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An Adequate Threshold for Body Mass Index to Detect Underweight Condition in Elderly Persons: The Italian Longitudinal Study on Aging (ILSA)

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Background. The present study aims at defining a body mass index (BMI) threshold for risk of being underweight in elderly persons on the basis of the BMI distribution in a large Italian population-based sample and on its ability to predict short-term mortality.

Methods. At baseline (1992), BMI was obtained for 3110 (1663 males and 1447 females) persons aged 65–84 participating in the Italian Longitudinal Study on Aging (ILSA). BMI and risk factors (age, sex, education, smoking status, disability, and disease status) have been considered for their potential association with 4-year all-cause mortality. Information on vital status at 1995 was obtained for 2551 participants.

Results. The fifth centile of BMI was well approximated by a value of 20 for both sexes. Also in both sexes, at a BMI value of 24 the a posteriori probability of death started to increase, doubling at a value of 22 for men and 20 for women. Crude mortality was 14.6% for men and 9.8% for women. The hazard ratios and confidence intervals (CIs) comparing mortality for each BMI two-unit class to the 26–28 class, after adjusting for confounding variables, showed significantly higher rates only for BMI values below 20 (2.9; 95% CI, 1.2–7.0), although a consistent increase in hazard ratio (1.6; 95% CI, 0.9–3.0) already appeared for the 20–22 BMI group.

Conclusions. Our study confirms that low BMI is an independent predictive factor of short-term mortality in elderly persons. A BMI value of 20 kg/m^2 seems to be a reliable threshold for defining underweight elderly persons at high risk. Nevertheless, more careful clinical and nutritional management should also be applied to elderly persons with higher BMI values.

POOR nutritional status is generally considered the consequence of an imbalance between dietary intake and nutritional needs. As energy and protein deficit leads to weight loss, the underweight state can be an indirect sign of undernutrition.

Being underweight, particularly in elderly persons, is associated with physical, functional, and psychological impairment, increased hospitalization risk, and delay in recovery from illness, with higher costs for public health service. As of today, the prevalence of this condition in different countries and age strata is generally unknown and at least incomparable because of the absence of consensus on the best method for classifying a patient as underweight (1–4). Surely, among other measures, all the proposed assessments require body mass index (BMI) evaluation.

Although criticized because of the limits of its meaning, BMI is widely applied in nutritional assessment. Its known association with disease and death makes it a useful tool to detect persons at risk both in screening and clinical interventions, with reference to specific standard values (5). Its use in frail and disabled older populations could be limited by additional difficulties in collecting measurements and ensuring their accuracy.

Because of age-related changes in body composition, during the life span reference BMI values rise from childhood to old age, reflecting a modification of the relation between BMI and morbidity and mortality (6,7). In adults, being overweight is associated with higher mortality risk (8–10); in elderly persons, being underweight seems to be a better predictor of negative outcomes than does obesity (11–13). Seidell and Visscher (14) considered BMI an appropriate measure of low lean body mass in elderly persons. British guidelines (15) have been launched for the detection and treatment of malnutrition in the community, focusing on the screening approach by primary care health professionals. The guidelines included as criteria BMI and the extent of unintentional weight loss. The thresholds generally used for BMI in elderly persons were estimated on marked ($<$18 kg/m^2) and marginal (18–20 kg/m^2) undernutrition in adults (16). Other researchers suggested higher cut-point values for detecting risk of poor nutritional conditions in elderly persons (2,17,18), as lower thresholds might exclude patients at risk.

The present study aims at defining a BMI threshold for poor nutritional risk in elderly persons on the basis of the BMI distribution in a large Italian population-based sample and on its ability to predict short-term (3.5 year) mortality.

Methods

Sample Population

The design and methods of the study have been reported elsewhere (19). Briefly, a sex- and age-stratified sample of 5462 persons aged 65–84 was randomly drawn from the demographic lists of the registry office in eight Italian municipalities. The participation rate was 83% (4521 persons). All of the persons were mobile and able to come on her/his own to the Center for the examination. The Italian Longitudinal Study on Aging (ILSA) includes cross-sectional and longitudinal phases.

Data and Variables

The baseline data collection was performed in the period 1992–1993. By nurses' and physicians' evaluations, data were collected on demographic, behavioral, anthropometric, cognitive, psychological, physical, and clinical aspects and on drug consumption of the sample population. In addition, participants who screened positively for neurological and/or internal chronic diseases were evaluated by specialists for the clinical diagnosis of cardiovascular disease, diabetes, Parkinson's disease, dementia, stroke, and peripheral neuropathy (19). Adopted diagnostic criteria have been previously described by the ILSA working group (20).

