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ORIGINAL ARTICLE

# Long-term obesity and physical functioning in older Americans

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**BACKGROUND:** Americans are becoming obese earlier in their lives, increasing the average exposure to obesity. Nonetheless, the impact of long-term obesity on later life functioning is not well known.
**METHODS:** We analyzed data from 7258 adults aged 60–79 years from the US 1999–2010 National Health and Nutrition Examination Survey. Respondents were defined as limited if they reported 'some difficulty' 'much difficulty' or 'unable to do' any of the eight functional tasks. Respondents were defined as severely limited if they reported 'much difficulty' or 'unable to do' any task. Generalized regression models (logistic and Poisson) predicted the relative odds of any limitation, severe limitation, the total number of limitations and each individual limitation as a function of body mass index (BMI) at age 25 years and current BMI. Models were adjusted for age, sex, race/ethnicity and level of education.
**RESULTS:** Overall, being overweight or obese at age 25 years was associated with higher odds of being functionally limited, but these associations were greatly diminished or eliminated after adjustment for current BMI. For example, those obese at age 25 years had 2.38 times the odds (95% confidence interval (CI): 1.77, 3.20) of reporting any functional limitations compared with those normal weight at 25 years, but only 1.28 times the odds (95% CI: 0.93, 1.76) after adjustment for current BMI. For severe limitations, the corresponding results were 2.72 (95% CI: 2.13–3.46) and 1.32 (95% CI:1.00–1.75) before and after adjustment for current BMI. Some associations between obesity at age 25 years and individual tasks remained significant after adjustment for current BMI.
**CONCLUSIONS:** We conclude that long-term overweight/obesity are significantly associated with later life functional limitations, though this is largely explained by their strong association with higher levels of later-life BMI. Prevention of additional weight gain for those who are overweight or obese early in life could help mitigate their risk of future loss of functioning.

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## INTRODUCTION

The health implications of long-term obesity are of increasing medical and public health importance, given the high prevalence of overweight and obesity among the aging US population coupled with the increased average exposure to excess weight over the lifetime of recent cohorts.[1] Recent estimates found a prevalence of overweight and obesity of 76.5% for men and 73.5% for women aged ⩾60 in the United States.[2] The leading edge of the baby-boom generation reached age 65 years in 2011, and the current growth in the number and proportion of older adults in the United States is unprecedented in our demographic history. Disability among older adults can lead to loss of independence and the need for expensive hospital and long-term nursing care,[3,4] both of which are associated with high personal and societal costs. In addition, Medicare costs for the obese have been growing more rapidly than for the non-obese population.[5] On top of direct medical costs, obesity-related disability contributes substantial indirect costs to individuals and society in the form of disability pensions, work absenteeism and early retirement.[6] Despite projections that increased exposure to obesity in recent cohorts will decrease life expectancy and increase disability rates in the United States,[1,7] the impact of long-term obesity on functioning and disability has not been well established. If long-term exposure to obesity affects physical functioning similarly to the cumulative risks of pack-years of smoking,[8] the implications for population aging and disability-related health-care costs in the United States and worldwide could be dramatic.[5]

Cross-sectional and prospective studies have linked obesity with functional decline and disability in older adults,[9–13] but thus far few studies have looked explicitly at the impact of long-term obesity on functional limitations. The current study analyzed the association of obesity at age 25 years with self-reported functional limitations later in adulthood in a nationally representative US sample of adults aged 60–79 years. We hypothesized that longer exposure to obesity could exacerbate the pro-inflammatory and insulin resistance impacts on muscle strength over time, as well as directly impact wear and tear on connective tissues and joints, leading to an increased risk of limitations.

## MATERIALS AND METHODS

### Data

Data for the analysis come from the National Health and Nutrition Examination Survey (NHANES), 1999–2010, a representative survey of the non-institutionalized US population. These continuous surveys conducted by the National Center for Health Statistics collect extensive demographic and health data, including biological markers, through a household interview and a separate medical examination. NHANES data are de-identified and publicly available and thus exempt from human subjects' approval. Additional details of the NHANES survey design have been published elsewhere.[14]

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## Analytical sample

Our sample was defined as adults aged 60–79 years who participated in the medical examination ($N = 7487$). This age group was chosen, because functional limitation questions in NHANES were asked only of adults ⩾60 years, and age in the 2007–2010 NHANES survey years was top-coded at ⩾80 years. Looking under age 80 years also helps to minimize potential confounding from illness-related weight loss at older ages. From this group, two individuals were missing all data on physical functioning, and an additional 229 (3.06%) had body mass index (BMI) $< 20\ \mathrm{kg\ m^{-2}}$ at the time of the NHANES examination. We excluded this group to reduce confounding by very low BMI among those in declining health,[15] but results including those with BMI $< 20\ \mathrm{kg\ m^{-2}}$ were substantively similar. This higher threshold for underweight has been shown to better capture health risk among older adults,[15] but our results were identical excluding those only with a BMI less than the conventional underweight cutoff of $18.5\ \mathrm{kg\ m^{-2}}$. Our final sample size was $N = 7258$.

