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Original Study

Association of Body Mass Index With All-Cause Mortality in Acutely Hospitalized Older Patients

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A B S T R A C T

Objectives: The aim was to examine the relationship between body mass index (BMI) and mortality in older hospitalized patients taking activities of daily living (ADLs) into account.
Design: Retrospective cohort study.
Setting and Participants: Nationwide population-based study of all patients aged ≥65 years admitted to Danish geriatric medical departments during 2005 to 2014 and included in the National Danish Geriatric Database.
Methods: Patients were followed until death, emigration, or study termination (December 31, 2015). Primary outcome was all-cause mortality. BMI and ADLs were routinely assessed on admission and linked at an individual level to the Danish national health registers. Kaplan-Meier analysis was used to estimate crude survival according to each BMI subcategory and Cox regression to examine the association with mortality adjusting for age, comorbidity, polypharmacy, ADLs, marital status, prior hospitalizations, and admission year.
Results: In total, 74,589 patients (63% women) were included aged [mean (SD)] 82.5 (7.5) years with BMI [mean (SD)] of 23.9 (5.1) kg/m^2. During follow-up 51,188 died. Follow-up time was 191,972 person-years. Unadjusted and adjusted hazard ratio (HR) for overall, 30-day, and 1-year mortality decreased significantly with increasing BMI. In women, the highest adjusted HR (95% confidence interval) for overall mortality was seen for underweight patients (BMI <16) 1.83 (1.72–1.95) and the lowest for obesity grade II patients (BMI = 35.0–39.9) 0.66 (0.60–0.73) when using normal weight (BMI = 18.5–24.9) as reference. In men, the HR for BMI <16 and BMI = 35.0–39.9 were 1.98 (1.76–2.23) and 0.56 (0.49–0.65), respectively.
Conclusions and Implications: In hospitalized older patients, association between mortality and BMI did not show a U-shaped or J-shaped curve after adjustment of multiple confounders, including ADLs. Instead, mortality was highest in patients with low BMI and decreased with increasing BMI before leveling off in the obese range. Our study highlights the need for a debate and reassessment of what should be the ideal BMI in this vulnerable patient group.

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The prevalence of obesity is high among adults,[1] including those in the older age group.[2,3] Although decreasing with age, still 15% are considered obese at age 70 years and older.[3] Previous studies on the association between body mass index (BMI) and mortality show conflicting results depending on the studied population. In the general population, high BMI is associated with disability, additional costs, and both disease-specific mortality like cardiovascular and cancer, and all-cause mortality.[4–6] Most studies report a U-shaped association when assessing the general population.[1,5–8] Other studies addressing specific diseases such as type 2 diabetes[9] show a J-shaped or even an inverse association with increasing BMI after disease onset of heart failure,[10] acute myocardial infarction,[11] pneumonia,[12] and hip fracture.[13] Among oldest-old individuals, high BMI has been reported to be associated with lower mortality,[14–19] maybe because it requires good health to maintain a high BMI at advanced ages.[20]

Although many risk factors are associated with increased mortality, activities of daily living (ADLs) are the strongest predictors of survival, and hence the best indicators of general health among oldest-old individuals.[21,22] However, studies documenting the positive association between BMI and survival did not take general health into account[14–17] or only included a few patients.[18] Furthermore, underweight and malnutrition also play a major role in the health and well-being of frail older adults and are therefore essential to address as well.[23]

Weight, height, and ADLs are routinely assessed when an older acutely ill patient is hospitalized and admitted to a geriatric department in Denmark. Therefore, the aim of the present study was to explore the association between BMI and survival in a nationwide population of hospitalized older patients after taking ADLs into account.

Methods

Design and Setting

This is a nationwide population-based longitudinal cohort study. Each Danish citizen has a unique personal registry number, which enables accurate linkage of information at the individual level between the many population-based national registers.[24] We used data from 4 different Danish national registers (Supplementary Table 1): the Danish National Database of Geriatrics,[25] the Danish National Patient Register (all somatic inpatient contacts since 1977; psychiatric inpatient, emergency department, and outpatient specialty clinic contacts since 1995),[26] the Danish Civil Registration System (deaths, migration, and marital status with 100% completeness),[27] and the Danish National Database of Reimbursed Prescriptions (all individually redeemed reimbursed prescriptions).[28] Data were used to assess the association between BMI and overall, 30-day, and 1-year mortality.