Among all the variables collected during the prevalence phase, anthropometric measurements (body weight, height, BMI) and risk factors (age, sex, education, smoking status, disability, diabetes, congestive heart failure, myocardial infarction, peripheral artery disease, stroke, dementia, Parkinsonism) have been considered for their potential association with 4-year all-cause mortality in the present study.

At baseline, anthropometric measures were collected by trained personnel at the clinical center of the study. Details on method of collection were previously described (21). BMI was obtained for 3110 (1663 males and 1447 females) participants (69%). Physical disability was evaluated by activities of daily living (ADLs) (22).

An intermediate telephone survey on hospitalization was performed in 1994. At that stage, vital status for about 99% of the sample population was known. Information on vital status at 1994 was used in survival analysis for the participants missing at the 1995 follow-up.

The longitudinal phase of the ILSA study, based on the complete assessment as done at baseline, was performed in 1995 on the whole cohort. Information on 2876 (92.5%) participants in the study was collected. Information about death was obtained from relatives and general practitioners. A copy of the death certificate was obtained from the national registry for each participant whose death had been reported. The mean duration of follow-up was approximately 3.5 years. Using all-cause mortality as the outcome in evaluating the BMI predictive value, we excluded from the analysis 425 participants declaring at baseline a weight loss of almost 5 kg during the last year, and 93 participants missing this piece of information. Fourteen participants who died within 6 months of the beginning of the study were excluded. At the end of the study, the relation between BMI at baseline and survival was assessed among 2551 participants.

Statistical Analysis

All statistical analyses were performed using the SAS Statistical Software Package (version 8.2; SAS Institute, Cary, NC). For testing sex differences between mean values, the unpaired Student t test ($p = .05$) was applied. Differences among prevalence rates were verified by the chi-square test ($p = .05$).

The aim of identifying the most reliable BMI value for defining underweight has been pursued by three different approaches: 1) the reference value chosen from the population distribution, 2) the value doubling the positive predictive value for death, and 3) the earliest value detecting an adjusted hazard ratio of death significantly greater than 1 ($\alpha = 0.05$).

Descriptive statistics (mean, quantiles, standard deviation [*SD*]) were calculated for baseline BMI values by sex and age group (65–74 years; 75–84 years). As reference intervals for ''normal'' values usually encompass 95% of the values, we adopted the fifth centile of the distributions (considering values at the lowest extreme suspicious) to identify a reference cut-point for evaluating underweight. For each BMI value, the proportional positive predictive value (PPV%) and the likelihood ratio (LR) were produced. Crude mortality rates were calculated by sex. Sex- and age-specific mortality rates were calculated and expressed as number of events per 1000 person-years.

Survival was modeled by Kaplan–Meier analysis, and stratified by BMI values. Different survival experiences were tested by the log-rank test. The Cox proportional hazard regression was used to model the time of survival (number of months) as a function of BMI (<20, 20–29.9, ≥ 30) adjusting for several covariates (education, disability, smoking status, and chronic diseases). Sex-specific mortality rates were computed for two-unit BMI intervals to highlight the minimum mortality interval, keeping an adequate sample size in each group. For each BMI interval, compared with the minimum mortality interval, the hazard ratio of dying during the follow-up period was computed by a Cox regression, adjusting for the previously listed covariates.

Results

The mean age was 73.5 years (*SD* 5.6 years) and 73.6 years (*SD* 5.7 years) in 1663 males and 1447 females, respectively. The majority (about 89.5%) of the participants was independent in all ADLs or dependent in no more than one item. Smoking status, defined as current/past or never, was significantly more prevalent among men (78.4%) than among women (18.1%). About 72% of the participants had attended no more than primary school.

BMI Distribution

The BMI mean value was significantly higher in women than in men in the whole group (27.5 ± 5.3 vs 26.3 ± 3.9). This index decreased significantly with age in both sexes.

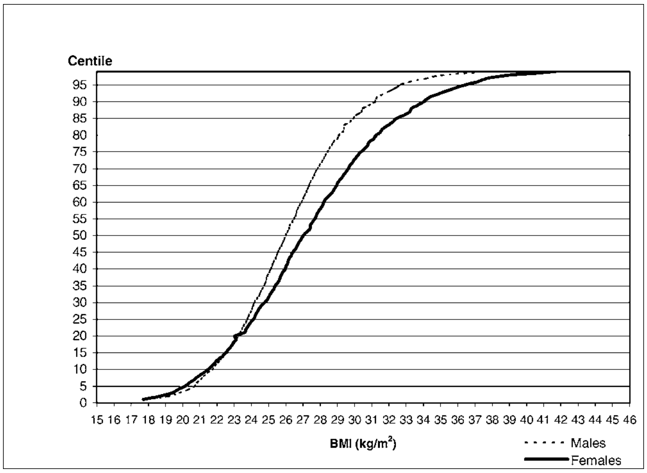

Figure 1. Percentile distribution of body mass index (BMI) by sex.