## Measures

*Predictors: BMI at age 25 years and current BMI*. The NHANES interview component included a weight history questionnaire asking, 'How much did you weigh at age 25?' Recalled weight has been found to have a high correlation with measured weight across long recall periods.[16,17] Current height and weight were measured by a trained technician during the medical examination, and current and BMI at age 25 years were calculated as BMI = (weight(kg)/height (m)$^2$), both using current height. BMI at age 25 years was then categorized according to the Centers for Disease Control and Prevention guidelines ($< 18.5\ \mathrm{kg\ m^{-2}}$ = underweight, 18.5–24.9 $\mathrm{kg\ m^{-2}}$ = normal, 25.0–29.9 $\mathrm{kg\ m^{-2}}$ = overweight, ⩾30 $\mathrm{kg\ m^{-2}}$ = obese).

*Outcomes*. We analyzed the presence of overall functional limitations as well as functioning in each individual task. For each question, respondents were asked 'by yourself and without using any special equipment, how much difficulty do you have' with the following eight tasks: walking one-fourth mile, walking up 10 steps without resting, stooping/crouching/kneeling, lifting or carrying 10 lb, walking between rooms on the same floor, standing from an armchair, getting in and out of bed, dressing oneself, and standing for long periods. The response choices included no difficulty, some difficulty, much difficulty or unable to do. From 2003 to 2004 onward, a new response category of 'don't do' was added to the survey. These responses comprised $< 1\%$ of responses for each item and were recoded as unable to do. Respondents were defined as limited if they reported 'some difficulty' 'much difficulty' or 'unable to do' any of the eight functional tasks. Respondents were defined as severely limited if they reported 'much difficulty' or 'unable to do' any task. We defined the total number of limitations as the sum of functional limitations (1–8) among those reporting any limitation. Reporting a severe limitation for each individual task was also examined separately.

*Covariates*. All models controlled for continuous age in years, sex, race/ethnicity (non-Hispanic white (reference), non-Hispanic black, Hispanic, and 'other'), education (less than high school, high school completion (reference), some college or completed college or higher) and smoking status (current, former or never). We also included indicators for the NHANES interview cycle, from the first in 1999–2000 to the last available in 2009–2010.

## Statistical analysis

Because of the strong persistence of obesity over time (see Table 1), we tested the association of long-term obesity with physical functioning both without and with adjustment for current level of BMI. We used logistic regression models to predict the relative odds of being limited overall and in each task as a function of BMI category at 25 (normal weight as reference), current BMI (continuous) and control variables. Poisson regression was used to model the outcome of total number of limitations (1–8) among those reporting any limitation. Model 1 included only BMI at 25 adjusting for socio-demographic covariates, while Model 2 additionally controlled for current BMI to account for the higher current BMI of those who were heavier at age 25 years. In additional analyses, we tested the interaction of current BMI and education level on limitations to assess whether the impact of obesity on disability varied by level of education, as well as interactions of current BMI and BMI at age 25 years to assess potential effect modification. All analyses were conducted using STATA 13.0 (Stata Corp, College Station, TX, USA) and adjusted for the NHANES weights and complex survey design.