The method by which the cohort was established has previously been published and described in detail elsewhere.[21] In short, the study population was identified using data from the Danish National Database of Geriatrics,[25] which is a clinical quality database established in 2005 designed to include all patients admitted to geriatric medical departments in Denmark. Patients were admitted directly from the general practitioner, through the emergency department, or by transfer from other hospital departments. The database has a patient completeness of 90%, reaching the standard requirement for Danish national databases.[25] We included all patients aged ≥65 years with a first registration (index date) in the database from January 1, 2005 to December 31, 2014. Patients were followed from index date until time of death (outcome), emigration, or end of study (December 31, 2015). Exact date of death from all-cause mortality was retrieved from the Danish Civil Registration System.[27]

At the time of admission to the geriatric department, level of ADL dependency was routinely assessed by a geriatric nurse or nursing assistant using the Barthel-Index-100.[29,30] This instrument is a sum score across 10 domains of ADLs, each scored on a weighted numerical scale with lowest score indicating total dependency and highest score indicating complete independence. Time for completion is approximately 5 minutes, and the index has high reliability.[30,31] Furthermore, weight and height allowed calculation of BMI as the weight in kilograms divided by the height in meters squared (kg/m^2). The BMI was divided into standard categories according to the World Health Organization: BMI <16 (severe underweight), BMI = 16.0–18.4 (underweight), BMI = 18.5–24.9 (normal weight), BMI = 25.0–29.9 (overweight), BMI = 30.0–34.9 (obesity grade 1), BMI = 35.0–39.9 (obesity grade 2), or BMI ≥40.0 (obesity grade 3).[32,33] Data on comorbidity were collected based on International Classification of Diseases, 10th Revision, hospital discharge diagnoses extracted from the Danish National Patient Register,[26] allowing for calculation of Charlson comorbidity index (CCI). Because patients in our study were included from January 1, 2005, we calculated CCI 10 years before the index date to allow the same time scale for comorbidity calculation in all patients. Number of medications was defined as the number of different medications purchased up to 120 days before the index date using information from the Danish National Database of Reimbursed Prescriptions.[28] Finally, the national registers were also used to assess number of prior hospitalizations and marital status. In general, confounders were chosen due to their known impact on burden of disease (prior hospitalizations) and mortality in older adults (ADLs,[21] polypharmacy,[34] CCI,[35] and marital status[36]). The present study is a post hoc analysis from a cohort study assessing the association between ADL and mortality.[21]

Statistics

Descriptive data are reported as means with corresponding standard deviation (SD) (normally distributed data) or as medians with corresponding interquartile range (IQR) (25%–75% percentile) (skewed data). Tests of differences in the categorical variables were performed using the χ^2 test. Differences between groups in the numeric variables were tested using the Wilcoxon rank sum test (median differences) or the Student *t*-test (mean differences), as appropriate. Kaplan-Meier survival curves were used to estimate crude survival according to each of the pre-specified BMI subcategories. Spearman correlation (ρ) was used to test the association between BMI and Barthel Index, age, CCI, or number of prescribed medications. Cox regression was used to carry out univariable and multivariable analysis adjusting for age, marital status, Barthel Index, CCI, number of prescribed medications, previous hospital admission, and year of index admission. All variables were treated as categorical in the models. The statistical significance of the categorical variables included in the multivariable Cox regression model was tested using Wald statistics. The proportional hazard assumption was inspected graphically for the BMI variable using a Log-Log plot and was found to be satisfactory. In the fully adjusted model, analyses were conducted as complete case analysis excluding patients with missing data on one or more of the included variables. Imputation methods were not used.[37] An additional descriptive nonresponse analysis was carried out for missing data on BMI or Barthel Index to examine whether patients with missing versus not missing data differed on outcome variable. Furthermore, a robustness analysis was performed in which all patients with missing data on BMI were added to either category BMI <18.5 or BMI ≥30 to address potential implications. Analyses were stratified by sex at birth according to the health registers. All analyses were performed using the statistical software STATA (StataCorp, College Station, TX). A *P* value of .05 indicated statistical significance.

Table 1
Baseline Characteristics of the Study Population

Measures	Total Cohort (n = 74,589)	Women 63% (n = 46,815)	Men 37% (n = 27,774)
Age (y), mean (SD)	82.5 (7.5)	83.4 (7.3)	80.9 (7.5)
Barthel Index, median (IQR)*	54 (29–77)	55 (30–77)	52 (26–77)
CCI, median (IQR)†	2 (1–3)	2 (1–3)	2 (1–4)
Number of drugs, median (IQR)‡	6 (4–9)	6 (4–9)	6 (4–9)
Prior hospitalization (1 year), median (IQR)§	0 (0–1)	0 (0–1)	1 (0–2)
BMI (kg/m^2), mean (SD)	23.9 (5.1)	23.6 (5.3)	24.5 (4.7)
<16, n (%)	1774 (2.4)	1449 (3.1)	325 (1.2)
16.0–18.4, n (%)	5313 (7.1)	3997 (8.5)	1316 (4.7)
18.5–24.9, n (%)	30,111 (40.4)	18,982 (40.5)	11,129 (40.1)
25.0–29.9, n (%)	15,060 (20.2)	8659 (18.5)	6401 (23.0)
30.0–34.9, n (%)	4955 (6.6)	2938 (6.3)	2017 (7.3)
35.0–39.9, n (%)	1235 (1.7)	835 (1.8)	400 (1.4)
≥40, n (%)	447 (0.6)	324 (0.7)	123 (0.4)
Missing, n (%)	15,694 (21.0)	9631 (20.6)	6063 (21.8)

*ADLs were assessed using Barthel-Index-100.
†The CCI was calculated based on hospital discharge diagnoses during 10 years before baseline.
‡Redeemed prescriptions within 120 days before index date.
§Based on hospital admissions during 1 year before baseline. Normally distributed data are presented with mean (SD).

