Research Article

Varying Associations Between Body Mass Index and Physical and Cognitive Function in Three Samples of Older Adults Living in Different Settings

Eva Kiesswetter,1 Eva Schrader,1 Rebecca Diekmann,1,2 Cornel Christian Sieber,1 and Dorothee Volkert1

1Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany. 2Department for Geriatric Medicine, Carl von Ossietzky Universität Oldenburg, Germany.

Address correspondence to Eva Kiesswetter, PhD, Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Kobergerstr. 60, 90408 Nürnberg, Germany. Email: eva.kiesswetter@fau.de

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Abstract

Background. The study investigates variations in the associations between body mass index (BMI) and (a) physical and (b) cognitive function across three samples of older adults living in different settings, and moreover determines if the association between BMI and physical function is confounded by cognitive abilities.

Methods. One hundred ninety-five patients of a geriatric day hospital, 322 persons receiving home care (HC), and 183 nursing home (NH) residents were examined regarding BMI, cognitive (Mini-Mental State Examination), and physical function (Barthel Index for activities of daily living). Differences in Mini-Mental State Examination and activities of daily living scores between BMI groups (<22, 22–<25, 25–<30, 30–<35, ≥35 kg/m²) were tested by analysis of covariance considering relevant confounders.

Results. Activities of daily living and Mini-Mental State Examination impairments increased from the geriatric day hospital over the HC to the NH sample, whereas prevalence rates of obesity (35%, 33%, 25%) decreased. In geriatric day hospital patients cognitive and physical function did not differ between BMI groups. In the HC and NH samples, cognitive abilities were highest in obese and severely obese subjects. Unadjusted mean activities of daily living scores differed between BMI groups in HC receivers (51.6±32.2, 61.8±26.1, 67.5±28.3, 72.0±23.4, 66.2±24.2, p = .002) and NH residents (35.6±28.6, 48.1±25.7, 39.9±28.7, 50.8±24.0, 57.1±28.2, p = .029). In both samples significance was lost after adjustment indicating cognitive function as dominant confounder.

Conclusions. In older adults the associations between BMI and physical and cognitive function were dependent on the health and care status corresponding to the setting. In the HC and the NH samples, cognitive status, as measured by the Mini-Mental State Examination, emerged as an important confounder within the association between BMI and physical function.

Key Words: Body mass index—Physical function—Cognition
The prevalence of overweight and obesity is growing in the older population of industrialized countries (1). In Germany, the number of overweight and obese older adults (≥65 y) has increased from 1999 to 2009 by 7% up to 70% in men and by 11% up to 58% in women (2).

This is a matter of concern as an elevated body mass index (BMI) is associated with numerous negative health consequences (3,4) and mortality (5). However, in the oldest old, the negative effects are less clear and even potential protective effects were reported (6,7). Obese older adults might be a selective group, healthier compared to their leaner counterparts, and little affected by unintended weight loss which is common in older age and known as risk factor for functional decline (8) and mortality (9).

There is also some controversy about BMI thresholds indicating an increased risk of limitations in physical function in older adults. A meta-analysis of eight cross-sectional studies (most subjects ≥65 y) derived a graded increase in the risk of disability in those overweight or with obesity and severe obesity, compared to normal weight (10). In contrast, a review of 30 prospective studies (baseline age ~ ≥50 y) concluded that underweight as well as severe obesity poses an increased risk of disability, while overweight might be protective and the effect of obesity remains controversial (11). Recent studies with nursing home (NH) residents observed better functional status with increasing BMI even in BMI groups ≥30 kg/m² (7,12). Analogous to the results concerning physical function inconsistencies were observed concerning the association between obesity and cognitive function (13,14). Generally these variations in results are explained by age and health status, however, also the factor “setting” seems to be relevant. A review on the nutritional status of older adults showed changes in prevalence rates of malnutrition across different settings and deduced that the setting represents different stages of morbidity and functional decline (15). In the present context, systematic comparisons of different settings are lacking.