**Table 1.** Descriptive statistics: respondents aged 60–79 years, NHANES 1999–2010

| *Variable* | *BMI category at age 25 years* | | | |
|---|---|---|---|---|
| | *Normal* | *Overweight* | *Obese* | *Total* |
| *Severely limited* | | | | |
| Walking for a quarter mile | 15.5% | 21.0% | 32.8% | 17.6% |
| Walking up 10 steps | 12.8% | 18.0% | 30.5% | 14.9% |
| Stooping, crouching, kneeling | 16.3% | 19.3% | 33.6% | 17.8% |
| Standing for long periods | 16.2% | 22.5% | 30.9% | 18.4% |
| Walking between rooms on same floor | 0.9% | 1.6% | 4.7% | 1.3% |
| Standing up from armless chair | 3.5% | 6.1% | 12.6% | 4.6% |
| Getting in and out of bed | 1.6% | 2.4% | 3.8% | 1.9% |
| Dressing yourself | 1.3% | 2.3% | 3.3% | 1.6% |
| Any severe limitations | 26.6% | 31.4% | 46.2% | 28.8% |
| Any reported limitations | 55.1% | 59.4% | 71.6% | 56.9% |
| Mean no. of limitations among limited | 3.14 | 3.48 | 4.03 | 3.28 |
| Mean BMI at age 25 years | 21.6 | 26.8 | 33.6 | 23.4 |
| Mean current BMI | 28.2 | 31.7 | 35.1 | 29.3 |
| Age | 68.0 | 68.0 | 68.0 | 68.0 |
| Female | 61.8% | 28.6% | 37.8% | 53.1% |
| *Race/ethnicity* | | | | |
| Non-Hispanic White | 80.9% | 81.4% | 77.7% | 80.8% |
| Non-Hispanic Black | 8.0% | 9.8% | 12.8% | 8.6% |
| Hispanic | 6.8% | 6.8% | 8.1% | 6.9% |
| Other | 4.3% | 2.0% | 1.5% | 3.7% |
| *Education level* | | | | |
| < High School completion | 23.3% | 24.3% | 30.3% | 23.9% |
| High School completion | 28.7% | 29.4% | 25.7% | 28.7% |
| Some college | 24.3% | 23.5% | 25.7% | 24.2% |
| College degree or higher | 23.7% | 22.8% | 18.1% | 23.2% |
| *Smoking status* | | | | |
| Never | 45.2% | 38.3% | 41.4% | 43.5% |
| Former | 38.0% | 41.6% | 40.1% | 39.0% |
| Current | 14.5% | 17.1% | 16.1% | 15.2% |
| Do not know | 2.3% | 3.0% | 2.5% | 2.4% |
| *N* | 5041 | 1751 | 466 | 7258 |

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey.

## RESULTS

Table 1 shows descriptive statistics for the analytical sample broken down by BMI category at age 25 years. The mean age of the sample was 68 years, and the most common severe functional limitations reported were standing for long periods (18.4%), walking a quarter mile (17.6%) and stooping, crouching, kneeling (17.8%), while the least commonly reported difficulty was with walking between rooms on the same floor (1.3%). A total of 56.9% of the sample reported having at least some difficulty with a task, with 28.8% of those reporting at least one severe limitation. The mean BMI at age 25 years was $23.3\ \mathrm{kg\ m^{-2}}$, and the mean current BMI was $29.0\ \mathrm{kg\ m^{-2}}$. The persistence of BMI over time is reflected in the lower mean current BMI of those of normal weight at age 25 years ($27.8\ \mathrm{kg\ m^{-2}}$) compared with the mean current BMI of those who were overweight ($31.7\ \mathrm{kg\ m^{-2}}$) and obese ($35.1\ \mathrm{kg\ m^{-2}}$) at age 25 years.

Table 2 shows results for models of any limitations, severe limitations and the total number of limitations if limited. Model 1 shows the association of being overweight or obese at age 25 years compared with normal weight, adjusting for sociodemographic characteristics but without adjustment for current level of BMI. Model 2 adds adjustment for current BMI. Overall, being

**Table 2.** BMI at age 25 years, current BMI and functional limitations in adults aged 60–79 years, NHANES 1999–2010

| *Variable* | *Any limitation* | | *Any severe limitation* | | *Number of limitations (1–8)* | |
|---|---|---|---|---|---|---|
| | *Model 1* | *Model 2* | *Model 1* | *Model 2* | *Model 1* | *Model 2* |
| | *OR* | *OR* | *OR* | *OR* | *OR* | *OR* |
| Normal BMI at age 25 years | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Overweight at age 25 years | 1.45 (1.24, 1.70) | 1.01 (0.85, 1.20) | 1.54 (1.34, 1.79) | 1.01 (0.85, 1.19) | 1.14 (1.08, 1.20) | 1.02 (0.97, 1.08) |
| Obese at age 25 years | 2.38 (1.77, 3.20) | 1.28 (0.93, 1.76) | 2.72 (2.13, 3.46) | 1.32 (1.00, 1.75) | 1.29 (1.18 1.41) | 1.07 (0.99, 1.16) |
| Current BMI (continuous) | | 1.11 (1.09, 1.12) | | 1.12 (1.10, 1.13) | | 1.03 (1.02, 1.03) |
| Female | 2.09 (1.83, 2.38) | 1.97 (1.72, 2.24) | 1.91 (1.67, 2.18) | 1.73 (1.49, 1.99) | 1.99 (1.69, 2.34) | 1.72 (1.46, 2.02) |