Ethics

Informed consent from patients was not needed according to Danish legislation on medical ethics, due to the design using register-based data only. The study was approved by the Danish data protection agency (J.nr. 16/23359). Data are reported according to STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines.[38]

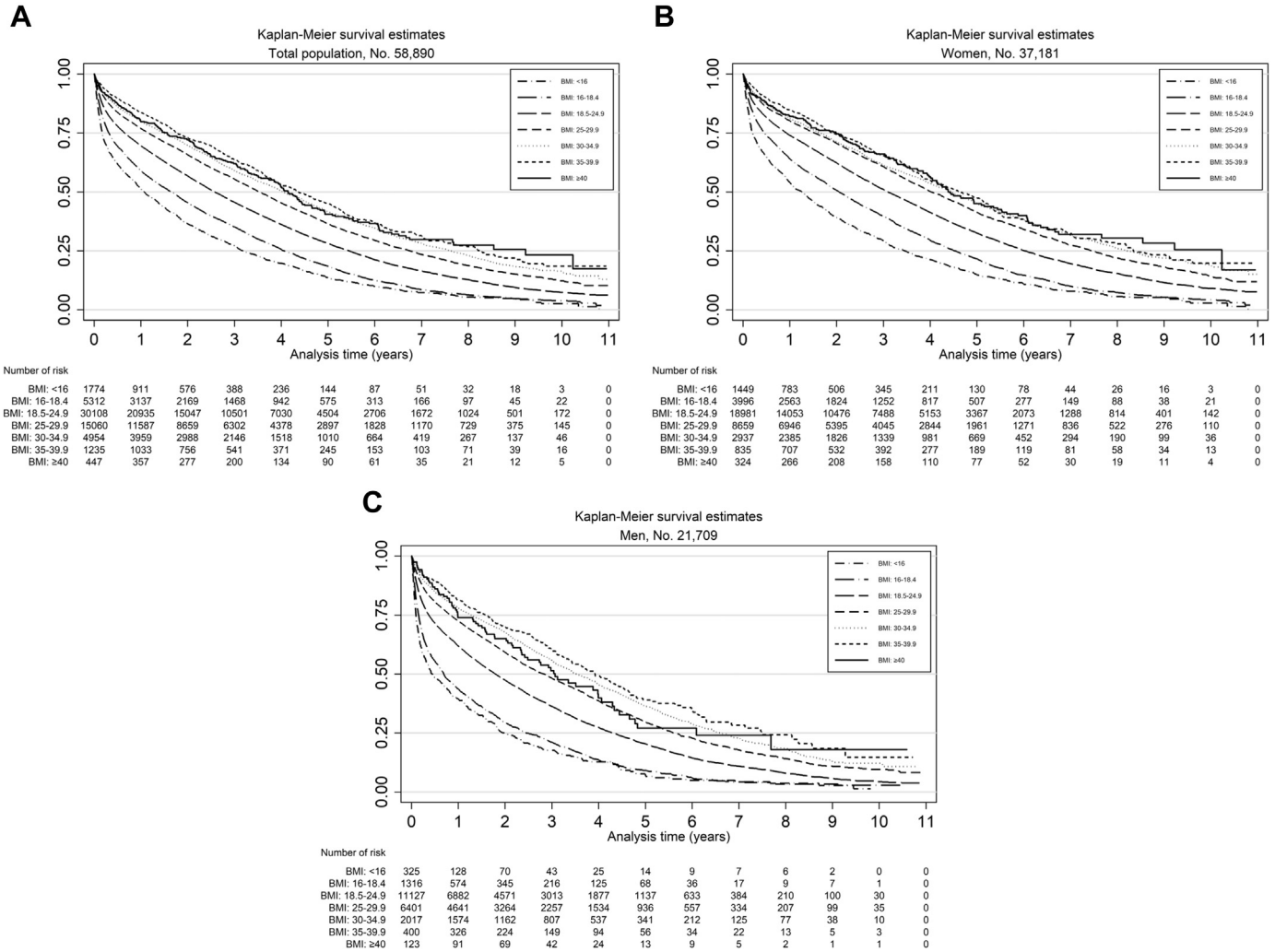

Fig. 1. Kaplan-Meier crude survival curves for the total cohort (A) and stratified by sex [women (B), men (C)]. Illustrated for each of the 7 BMI subcategories (<16.0, 16.0–18.4, 18.5–24.9, 25.0–29.9, 30.0–34.5, 35.0–39.9, ≥40.0).