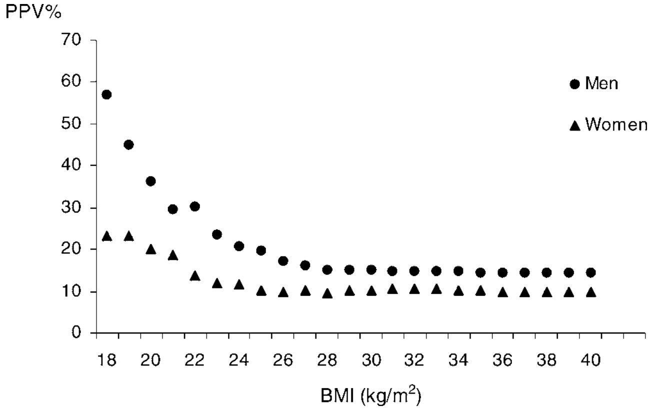

Figure 2. Male and female proportional positive predictive value (PPV%) of short-period death by body mass index (BMI) values.

The BMI value distributions in women and men only overlap on the left tail, assuming greater values for median and higher centiles in women (Figure 1). Even accounting for an age-dependent decreasing trend, the 5th centile value for women and men is well approximated by a value of 20.

Mortality and BMI

Excluding 157 participants lost to follow-up after 1994, during the entire follow-up period the crude all-cause mortality rate was 12.4% (298/2394). Among men, mortality was 14.6% (193/1326), 8.1% (62/762) in the younger age group (65–74 years) rising to 23.3% (131/564) in the oldest participants (75–84 years); in women, it was 9.8% (105/1068), 4.3% (26/603) in the younger age group rising to 17.0% (79/465) in the oldest participants.

All-cause mortality rates indicated higher rates for men than for women in both age groups. In the 65–74 year group, for men it was 23.7‰ person-years against 12.3‰ person-years for women; in the 75–84 year group, for men it was 66.1‰ person-years against 46.8‰ person-years for women.

In both sexes, at a BMI value of 24 the a posteriori probability of death (PPV%) started to increase, doubling at a value of 22 for men and 20 for women (Figure 2). The probability of dying, having such a BMI value, rises from 14.5% to 30.1% for men, and from 9.9% to 20.0% for women. The ability to predict mortality continued to rise for lower BMI values only for men, tripling at BMI = 19. LR values confirmed this trend, showing for men at BMI = 22 an LR of 2.5, and at BMI = 20 an LR of 3.3. For women, the probability of having a BMI equal to 20 is doubled (LR 2.3) for participants dying within a short period.

Survival Analysis

We classified our participants into three groups based on BMI value (<20, 20–29.9, ≥30) and we compared their survival by means of log-rank test. The survival of participants with BMI < 20 was significantly lower than that of the other two groups ($p < .0001$).

Cox proportional hazard regression was used to model the time of survival as a function of categorized BMI adjusting for education, disability, smoking status, and chronic diseases (Table 1). Among all tested variables, sex, age, BMI < 20, dementia, peripheral artery disease, congestive heart failure, and Parkinsonism resulted significantly associated. After adjusting for all variables, BMI < 20 corresponded to a relative risk of death of 2.65 (95% confidence interval [CI], 1.46–4.79). The continuous variable BMI was categorized into two-unit intervals (see Figure 3), to have sufficient sample size in each group, the lowest mortality rate was obtained for the 26–28 class in both sexes (29.7% person-years in males and 23.0% person-years for females).

Figure 3 shows the hazard ratios and 95% CIs computed by Cox regression, comparing mortality for each BMI class to the 26–28 BMI class, after adjusting for associated variables previously listed (Table 1). Mortality risk increased for BMI values below 26. Significantly higher rates were observed only for BMI groups lower than 20 (2.9; 95% CI, 1.2–7.0). A consistent increase in hazard ratio (1.6; 95% CI, 0.9–3.0) already appeared for the 20–22 BMI group.