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio. $N = 7258$. Odds ratios from logistic regression models (number of limitations estimated using Poisson regression). All models also control for age, smoking, race/ethnicity, level of education and NHANES survey wave. 95% confidence intervals in brackets.

overweight or obese at age 25 years was strongly associated with higher odds of reporting any limitation or a severe limitation after age 60 years, as well as the total number of reported limitations among those limited. Adjusting for current BMI level in Model 2, it is evident that higher levels of current BMI account for a significant portion of the association between long-term obesity and functional limitations. After adjusting for current BMI, the magnitude of the associations of being overweight or obese at 25 years and the overall limitation measures were greatly reduced and no longer statistically significant. For example, being overweight at age 25 years was associated with 1.45 times (95% confidence interval (CI) 1.44, 1.70) the odds of reporting any limitation in Model 1, which was reduced to 1.01 (95% CI 0.85, 1.20) after adjustment for current BMI. Similarly, obesity at age 25 years was associated with 2.38 (95% CI 1.77, 3.20) times the odds of reporting any limitation, which was reduced to 1.28 (95% CI 0.93, 1.76) after adjustment for current BMI. The likelihood of severe limitations followed the same pattern, as did the total number of limitations. Among those reporting any limitation, obesity at age 25 years was associated with 29% higher odds of an additional limitation in Model 1 (odds ratio (OR) 1.29, 95% CI 1.18,1.41), compared with 7% higher odds after adjusting for current BMI (OR 1.07, 95% CI 0.99–1.16). Figures 1 and 2 illustrate these patterns for the association of BMI at age 25 years with having any limitations and the total number of limitations.

Tables 3 and 4 show results for the likelihood of having ‘much difficulty’ or ‘unable to do’ each individual task compared with ‘none’ or ‘some’ difficulty. As seen in Table 1, the individual limitations in Table 3 are more prevalent, whereas the limitations in Table 4 are relatively rare. The pattern of associations for BMI at age 25 years is similar to the overall measures when broken down by task; overweight and obesity at age 25 years were strongly associated with higher odds of every functional limitation after age 60 years, with these associations substantially reduced or eliminated upon adjustment for current BMI. Though substantially reduced in magnitude, elevated odds of limitation remained significant for four out of eight tasks for those who were obese at age 25 years. The strongest remaining associations between long-term obesity and limitations were found for walking up 10 steps (adjusted OR 1.60, 95% CI 1.17, 2.18) and standing up from an armless chair (adjusted OR 2.11, 95% CI 1.28, 3.40).

As expected, higher levels of current BMI were associated with greater odds of reporting any or severe limitation, each individual limitation, as well as an increase in the total number of limitations reported among those limited. A one-unit increase in current BMI was associated with 11% higher odds of having any limitation, 12% higher odds of a severe limitation and 3% higher odds of an additional limitation (Table 2). Female respondents reported a higher prevalence of almost all functional limitations, so as a sensitivity analysis we also ran models stratified by gender. The patterns of association for long-term overweight/obesity and limitations were very similar for men and women; therefore we report only the combined results here and the sex-stratified results are available upon request. We also observed strong associations of lower levels of education with higher odds of all limitations, both with and without adjustment for current BMI (not shown). In additional analysis, we tested interactions to determine whether education modified the impact of long-term or current BMI on the

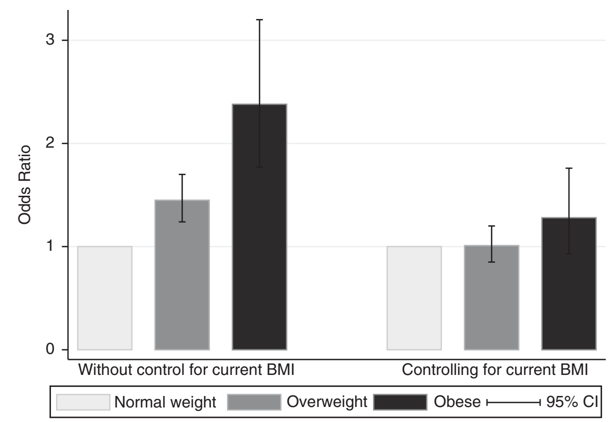


**Figure 1.** Relative odds of any functional limitation by BMI category at age 25 years, NHANES (1999–2010), adults aged 60–79 years.