Results

The final study population consisted of 74,589 patients (63% women) (Table 1). The age [mean (SD)] and BMI [mean (SD)] of the total cohort were 82.5 (7.5) years and 23.9 (5.1) kg/m^2, respectively, and the median follow-up time was 2 years. More men were obese (BMI ≥30) (9.1%) than underweight (BMI <18.5) (5.9%), whereas more women were underweight (11.6%) than obese (8.8%) (Table 1).

Crude Survival

A total of 51,188 deaths occurred, with no patients lost to follow-up. Age [mean (SD)] at time of death was 87.2 (7.1) years in women and 84.2 (7.2) years in men. Among patients still hospitalized 3108 had died within 30 days. Total follow-up corresponded to 191,972 person-years. Survival (years) [median (95% confidence interval [CI])] was higher in women [3.1 (3.0–3.1)] compared with men [2.0 (2.0–2.1)]. Crude survival proportions decreased with decreasing BMI category for the total study population and both sexes, with men in the lowest BMI categories having the shortest median survival (Figure 1). No correlation was found between BMI and Barthel Index ($\rho = 0.05$), age ($\rho = -0.18$), CCI ($\rho = 0.08$), or numbers of prescribed medications ($\rho = 0.13$). Supplementary Table 2 displays baseline characteristics of study population with complete data used for the multivariable analysis (n = 56,564). Of these, 38,966 patients died during follow-up, with 3574 dying within 30 days and 16,488 within 1 year.

Association Between BMI Category and Mortality

Unadjusted hazard ratio (HR) (95% CI) for mortality decreased significantly with increasing BMI category (reference: normal weight (BMI = 18.5–24.9) HR = 1) in the total cohort and in women (n = 37,181) and men (n = 21,709) separately (Table 2). In the multivariable model, adjusting for Barthel Index and other covariables, the relationship persisted with the strongest association seen for 30-day mortality (Table 2). Obesity (BMI ≥30) was associated with an adjusted HR (95% CI) for overall mortality of 0.71 (0.64–0.78) in women and 0.64 (0.55–0.75) in men. The significant association was present in all 3 obesity grades for overall, 30-day, and 1-year mortality (Table 2). Furthermore, patients with BMI ≥30 also had significantly lower mortality when compared with patients with BMI = 25.0–29.9 (data not shown).

Association Between BMI as a Continuous Variable and Mortality

Graphical presentation of BMI as a continuous variable plotted against risk of overall, 30-day, and 1-year mortality in the fully adjusted model (using BMI = 25 as reference) is shown in Figure 2. Low BMI was associated with the highest HR in both short-term and long-term mortality, whereas increasing BMI was associated with decreasing mortality. The most optimal BMI (nadir) for overall mortality was observed for BMI = 37.8 in the total cohort, BMI = 35.2 in men, and BMI = 37.0 in women. For 30-day mortality, nadir was BMI = 37.3 in the total cohort, BMI = 45.0 in men, and BMI = 36.5 in women. And for 1-year mortality, nadir was BMI = 38.5 in the total cohort, BMI = 35.7 in men, and BMI = 45.0 in women. Dividing the cohort into 5-year age subcategories (65–69, 70–74, 75–79, 80–84, 85–89, 90–94, ≥95) did not change the association between BMI and mortality (data not shown).

The fully adjusted model with BMI as a continuous variable revealed a significantly decreased overall mortality risk [HR (95% CI)] of 6% (6%–7%) in the total cohort for every 1 kg/m^2 increase in BMI up

Table 2
Overall, 30-Day, and 1-Year Mortality Risk (HR and 95% CI) According to BMI in Total Cohort and by Sex Using the Subcategory "BMI = 18.5–24.9 (Normal Weight)" as the Reference Category