Functional status is usually assessed by self-reports on the ability to perform activities of daily living (ADL), focusing on essential physical skills needed to retain autonomy in everyday life. However, independency in ADL demands besides physical also cognitive abilities like motor control, attention, and decision making. Cognitive status as potential confounder was hardly considered when investigating the association between BMI and ADL (10,11) but might contribute to explain differences in study results. The aim of the present analysis was to investigate variations in the associations between BMI and (a) physical and (b) cognitive function systematically across three samples of older adults living in different settings, and moreover to determine if the association between BMI and physical function is confounded by cognitive abilities.

Methods
Study design
This analysis is based on the data of three cross-sectional studies with older adults living in different settings. Inclusion criteria of all three studies were age ≥65 years and no medical diagnosis of terminal illness. Persons unable to communicate had to be excluded if no proxies were available.

The first sample comprises patients of a geriatric day hospital (GDH, n = 198), who were recruited during the first week after admission (Nuremberg, Germany, 2012). Specific exclusion criterion was discharge within the first days after admission.

The second sample consists of older adults receiving home care (HC, n = 353), who were recruited with the help of local medical services of health insurance companies, home care services, care counseling offices, and day care institutions in three German cities (Bonn, Nuremberg, and Paderborn, Germany, 2010). Specific inclusion criterion was the allocation of a care level according to the German nursing insurance system (16). The third sample comprises residents of two municipal NH (n = 200, Nuremberg, 2007).

Only participants with complete BMI, ADL, and Mini-Mental State Examination (MMSE) data were considered for this analysis. The final sample included 700 participants: 195 GDH patients, 322 HC receivers, and 183 NH residents.

The study protocols were approved by the ethics committees of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, and the Rheinische Friedrich-Wilhelms-Universität Bonn, Germany. Written informed consent was obtained from every participant or participant’s legal proxy. All three studies were conducted by trained research associates using the same standardized methods.

Subjects’ characteristics
Age, gender, care level, chronic diseases, and medication were assessed during a personal interview with the participants or, in case of severe cognitive impairment or inability to communicate, with their primary caregivers. Data were completed by the participant’s medical records. According to the German Social Security Code (16), care level I equates 90–<180 min of care per day, care level II 180–<300 min/day, and care level III ≥300 min/day. Emotional status was assessed by the 15-item Geriatric Depression Scale (0–15 points) (17).

Body Mass Index
Weight was measured with a standard scale in GDH patients and HC receivers. In NH residents, weight was assessed with a chair scale. Height was measured by a conventional or an ultrasound stadiometer. In participants unable to stand upright (n = 269) knee height was measured by a sliding caliper and height was calculated by the formulas of Chumlea and coworkers (18). If measurements were not feasible, data were taken from medical records (n = 60). BMI was calculated as weight (kg)/height (m²) and categorized according to the definition of the World Health Organisation (19): underweight: <22; normal weight: 22–<25; overweight: 25–<30; obesity: 30–<35; and severe obesity: ≥35 kg/m². As only few participants had a BMI <18.5 and <20 kg/m², respectively, BMI <22 kg/m² was chosen as cut-off indicating underweight.

Functional status
Physical function was assessed by the Barthel Index for ADL (0–100 points) (20). The score of 100 points represents complete independence in performing ten basic activities. Cognitive function was assessed by the MMSE (0–30 points) (21).

Data analysis
Subjects’ characteristics are given as mean ± standard deviation. The three study samples were compared by Kruskal–Wallis test and Mann–Whitney U-test (posthoc test) for continuous variables and by Chi²-test for categorical or nominal data.

Analysis of variance and covariance were applied to compare unadjusted and adjusted means of ADL and MMSE scores between the five BMI categories in the total sample and in each subsample. ANCOVA with MMSE score as dependent variable included gender.
(grouping factor), age, and number of chronic diseases (covariate). ANCOVA with ADL score as dependent variable considered additionally MMSE as covariate. In a second model, the setting (GDH, HC, NH) was introduced as a further grouping factor. The explained variance (%) is based on $\eta^2$ (eta-square).