Discussion

The aim of the present study was to define a BMI threshold for identifying when underweight became a negative prognostic factor in elderly persons. The BMI distribution and short-term all-cause mortality were detected in a large representative sample of older Italians. Previous

Table 1. Results for Cox Proportional Hazard Model of Death

Variable	Risk Ratio	95% Confidence Interval	p Value
Sex (0 = women, 1 = men)	1.80	1.32–2.47	.0002
Age	1.13	1.09–1.12	.0001
Body mass index < 20 kg/m^2	2.65	1.46–4.79	.0013
Dementia	2.66	1.72–4.11	.0001
Congestive heart failure	2.35	1.56–3.58	.0001
Peripheral artery disease	1.74	1.11–2.75	.0166
Parkinsonism	1.83	1.06–3.13	.0289

Notes: Only significantly associated variables at baseline are reported. A stepwise procedure was applied. Variables at baseline included in the model and not associated were BMI ≥ 30, disability, hypertension, diabetes, myocardial infarction, stroke, smoking status, and education.

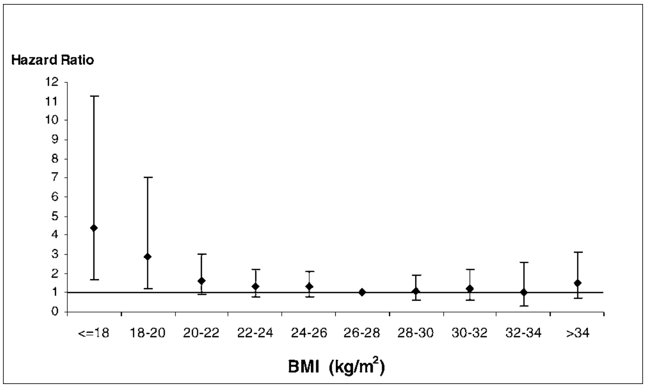

Figure 3. Hazard ratios of all-cause mortality by two-unit interval of body mass index (BMI) in the total elderly sample. The 26–28 range is the reference group; 95% confidence intervals are indicated by the vertical line. Analyses are adjusted for age, sex, dementia, peripheral artery disease, congestive heart failure, and Parkinsonism.

studies investigated this matter including both adult and elderly persons. We studied a cohort including only elderly people (65–84 years).

The distribution of low BMI values showed the overlap of centile curves for both sexes up to the 20th centile. On the basis of this distribution, we can identify the same cut-off value for underweight in men and women (Figure 1).

In both sexes, the 10th centile BMI value was about 21.5, and the 5th centile value was slightly higher in men (20.7) than in women (20.1). Our values were in agreement with the results of a previous cross-sectional multicenter survey carried out in Italy by the National Research Council in 1984 (23).

As compared with National Health and Nutrition Examination Survey (NHANES) III data (24), our 10th centile of BMI appeared quite similar for men, American 10th centile values being 21.9 for 60–69 years and 21.5 for 70–79 years. To the contrary, American data showed lower values for women, on average under 21. This comparison might be partially biased by different age classes and the lack of the fifth centile for American data. Based on NHANES I and II data, 19.5 kg/m^2 represented the 4.7th centile (25).

With regard to European data, the SENECA study (Survey Europe on Nutrition in the Elderly: a Concerted Action) on elderly people was carried out starting from 1988 (26,27). The authors did not show the distribution of BMI centiles, they only indicated the prevalence of BMI < 20 in each center. On average, it looks like the prevalence rate was about 5.5% both in men and in women, supporting the 20 value as the 5th centile for European elderly people. The 10th French anthropometric reference values, performed on persons 65 years and older (28), were comparable with ours, generally ranging from 21 to 22 kg/m^2.

The comparison with the smoothed centiles curves shaped by a recent Irish survey on the anthropometric measurements of free living elderly persons (29) showed a plain overlap of the lower part of the Irish and Italian distributions in females. For men, the 5th and the 10th centiles of Irish distribution were almost 1 unit higher than those in our data. The slight differences raised in the comparison with other European studies could depend on the limited sample sizes of previous studies, smaller than the Italian one.

In contrast to what was reported for overweight, globally these results would support the hypothesis of a similar distribution of being underweight among elderly persons in different developed countries. As a consequence, it seems reasonable to apply similar BMI values to identify elderly persons in Caucasian populations at risk for being underweight.