	Total		Women		Men	
	HR (95% CI)		HR (95% CI)		HR (95% CI)	
	Univariable	Multivariable*	Univariable	Multivariable*	Univariable	Multivariable*
Overall mortality						
BMI (kg/m^2)						
<16.0	1.67 (1.59–1.76)	1.71 (1.62–1.81)	1.82 (1.71–1.93)	1.83 (1.72–1.95)	1.81 (1.61–2.03)	1.98 (1.76–2.23)
16.0–18.4	1.37 (1.32–1.41)	1.37 (1.33–1.42)	1.40 (1.35–1.46)	1.41 (1.35–1.46)	1.60 (1.50–1.70)	1.61 (1.51–1.72)
18.5–24.9	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
25.0–29.9	0.77 (0.75–0.79)	0.79 (0.77–0.81)	0.77 (0.75–0.80)	0.78 (0.75–0.81)	0.73 (0.70–0.75)	0.76 (0.73–0.79)
30.0–34.9	0.67 (0.65–0.70)	0.71 (0.68–0.74)	0.71 (0.67–0.74)	0.74 (0.70–0.78)	0.60 (0.56–0.64)	0.65 (0.61–0.70)
35.0–39.9	0.60 (0.55–0.65)	0.61 (0.57–0.67)	0.66 (0.60–0.72)	0.66 (0.60–0.73)	0.52 (0.45–0.60)	0.56 (0.49–0.65)
≥40.0	0.63 (0.56–0.72)	0.68 (0.59–0.77)	0.66 (0.56–0.77)	0.72 (0.61–0.84)	0.64 (0.51–0.81)	0.71 (0.56–0.90)
30-day mortality						
BMI (kg/m^2)						
<16.0	2.15 (1.88–2.45)	2.11 (1.84–2.42)	2.35 (2.00–2.75)	2.15 (1.82–2.54)	2.55 (2.00–3.25)	2.73 (2.13–3.50)
16.0–18.4	1.49 (1.36–1.64)	1.46 (1.32–1.61)	1.50 (1.33–1.70)	1.45 (1.27–1.65)	1.79 (1.54–2.08)	1.70 (1.45–1.98)
18.5–24.9	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
25.0–29.9	0.65 (0.60–0.71)	0.67 (0.62–0.74)	0.67 (0.59–0.76)	0.69 (0.60–0.78)	0.60 (0.53–0.68)	0.64 (0.57–0.72)
30.0–34.9	0.52 (0.45–0.61)	0.55 (0.47–0.64)	0.57 (0.46–0.71)	0.58 (0.47–0.72)	0.46 (0.37–0.58)	0.52 (0.41–0.65)
35.0–39.9	0.42 (0.30–0.59)	0.36 (0.26–0.51)	0.57 (0.38–0.83)	0.49 (0.33–0.74)	0.27 (0.14–0.50)	0.22 (0.11–0.43)
≥40.0	0.52 (0.32–0.85)	0.44 (0.27–0.74)	0.73 (0.42–1.26)	0.60 (0.34–1.06)	0.26 (0.08–0.81)	0.25 (0.08–0.79)
1-y mortality						
BMI (kg/m^2)						
<16.0	1.88 (1.75–2.01)	1.90 (1.77–2.04)	2.09 (1.92–2.26)	2.03 (1.86–2.20)	2.07 (1.79–2.38)	2.21 (1.91–2.56)
16.0–18.4	1.45 (1.39–1.52)	1.44 (1.37–1.51)	1.48 (1.39–1.57)	1.44 (1.36–1.53)	1.75 (1.62–1.89)	1.72 (1.59–1.87)
18.5–24.9	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
25.0–29.9	0.72 (0.69–0.75)	0.73 (0.70–0.76)	0.73 (0.69–0.77)	0.74 (0.70–0.78)	0.66 (0.63–0.70)	0.69 (0.65–0.73)
30.0–34.9	0.61 (0.57–0.65)	0.64 (0.60–0.68)	0.69 (0.63–0.75)	0.70 (0.64–0.77)	0.51 (0.46–0.57)	0.57 (0.51–0.63)
35.0–39.9	0.49 (0.42–0.56)	0.46 (0.40–0.53)	0.55 (0.46–0.66)	0.50 (0.42–0.60)	0.42 (0.33–0.53)	0.43 (0.34–0.54)
≥40.0	0.61 (0.50–0.75)	0.60 (0.49–0.74)	0.66 (0.51–0.85)	0.63 (0.48–0.82)	0.60 (0.42–0.85)	0.63 (0.44–0.90)

Women: n = 37,181 (univariable), n = 35,814 (multivariable); Men: n = 21,709 (univariable), n = 20,750 (multivariable).
*Adjusted for age, marital status, Barthel Index, CCI, number of different medications purchased in the 120 days before index date, number of hospital admissions during 1 year before baseline, and period of index admission.