**Results**

**Subjects’ characteristics**

The subjects’ characteristics of the total sample and each subsample are presented in Table 1. The mean age of the participants was 81.6 ± 7.9 years, 69% were female. Patients of a GDH were the youngest and NH residents the oldest sample. NH residents showed the highest need of care compared to the other samples, represented by the highest portion of care level II and III. Accordingly, ADL and MMSE scores were lowest in NH residents (Figure 1a and b). Both HC receivers and NH residents suffered from more chronic diseases than GDH patients. While GDH patients suffered more often from hypertension, HC receivers and NH residents showed a higher prevalence of heart failure and stroke.

**Prevalence of overweight, obesity, and severe obesity**

Thirty-seven percent of the GDH patients, 34% of the HC receivers, and 31% of the NH residents were overweight, 19%, 21%, and 18% obese, and 16%, 12%, and 7% severely obese (Figure 2). In NH residents, prevalence of overweight, obesity, and severe obesity was significantly lower than in GDH patients and HC receivers.

**BMI and cognitive function**

Table 2 shows unadjusted and adjusted mean MMSE scores stratified by BMI categories for the total sample and the three subsamples.

In the total sample, as well as in HC receivers and NH residents, MMSE scores were highest in the BMI groups ≥30 kg/m² (all $p < .001$). The associations remained significant after adjustment. For GDH patients, no association between BMI and MMSE score was found.

**BMI and physical function**

In Table 3, unadjusted and adjusted mean ADL scores are shown stratified by BMI categories. In the total sample, unadjusted mean ADL scores differed significantly between BMI categories with lowest values in the BMI group <22 kg/m² and highest values in the BMI groups ≥30 kg/m² ($p < .001$). Regarding the subsamples, unadjusted ADL scores did not differ between BMI categories in GDH patients, showed an inverted U-shaped trend in HC receivers ($p = .002$), and were highest in BMI group ≥35 kg/m² in NH residents ($p = .029$). After adjustment, the association between BMI and physical function remained significant ($p = .041$) in the total sample, but the variance explained by BMI was marginal (1%). In the subsamples of HC receivers and NH residents, the associations were lost. Cognitive status was the main confounder explaining 34% of the variance within the total sample, 16% in HC receivers, and 37% in NH residents. In the model with the setting as additional grouping factor cognitive status remained the main confounder explaining 34% of the variance within the total sample, 16% in HC receivers, and 37% in NH residents.

**Discussion**

This study found differences in the associations between BMI and both cognitive and physical function in older adults depending on the health and care status. In the samples of older adults in need of care the associations between BMI and physical function were

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**Table 1. Subjects’ Characteristics of the Total Sample, Patients of a Geriatric Day Hospital (GDH), People Receiving Home Care (HC), and Nursing Home (NH) Residents**