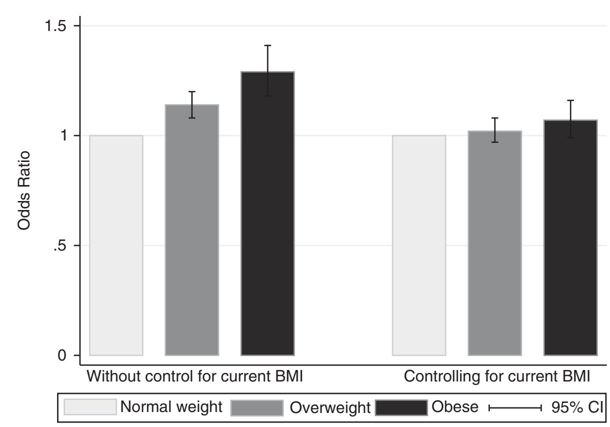


**Figure 2.** Relative odds of an additional functional limitation by BMI category at age 25 years, NHANES (1999–2010), adults aged 60–79 years.

Table 3. BMI at age 25 years, current BMI and individual functional limitations (higher prevalence) in adults aged 60–79 years, NHANES 1999–2010

| Variable | Mobility | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Walking 1/4 mile | | Walking up 10 steps | | Stooping, crouching or kneeling | | Standing for long periods | |
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| | OR | OR | OR | OR | OR | OR | OR | OR |
| Normal weight at age 25 years | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Overweight at age 25 years | 1.72 (1.46, 2.02) | 1.10 (0.92, 1.31) | 1.78 (1.47, 2.15) | 1.16 (0.93, 1.44) | 1.53 (1.30, 1.82) | 0.96 (0.80, 1.16) | 1.82 (1.51, 2.19) | 1.18 (0.96, 1.45) |
| Obese at age 25 years | 2.94 (2.31, 3.74) | 1.37 (1.04, 1.82) | 3.31 (2.53, 4.34) | 1.60 (1.17, 2.18) | 3.01 (2.31, 3.92) | 1.40 (1.03, 1.90) | 2.58 (1.95, 3.41) | 1.21 (0.88, 1.66) |
| Current BMI | | 1.12 (1.10, 1.14) | | 1.11 (1.09, 1.13) | | 1.12 (1.11, 1.14) | | 1.12 (1.10, 1.13) |
| Female | 1.93 (1.60, 2.34) | 1.62 (1.33, 1.98) | 1.86 (1.50, 2.31) | 1.55 (1.24, 1.94) | 2.21 (1.88, 2.59) | 1.86 (1.60, 2.17) | 1.90 (1.61, 2.24) | 1.60 (1.35, 1.90) |

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio. Logistic regression models. Limited defined as much difficulty or unable to do vs no/some difficulty. All models also control for age, smoking, race/ethnicity, education level and NHANES survey wave. 95% confidence intervals in brackets.

Table 4. BMI at age 25 years, current BMI, and individual functional lLimitations (low prevalence) in adults aged 60–79 years, NHANES 1999–2010

| Variable | Mobility | | | | Transfers | | Self-care | |
|---|---|---|---|---|---|---|---|---|
| | Walking between rooms on the same floor | | Standing up from armless chair difficulty | | Getting in and out of bed | | Dressing yourself | |
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Normal weight at age 25 years | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Overweight at age 25 years | 2.04 (1.08, 3.84) | 1.31 (0.68, 2.54) | 2.27 (1.66, 3.12) | 1.48 (1.05, 2.10) | 1.75 (1.04, 2.93) | 1.27 (0.78, 2.08) | 1.94 (1.12, 3.35) | 1.31 (0.77, 2.24) |
| Obese at age 25 years | 5.09 (2.29, 11.31) | 2.33 (1.00, 5.39) | 4.44 (2.98, 6.61) | 2.11 (1.31, 3.40) | 2.33 (1.28, 4.24) | 1.35 (0.71, 2.55) | 2.53 (1.28, 5.02) | 1.23 (0.64, 2.34) |
| Current BMI | | 1.11 (1.06, 1.16) | | 1.11 (1.08, 1.13) | | 1.08 (1.04, 1.11) | | 1.1 (1.05, 1.15) |
| Female | 2.36 (1.43, 3.91) | 1.95 (1.16, 3.29) | 2.75 (2.12, 3.58) | 2.27 (1.71, 3.00) | 2.42 (1.68, 3.51) | 2.1 (1.44, 3.06) | 1.55 (0.92, 2.60) | 1.25 (0.74, 2.13) |

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio. Logistic regression models. Limited defined as much difficulty or unable to do vs no/some difficulty. All models also control for smoking and NHANES survey wave. 95% confidence intervals in brackets.

risk of functional limitations, but these interactions were not significant. Models assessing interactions between current BMI and BMI at age 25 years likewise found no evidence of effect modification.

