[0.43-0.80]	0.001
Financial difficulties (0/1)	1.54[1.17-2.03]	0.002			1.35[1.02-1.79]	0.038
IWL in 2005 (12 mo.)	2.02[1.39-2.94]	<0.001			2.30[1.57-3.36]	<0.001
Smoking status						
Never	1 (ref)				1 (ref)	
Former	1.07[0.80-1.44]	0.643			0.90[0.66-1.24]	0.535
Current smoker	1.26[0.89-1.77]	0.187			1.19[0.84-1.70]	0.322

HR: hazard ratio from Cox regression models; N indicated in the first line represents the number of participants included in the model; Sex-specific BMI and WC quintiles have been aggregated; Adjustment variables: sex, age at first visit (linear), education ≥high school (0/1), financial difficulties (0/1), involuntary weight loss during the past 12 months (IWL) in 2005 (0/1); smoking status (never/former/current smoker); Financial difficulties were considered if any of the following criteria was fulfilled: 1) current income clearly lower than others, 2) sometimes difficulty to make ends meet, 3) subsidy for health insurance, or 4) complementary subsidy (from old age insurance); IWL in 2005 was assessed (in the postal questionnaire) by the question: “In the last 12 months, have you involuntarily lost weight?” (yes/no) age. To further address this issue, one should also be able to distinguish leanness due to disease in older persons from leanness maintained during a whole life-course among fully healthy persons, which would incur the use of more complex measurements (e.g. dual-energy X-ray absorptiometry or abdominal CT scan) that often exceed what is acceptable and/or feasible in epidemiological studies. Nonetheless, our findings, consistent with evidence in the literature, stress the need to prevent functional decline and muscle loss in older adults through adequate nutrition (e.g. a number of older persons tend to lessen their intake of protein and other important nutrients) and encourage them to sustain regular physical activity, including resistance training at all ages (8, 61). Another practical issue applicable for all older persons, but likely even more for older individuals with overweight, is to adapt the living environment to facilitate daily life movements and activities, including for the prevention of falls, e.g. by installing chairs in the shower, anti-slide mats, electronic devices for seeking help in case of fall, medical walkers.

This study has some limitations. First, of all 3,056 individuals initially contacted, 1,307 participated at the baseline physical examination and 1,293 of them (42% of the initial sample) could be included in the 8-year mortality analyses. This final participation rate was comparable with other surveys involving community-dwelling individuals (rather than hospitalized persons) in Western countries (62-64); for example, in the Cardiovascular Health Study in the USA (65), 31% of those contacted in the randomly selected sample were initially enrolled. Differential participation of population subgroups in Lc65+ is likely to be small since only 8% of those refusing to participate attributed their refusal to poor health (36, 37). Participants and non-participants showed no significant difference in their distribution of sex and year of birth. Furthermore, the social characteristics of participants closely reflected the local population of same age according to data from the population census.

Extreme quintiles might include persons with very different BMI or WC values (e.g. BMI in fifth quintile ranging between 31 and 54 kg/m^2, as mentioned in Table 1). In mortality analyses, 21 men (with a BMI in quintile 5) had a BMI ≥35 kg/m^2 and among them, 4 men had a BMI ≥40 kg/m^2; 53 women (with a BMI in quintile 5) had a BMI ≥35 kg/m^2 and among them, 18 women had a BMI ≥40 kg/m^2. We preferred to use quintiles over quartiles despite fairly small size numbers, in order to better examine the associations of outcomes (BADL, mortality) with low and high BMI/waist, as a major contemporary question precisely relates to the shape of the associations of outcomes with BMI/waist at such extreme low and high values in older persons. In addition, the use of quintiles allows better assessing a graded effect. Our study lacked statistical power to demonstrate a relationship between BMI/WC and mortality and to assess whether the graded relationship with disability was linear or J-curved. However, despite the relatively small sample size, our study had a fairly long follow-up time, which allowed accumulating a large number of person-years to be used in denominators. The consistency of our results in both univariate and multivariate analyses suggests that the J-shape association between adiposity and mortality and a graded association between adiposity and disability in our study are true. The limited study power explains why only extreme quintiles showed statistically significant associations with disability. Inversely, precise assessment of disability as done in our study has not been often performed in large studies so that our results are informative. Further studies aiming at clarifying the relation between BMI/WC and disability will need to include larger sample sizes (31) and/or longer follow-ups. Our study also has strengths. BMI and WC were measured and not self-reported. Another important strength (41) is our explicit adjustment for involuntary weight loss at baseline, while most other similar studies reported weight loss with no distinction of participants' intention (31, 43). The truly population-based nature of our sample is another strength.

In conclusion, we found that adiposity markers tended to show a J-shaped relation with mortality and a graded relation with disability in "young old" adults aged 65 to 70 years at baseline. Studies with larger sample sizes and/or longer follow-up should further clarify the exact shapes of these associations, including by assessing the role of exposures (adiposity) measured at different ages (31) on later health outcomes and the potentially different predictive values of different adiposity markers (BMI, WC), which may represent different phenotypes (e.g. overall adiposity versus abdominal adiposity). The findings emphasize the need for life-long strategies to maintain a healthy weight during the entire life course and, specifically, the need for supportive tools for older persons with excess weight in order to reduce their functional limitations and improve their quality of life.

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