<table>
<thead>
<tr>
<th></th>
<th>Total sample, $n = 700$</th>
<th>GDH patients, $n = 195$</th>
<th>HC receivers, $n = 322$</th>
<th>NH residents, $n = 183$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>81.6 ± 7.9</td>
<td>78.8 ± 7.0</td>
<td>81.1 ± 7.6</td>
<td>85.5 ± 7.7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female gender</td>
<td>69.0</td>
<td>69.2</td>
<td>63.7</td>
<td>74.3</td>
<td>.018</td>
</tr>
<tr>
<td>Care level none</td>
<td>26.0</td>
<td>89.2</td>
<td>0.0</td>
<td>4.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>I</td>
<td>41.4</td>
<td>8.7</td>
<td>62.1</td>
<td>39.9</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>24.9</td>
<td>2.1</td>
<td>29.5</td>
<td>41.1</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>7.7</td>
<td>0.0</td>
<td>8.4</td>
<td>14.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ADL (points)</td>
<td>66.7 ± 30.0</td>
<td>91.0 ± 12.5</td>
<td>65.1 ± 27.6</td>
<td>43.7 ± 27.7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MMSE (points)</td>
<td>22.1 ± 8.8</td>
<td>26.9 ± 3.0</td>
<td>22.6 ± 7.9</td>
<td>15.8 ± 10.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>GDS§ (points)</td>
<td>5.1 ± 3.3</td>
<td>4.4 ± 3.3</td>
<td>5.4 ± 3.0</td>
<td>5.3 ± 3.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No. chronic diseases</td>
<td>3.8 ± 1.9</td>
<td>3.3 ± 1.4</td>
<td>4.1 ± 2.0</td>
<td>3.8 ± 1.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>77.9</td>
<td>84.6</td>
<td>74.8</td>
<td>76.0</td>
<td>.027</td>
</tr>
<tr>
<td>Heart failure</td>
<td>50.9</td>
<td>14.4</td>
<td>39.6</td>
<td>74.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other heart disease</td>
<td>39.9</td>
<td>37.9</td>
<td>43.8</td>
<td>33.2</td>
<td>.123</td>
</tr>
<tr>
<td>Stroke</td>
<td>24.9</td>
<td>13.8</td>
<td>28.9</td>
<td>26.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>21.7</td>
<td>16.9</td>
<td>26.7</td>
<td>18.0</td>
<td>.012</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>32.9</td>
<td>37.9</td>
<td>27.6</td>
<td>36.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Arthropathy</td>
<td>45.1</td>
<td>43.1</td>
<td>55.0</td>
<td>30.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>20.6</td>
<td>13.8</td>
<td>26.4</td>
<td>17.5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt;3 prescribed drugs/day</td>
<td>81.3</td>
<td>86.2</td>
<td>83.9</td>
<td>71.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.0 ± 6.0</td>
<td>28.9 ± 5.7</td>
<td>28.2 ± 6.2</td>
<td>26.3 ± 5.3</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Continuous data: mean ± standard deviation, Kruskal–Wallis test followed by Mann–Whitney U-test as posthoc test; categorical or nominal data: percent, Chi²-test; *GDH vs. HC, $p < .05$; †GDH vs. NH, $p < .05$; ‡HC vs. NH, $p < .05$.

Reduction sample size: total $n = 619$, GDH $n = 194$, HC $n = 286$, NH $n = 139$.

ADL, activities of daily living; BMI, body mass index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental State Examination.
mainly confounded by the cognitive status. The results may contribute to the discussion on the so called “obesity paradox” indicating, against expectation, that obesity seems to decrease the risk of chronic disease, functional decline, and mortality in older adults (22).

The health status of the participants, based on care level and physical and cognitive functional aspects, decreased from patients of a GDH, across older adults receiving HC to NH residents. GDH patients represent older adults who still live independently in the community but are vulnerable to become dependent on care. Both HC receivers and NH residents belong to the population dependent on care. As governments generally support older people to remain in their own homes as long as possible (23), NH residents are even more dependent on care than HC receivers. The study presents three samples of older adults with clearly different need of care and accordingly a total sample with a wide range of physical and cognitive abilities.

In line with the decreasing health status, the prevalence of obesity and severe obesity decreased from 35% in GDH patients to 33% in HC receivers and 25% in NH residents. The observed obesity rates of HC receivers and NH residents are comparable to other studies reporting prevalence rates between 29% and 35% for HC receivers (24–26) and between 16% and 22% for NH residents (12,27,28). In contrast to our results in Turkish GDH patients, a lower obesity rate (23%) was described (29).

Global epidemiological studies show that in industrialized countries the prevalence of obesity follows a strong decreasing trend above the age of 70 years (30). The present comparison revealed that the prevalence of obesity strongly depends, besides age influences, on the health and care status of the particular sample.