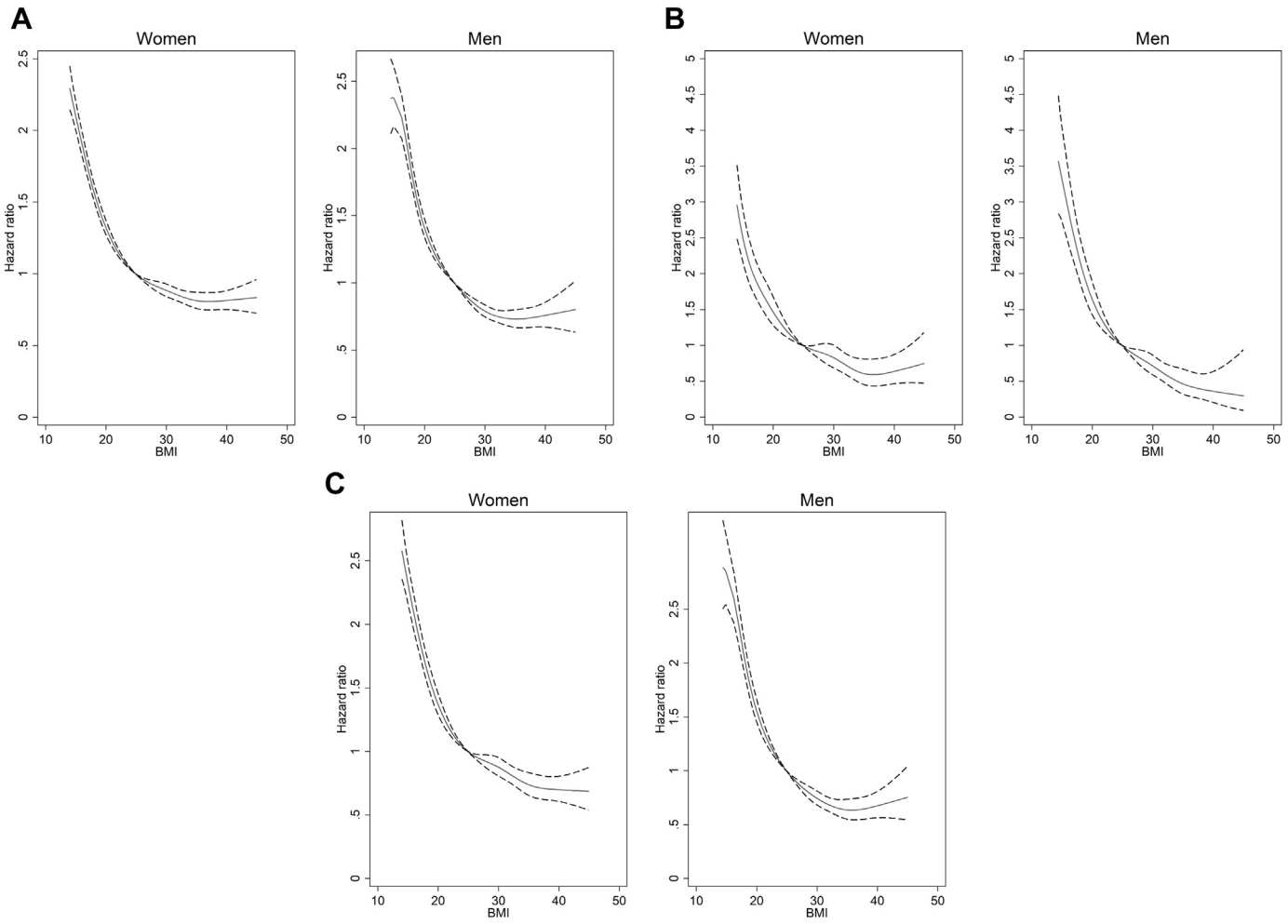

Fig. 2. BMI as continuous variable plotted against risk of mortality using BMI = 25 as reference. Broken lines indicate 95% CIs. Illustrated for each sex separately for overall mortality (A), 30-day mortality (B), and 1-year mortality (C).

to BMI = 24.9 and 2% (2%–3%) for BMI range 25.0–34.9 (Table 3). The corresponding figures for 30-day mortality were 9% (7%–10%) and 5% (2%–7%) and for 1-year mortality 8% (7%–8%) and 3% (2%–4%). Similar associations were seen when looking at data stratified for sex (Table 3). No change was seen for BMI ≥35 in any outcome (Table 3).

Robustness Analysis

In a robustness analysis, BMI was divided into the following 4 subcategories: <18.5, 18.5–24.9, 25.0–29.9, and ≥30. Adding all patients with missing data on BMI to either subcategory <18.5 or ≥30 did not alter the significant association between BMI and overall mortality when using BMI 18.5–24.9 as reference (data not shown).

Discussion

In this nationwide population-based longitudinal cohort study, we found BMI independently associated with mortality in hospitalized geriatric patients even when adjusting for relevant confounders including ADL. The mortality decreased steeply with increasing BMI while leveling off at obesity levels. This finding is in contrast to what would be expected in the general population where a U-shaped association is a common finding.

ADLs are known to be very strong predictors of survival in older patients,[21,22] but only a few studies have taken this into account when assessing association between BMI and mortality. One study assessing 1306 older hospitalized patients (mean age 85 years), reported decreased 1- and 2-year mortality with higher BMI when adjusting for ADL and comorbidity, but not on short-term mortality, possibly due to lack of power.[18] An older study reporting data on 18,316 hospitalized patients [mean age 71 years (women) and 70 years (men)] found a significant J-shaped curve association between BMI and mortality in the adjusted model including ADL and morbidity.[19] In the present study, combining data from reliable Danish registers on an individual level with objective measurements allowed adjustment of relevant confounders including ADL. The fully adjusted model only changed the association marginally on both short- and long-term follow-up (Tables 2 and 3) indicating that BMI is an independent prognostic indicator on top of ADL in frail oldest-old individuals.