The relationship between BMI and mortality has been investigated in a large number of epidemiological studies to evaluate the risk of obesity in elderly persons, as compared to adults. The conclusion on this matter is still controversial, although there is a general agreement on the higher mortality risk for lower BMI values (13). Actually, as the relationship is described by a U or inverse J shaped curve, the minimum mortality point is detectable as the first derivate of a fitted quadratic function. On the contrary, the starting point of a significant increase in mortality rate does not have a mathematical solution, but it depends on the adopted approach. In many surveys, BMI is the predictive variable categorized on the basis of quartiles (30), quintiles (12), or different centiles (13) of BMI distribution. Alternatively, the World Health Organization (WHO) reference values are used, referring the mortality to the normal class (31–33). The first approach produces population-dependent results; the second identifies only an extreme underweight condition in elderly persons. More detailed analyses were performed by Allison and colleagues (34) who considered the relationship between BMI and mortality by means of unadjusted death rate in each of the BMI deciles and by means of different regression models including BMI and potential confounders as continuous and categorical variables. They depicted a significant increase of mortality for BMI values lower than 20.4 (2nd decile), for both sexes, with observed minimum mortality in the 9th decile at about 27.5–30.1. Analyzing the same data set, Grabowsky and Ellis (13) used BMI 19.4, corresponding to the 10th centile, to classify the thin people. They found a significantly higher mortality rate for thin elderly people, as compared to normal, after adjustment.

In the present study, the analysis of unadjusted PPV% for each BMI value (Figure 2) showed a rise of the predictive value of BMI starting from 24 kg/m^2. Low BMI values seem to be more dangerous in males than in females, because mortality risk doubles in men at higher values (22 kg/m^2) and rapidly increases for lower figures. When modeled adjusting for confounders, hazard ratio estimated by Cox regression became statistically significant for the 18–20 kg/m^2 class and lower, with a value equal to 2.9 (95% CI, 1.2–7.0). A hazard ratio appreciably greater than 1 (1.6; 95% CI, 0.9–3.0) also appeared for higher BMI values (20–22 kg/m^2), although not yet statistically significant. Taking into account more the trend than the statistical significance of estimated absolute values, the 20–22 group risk condition should be considered as the first step of a rising risk function.

On the whole, these results suggest that the threshold for defining a ''high risk'' underweight condition in elderly persons be set at least at 20 kg/m^2. To be cautious, those providing health care for elderly persons should consider ''at risk'' also those persons with higher BMI values (20–22 kg/m^2). An early intervention could yet reverse the process before the condition becomes more precarious.

In estimating the BMI–mortality relationship, many authors stressed the opportunity to take into account potential confounders such as smoking status, education, disability, illness, and above all, recent weight loss. We controlled for those covariates, including in the analysis only persons without recent weight loss (>5 kg during the last year), and excluding deaths within the first 6 months of follow-up.

Many authors explain the higher probability of death for underweight participants as a consequence of previous diseases or smoking status. By excluding persons with recent weight loss and those dying earlier during the follow-up, we hope to have avoided this bias (35). Even excluding the deaths registered in the first 12 months, our results were confirmed. The relevance of smoking status on mortality suggested by many authors was not confirmed by the present results, according to other studies on elderly people (12). Our interpretation is that smoking is a significant risk factor for mortality at an earlier age, but its relevance decreases in elderly persons.

As already stated, the present longitudinal study has a mean length of 3.5 years, shorter than most of previous studies, but comparable with other research in the elderly population (18,30,33). Actually, the reduced life expectancy of older people, the possibility to exclude negative events within short periods, and the agreement of studies with different follow-up periods on the role of being underweight in general mortality support the adequacy of this follow-up length.

Our results support the independent effect of being underweight on mortality, as a contributing factor to frailty in older people. To verify a potential different effect of a recent versus a stable underweight state, we compared the mortality between participants with constitutional underweight and participants who became underweight at an older age. No significant differences were found (data not shown), confirming that being underweight is an independent risk factor as stated by other authors (31).

Several limitations of our study deserve comment. The 82% of the studied cohort had information at follow-up, and we have no data on the mortality rate of lost participants. Also, although we adjusted analyses for the main risk factors, it might be that the relationship between BMI and mortality was affected by unmeasured variables not included in the protocol of the survey.

This study has some peculiar strengths. To our knowledge, it is the first study analyzing the relation between BMI and mortality in a large sample of older Italians, providing anthropometric and health status data by means of an objective clinical evaluation. Moreover, the use of death certification allows a more reliable ascertainment of vital status.

Conclusion

Our study confirms that low BMI is an independent predictive factor of short-term mortality in elderly persons. A BMI value of 20 kg/m^2 seems to be a reliable threshold for defining underweight elderly persons at high risk. Nevertheless, more careful clinical and nutritional management should be applied to elderly persons with higher BMI values.

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