With increasing need of care across the samples, distinguishably higher physical and cognitive capacities were observed in obese subjects compared to subjects with low BMI. However, in relatively healthy GDH patients differences in ADL and MMSE scores between BMI groups were not significant, probably due to ceiling effects and lacking variation and sensitivity of measures. Most studies reporting an association between obesity and physical impairment were performed in independently living older adults with a distinctly lower mean age (~70–75 y) than in our samples (31–33). A meta-analysis showing an increased risk of disability in obese and severely obese older adults restricted the generalizability of the results due to the limited age range in the included studies (10). In a homebound sample (~79 y), Sharkey and coworkers found that severe obesity, but not obesity or overweight, contributed to diminished lower extremity function (26). In line with our results, a study on Turkish NH
and age, number of chronic diseases (no. CD) as covariates; error probability;

\[ \eta^2 \] 

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adults may therefore migrate to lower BMI groups. Second, acceler-

prevalence rates of low BMI were found compared to those who

the biological age, for example, expressed by the health status and

mostly found no association or positive associations between obesity

function or cognitive decline, whereas studies of later-life phases

BMI (12).

\[ \text{Table 3. Unadjusted and Adjusted Mean ADL Scores Stratified by BMI Categories for the Total Sample, Patients of a Geriatric Day Hospital (GDH), People Receiving Home Care (HC), and Nursing Home (NH) Residents} \]

\[
\begin{array}{cccccccc}
\text{BMI (kg/m²)} & <22 & 22–<25 & 25–<30 & 30–<35 & \geq35 & \text{Gender} & \text{Age} & \text{No. CD} & \text{MMSE} \\
\hline
\text{Total sample} & n = 100 & n = 140 & n = 238 & n = 139 & n = 83 & p (\eta^2) & p (\eta^2) & p (\eta^2) & p (\eta^2) \\
\text{Unadjusted} & 49.7 ± 33.5 & 67.6 ± 28.7 & 67.8 ± 30.9 & 72.0 ± 25.2 & 73.5 ± 24.7 & <.001 (.06) & .053 (.01) & .309 (.00) & .001 (.02) & .001 (.34) \\
\text{Adjusted} & 58.8 ± 25.9 & 65.8 ± 25.7 & 68.5 ± 25.0 & 65.0 ± 26.1 & 66.8 ± 27.8 & .041 (.01) & .053 (.01) & .309 (.00) & .001 (.02) & .001 (.34) \\
\text{GDH patients} & n = 13 & n = 41 & n = 72 & n = 37 & n = 32 & & & & & \\
\text{Unadjusted} & 90.0 ± 13.7 & 94.6 ± 7.8 & 90.1 ± 14.4 & 91.1 ± 10.4 & 88.6 ± 14.4 & .283 (.03) & & & & \\
\text{Adjusted} & 92.0 ± 13.0 & 94.5 ± 14.0 & 87.9 ± 12.9 & 90.0 ± 14.0 & 91.1 ± 15.0 & .165 (.04) & .862 (.00) & .025 (.03) & .667 (.00) & .423 (.00) \\
\text{HC receivers} & n = 44 & n = 60 & n = 110 & n = 69 & n = 39 & & & & & \\
\text{Unadjusted} & 51.6 ± 32.2 & 61.8 ± 26.1 & 67.5 ± 28.3 & 72.0 ± 23.4 & 66.2 ± 24.2 & .002 (.05) & & & & \\
\text{Adjusted} & 57.3 ± 26.2 & 61.0 ± 26.2 & 68.2 ± 25.3 & 67.6 ± 26.4 & 62.1 ± 26.6 & .092 (.03) & .156 (.01) & <.001 (.05) & .884 (.00) & <.001 (.16) \\
\text{NH residents} & n = 43 & n = 39 & n = 56 & n = 33 & n = 12 & & & & & \\
\text{Unadjusted} & 35.6 ± 28.6 & 48.1 ± 25.7 & 39.9 ± 28.7 & 50.8 ± 24.0 & 57.1 ± 28.2 & .029 (.06) & & & & \\
\text{Adjusted} & 39.2 ± 25.6 & 45.9 ± 23.5 & 45.4 ± 24.5 & 45.2 ± 25.2 & 45.7 ± 41.1 & .641 (.02) & .773 (.00) & .189 (.01) & .001 (.06) & <.001 (.37) \\
\end{array}
\]

\[
\text{Mean ± standard deviation; unadjusted: ANOVA with BMI as grouping factor; adjusted: ANCOVA with BMI (body mass index) and gender as grouping factors and age and number of chronic diseases (no. CD) as covariates; } p, \text{ error probability; } \eta^2 \text{ (eta-square), explained variance; MMSE, Mini-Mental State Examination.}
\]

Residents observed increasing functional capacities with increasing

BMI (12).