Optimal BMI according to mortality risk has been increasingly and heavily debated in the past decades. In contrast to previous studies, we found no U- or J-shaped curve,[1,5–8] but a continuously inverse relationship before leveling off when a BMI of 35.0–39.9 was reached. This optimal BMI is higher than previously reported. A meta-analysis of 19,538 old nursing home residents reported same relationship as seen in the present study, but all residents with overweight were pooled in one category (BMI ≥30).[15] Another meta-analysis on 64,076 community-dwelling older adults ≥65 years reported a J-shaped curve with an optimal BMI of 27.5–30.0 (extracted from their graphical presentation).[14] Several prior studies report an optimal BMI of

Table 3
Overall, 30-Day, and 1-Year Mortality Risk (HRs and 95% CIs) for Every 1 kg/m^2 Increase in BMI in the Fully Adjusted Model* With BMI as a Continuous Variable

	Total	Women	Men
	HR (95% CI)	HR (95% CI)	HR (95% CI)
Overall mortality			
BMI (kg/m^2)			
<25.0	0.94 (0.93–0.94)	0.93 (0.92–0.93)	0.92 (0.91–0.92)
25.0–34.9	0.98 (0.97–0.98)	0.99 (0.98–1.00)	0.96 (0.95–0.98)
≥35.0	1.01 (0.99–1.03)	1.01 (0.99–1.03)	1.03 (1.00–1.06)
30-day mortality			
BMI (kg/m^2)			
<25.0	0.91 (0.90–0.93)	0.91 (0.89–0.93)	0.89 (0.87–0.91)
25.0–34.9	0.95 (0.93–0.98)	0.97 (0.93–1.01)	0.95 (0.91–0.99)
≥35.0	1.03 (0.97–1.09)	1.03 (0.97–1.10)	1.02 (0.88–1.17)
1-y mortality			
BMI (kg/m^2)			
<25.0	0.92 (0.92–0.93)	0.92 (0.91–0.93)	0.90 (0.89–0.91)
25.0–34.9	0.97 (0.96–0.98)	0.99 (0.97–1.01)	0.96 (0.94–0.97)
≥35.0	1.02 (0.99–1.04)	1.02 (0.98–1.05)	1.04 (0.99–1.08)

Women: n = 35,814; Men: n = 20,750.
*Adjusted for age, marital status, Barthel Index, CCI, number of different medications purchased in the 120 days before index date, number of hospital admissions during 1 year before baseline, and period of index admission.

20–25 in U-shaped curves,[5–8] whereas a meta-analysis on 2.88 million individuals found an optimal nadir between 25 and 30 in adults ≥65 years.[1] Some argue against the higher optimal BMI found in the meta-analysis since it used normal weight as reference in the analysis and the span from 18.5–24.9 may be too wide.[1] However, this cannot explain our findings because we plotted BMI against mortality HR using BMI 25 as reference following a prior study showing increased mortality already at BMI levels of 25.0 to 27.5.[8] Others have shown that using self-reported weight and height are less predictive compared to studies using measured BMI as in our study.[1] Combining this with no patients lost to follow-up in our nationwide study allows wide generalizability of our results in geriatric patients.

According to the World Health Organization, the goal for individual adults is to maintain BMI in the range of 18.5–24.9 to stay healthy irrespective of age because comorbidity and mortality increase with increasing degrees of overweight.[39] Our study pinpoints the paradox that while BMI increases the risk of several diseases having a BMI in the obese range seems to increase the chance of survival in older acutely ill patients. This does not advocate for weight increase in general. Instead, it highlights that in contrast to younger age groups, higher BMI is beneficial in older people, which adds to a more recent article showing that high BMI is associated with a lower risk of developing ADL disability in oldest-old individuals.[20] Other studies have not reported the same high optimal BMI as we find. Although studies addressing mortality after disease onset (heart failure,[10] acute myocardial infarction,[11] pneumonia,[12] and hip fracture[13]) have observed optimal BMI in the same range as we found, studies looking at mortality in the background population show different results. This may partly be because geriatric patients are admitted to hospital with many different acute illnesses combined with a common phenotype of multimorbidity, polypharmacy, and functional decline. Therefore, our data should be interpreted with caution and may not be generalizable outside a geriatric cohort.

The optimal BMI differs between groups of patients-at-risk. In geriatric patients, weight reduction is not the main focus.[23] Our study is yet another argument for having a strong focus on nutrition in older people to avoid weight loss, and for this BMI adds useful information to the clinician when discussing personalized care plans. Furthermore, our study shows that acutely ill older people do not fit into official health guidelines of an optimal BMI for the general population. Our data suggest that the presence of an energy reserve is beneficial during acute illness in the oldest patients. Because the population of older adults is increasing.[40] this demographic change highlights the need for official recommendations on optimal BMI in this vulnerable patient group.

Limitations

This study has important limitations. First, some of the increased risk seen in patients with low BMI may be partly facilitated by the effect of smoking as shown by others.[5,7] Unfortunately, we had no data on smoking to address this. Second, no data on body shape or distribution of fat and muscle exist in the database. We can therefore neither address speculations of sarcopenia nor sarco-obesity. Third, the acutely admitted older patients with overweight might be those with genetic or other advantages allowing them to achieve higher ages despite overweight. According to Statistics Denmark,[41] age at time of death in Denmark was 80.2 years in women and 77.1 years in men during the study period, compared with 87.2 years and 84.2 years in our study population. Our data on lower mortality seen in patients with high BMI might partly be explained by this survival bias. Fourth, we had 21% missing data on BMI. However, our analyses adding all patients with missing data on BMI to either subcategory <18.5 or ≥30.0 lowered the effect size of association between BMI and mortality, but not the significance association. Fifth, preexisting disease is a potential confounder. Disease status affects both exposure and outcome because disease often causes weight loss, but also increases mortality risk. Therefore, low BMI may be a result of underlying disease. We did adjust for known diseases in terms of CCI, but may have missed any underlying undiagnosed disease. If such an undiagnosed condition would have an impact on weight loss of major importance, it should be possible to detect differences in short-term mortality outcome. However, the association between mortality and BMI was the same when looking at short-term mortality (30 days), mid-term mortality (1 year), or long-term mortality (overall survival allowing up to 11 years of follow-up). Sixth, nonstandardization of weight measurement may have led to risk of misclassification of BMI subcategories in some patients. Finally, not all patients aged ≥65 years are hospitalized in a geriatric department. Therefore, our data should be interpreted with caution and may not be generalizable to all patients within this age group.

Conclusions and Implications

Association between BMI and mortality in hospitalized older patients did not show a U-shaped or a J-shaped curve when adjusting for relevant confounders including ADLs. Instead, mortality decreased continuously with increasing BMI before leveling off in the obese range. Our study highlights the need for a debate and reassessment of what should be the ideal BMI in this vulnerable patient group.

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Supplementary Table 1
Description of Data Sources

Data Sources	Description
The Danish National Database of Geriatrics[25]	A clinical quality database established in 2005. Designed to include all patients admitted to 1 of the 24 geriatric departments in Denmark. Patients are admitted directly from the general practitioner, through the emergency department, or by transfer from other hospital departments. Contains information on a number of variables collected at the time of hospital admission (ie, height, weight, and assessment of Barthel Index).
The Danish National Patient Register[26]	Established in 1977. Contains individual-level information on all hospital admissions, discharge diagnoses, and dates of admission and discharge.
The Danish Civil Registration System[27]	Each Danish citizen and residents on immigration have since 1968 been assigned a unique 10-digit civil personal registry number. This enables accurate linkage of information at the individual level between the many population-based national registers. Contains data on deaths, migration, and marital status.
The Danish National Database of Reimbursed Prescriptions[28]	Contains information on individually redeemed reimbursed prescriptions from all pharmacies in Denmark since 2004.

Supplementary Table 2
Baseline Characteristics of Study Population With Complete Data Used for the Multivariable Analysis

Measures	Total Cohort (n = 56,564)	Women 63% (n = 35,814)	Men 37% (n = 20,750)
Age (y), mean (SD)	82.4 (7.4)	83.3 (7.3)	80.8 (7.4)
Barthel Index, median (IQR)*	56 (31–78)	57 (33–78)	54 (29–78)
CCI, median (IQR)†	2 (1–3)	2 (1–3)	2 (1–4)
Number of drugs, median (IQR)‡	6 (4–9)	6 (4–9)	6 (4–9)
Prior hospitalization (1 y), median (IQR)§	0 (0–1)	0 (0–1)	1 (0–2)
BMI (kg/m^2), mean (SD)	24.0 (5.1)	23.6 (5.3)	24.5 (4.6)
<16.0, n (%)	1669 (3.0)	1364 (3.8)	305 (1.5)
16.0–18.4, n (%)	5061 (8.9)	3825 (10.7)	1236 (6.0)
18.5–24.9, n (%)	28,872 (51.0)	18,257 (51.0)	10,615 (51.2)
25.0–29.9, n (%)	14,538 (25.7)	8386 (23.4)	6152 (29.6)
30.0–34.9, n (%)	4800 (8.5)	2865 (8.0)	1935 (9.3)
35.0–39.9, n (%)	1191 (2.1)	802 (2.2)	389 (1.9)
≥40.0, n (%)	433 (0.8)	315 (0.9)	118 (0.6)

*ADLs were assessed using Barthel-Index-100.
†The CCI was calculated based on hospital discharge diagnoses during 10 years before baseline.
‡Redeemed prescriptions within 120 days before index date.
§Based on hospital admissions during 1 year before baseline. Normal distributed data are presented with mean (SD).