Regarding cognitive status, studies with middle-aged and young-

old adults reported high BMI to be associated with low cognitive

function or cognitive decline, whereas studies of later-life phases

mostly found no association or positive associations between obesity

and cognitive performance (13,14,34). According to our results, partly the chronological age, but mainly

the biological age, for example, expressed by the health status and

the level of care, is crucial for the association between BMI and func-

tion. It can be assumed that, first, with progressing morbidity, factors
like cognitive decline and chronic diseases come to the fore, which

often go in line with unintended weight loss (35,36). Consequently,
in older people with severe cognitive impairment or dementia, higher

prevalence rates of low BMI were found compared to those who

were not affected (37). With progressing morbidity, obese older

adults may therefore migrate to lower BMI groups. Second, acceler-

ated weight loss, and physical and cognitive decline were reported to

emerge in the years preceding death (38,39). Therefore, the higher

BMI groups may not include persons in the final stage of life. Third,

obese older adults showing higher functional capacities than non-
obese may belong to the group of “metabolic healthy obese” indi-

civuals having increased body fat storage but a normal metabolic

profile (40) and thus survived until old age despite high BMI. Fourth,
the presence of a survivor effect may support the paradoxical results,
as an increased BMI is associated with mortality in younger ages (5).

Obese older adults in need of care may therefore represent a highly

selective survivor group relatively resistant toward physical and cog-

nitive functional decline.

Cognitive status assessed by MMSE turned out to be the most

important confounding factor of the association between BMI and

physical function. In GDH patients the cognitive factor was unim-

important confounding factor of the association between BMI and

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literature cognitive status is described as an important predictor of disability in older adults (41,42).

Age was identified as an additional confounding factor in HC receivers and chronic diseases in NH residents. In both cases, the factors explained about 5% of variance, distinctly less than the cognitive factor. One review described both age and chronic diseases as predictors of functional decline (41). Gender showed no impact on the association between BMI and physical function in our study. In contrast, a recent study, which also investigated a combined sample of older adults (community-dwelling, institutionalized) at high age, suggested that women are more prone to the effects of obesity on physical functioning than men due to differences in body composition (43). Our results underline that in later life and in progressed care dependency, factors other than obesity, in particular cognition, are of greater importance for functional impairment.

There are some limitations of this analysis. We did not have any information on individual body composition and fat distribution precluding statements on fluid status, sarcopenia, and abdominal obesity. Wirth and coworkers showed that weight loss associated with dementia is predominantly a loss of fat mass, whereas the association between weight loss and ADL impairment results from a loss of muscle mass (37). Other studies suggest that waist circumference is more appropriate in predicting disability of older adults than the BMI (43,44). Due to the cross-sectional design no information on premorbid BMI, functional and cognitive status was available. Furthermore, ADL and MMSE might be tools too rough to detect small differences in functional status. The exploratory approach of this study with local recruitment and nonrandom sampling is not suited to generalize the results for the older population in Germany.

An advantage of our study is the high mean age of the samples, as there are only few studies focusing on the association of BMI and function in very old age. Moreover, in spite of the relatively small sample sizes, the study was able to show systematic differences between health care settings, allowing to map potential differences in the association between BMI and function.

Conclusion

Our study revealed that the relation between BMI and physical function depends on the health and care status of the sample. In the two samples with older adults in need of care the association was mainly moderated by cognitive abilities assessed by MMSE. The factor set-up depends on the health and care status of the sample. In the two studies for novel approaches to prevention and treatment. Our study revealed that the relation between BMI and function in very old age. Moreover, in spite of the relatively small sample sizes, the study was able to show systematic differences between health care settings, allowing to map potential differences in the association between BMI and function.

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