## DISCUSSION

The risk of disability among obese older individuals increased in the United States over the period 1988–2004, with speculation that this increase may be due to the longer average exposure to obesity among more recent cohorts.[7,18] There are several potential pathways through which obesity may contribute to disability in aging. Obesity can hinder mobility directly due to the weight-bearing burden on lower extremities during activities such as climbing stairs or rising from a seated position, and longer-term obesity may increase wear and tear on the musculoskeletal system and connective tissues.[19] Obesity has been associated with a variety of musculoskeletal conditions, including osteoarthritis, low back pain, gait disturbance, soft tissue conditions such as plantar fasciitis and gout.[19] Obesity also increases the risk of cardiovascular disease and diabetes, both of which are important risk factors for disablement.[20,21] Insulin resistance in particular has been shown to be an independent predictor of poor muscle strength, and diabetes predicts loss of muscle strength and quality.[22,23] Adipose tissue is also associated with increased expression of inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α,[24,25] and long-term obesity may inhibit regulatory responses resulting in a systemic pro-inflammatory state. Chronically elevated levels of inflammatory markers are strong predictors of incident disability, partly via acceleration of muscle catabolism.[26–28] As obese persons are typically more sedentary than normal-weight individuals, it is also possible that long-term effects of a sedentary lifestyle on muscle strength and aerobic capacity could contribute to functional limitations later in life.[29]

Despite the emerging importance of understanding the health consequences of long-term obesity, no previous papers to our knowledge have examined the direct association of long-term obesity and physical functioning among US adults. Two previous US studies examined associations of BMI earlier in life and later life disability but did not adjust for BMI level at follow-up, something our results have shown to be an important mediating factor.[30,31] Outside of the United States, two studies based on a cross-sectional sample of adults aged ⩾55 years in Finland have examined weight history and different measures of functioning. The first found that earlier onset of obesity was associated with lower hand grip strength even after adjusting for current body weight, and markers of inflammation had only a small mediating role in this association.[32] The second study found that longer duration of obesity predicted an increased risk of walking limitation among older adults, and consistent with our results, this association was greatly diminished but still significant after adjustment for current BMI.[33]

The present study expands previous examinations of cross-sectional and prospective associations between obesity and mobility limitations[9–13] and also contributes to the recent literature aiming to understand the impact of duration of obesity on morbidity and mortality.[8,34] Using nationally representative data, we found that overweight and obesity at age 25 years were strongly associated with the likelihood of being functionally limited, severely limited, the number of reporting limitations and each individual limitation. Importantly, much of these associations appeared to be explained by high levels of later life BMI, which are strongly correlated with early life BMI,[35] Current BMI had a strong association with limitations, and net of this covariate, the associations of BMI at age 25 years were substantially diminished, though some residual elevated risks for obesity at age 25 years on individual tasks remained.

There are several limitations to our analysis. Weight at age 25 years was self-reported and thus may have been subject to recall bias, particularly if those with higher risks systematically misreported their weight at 25 years.[36] Specifically, if respondents with higher BMI were more likely to under-report their weight and be misclassified as non-obese, this could bias downward the association of early life obesity and later life disability. On the other hand, such misclassification of those close to the cutoff could imply that those remaining in the obese category at age 25 years were even heavier on average than if measured weight had been used, potentially biasing upward the association of early life obesity with later outcomes. Future analyses utilizing data with measured height and weight both early and later in life where available could help minimize these potential biases. Another limitation is that the duration of weight history captured in this cross-sectional survey varied by current age of the respondent. We estimated sensitivity analyses stratifying the analysis by ages 60–69 and 70–79 years to look for evidence of different associations of BMI trajectories on functioning by age and found similar substantive results (available upon request). As is common in studies of aging populations, those who did not make it into our sample due to death or institutionalization may have been more likely to be obese and/or functionally limited, potentially limiting the strength of the associations examined. Despite limiting our age range to those not yet above age 80 years and those with BMI $>20$ kg m$^{-2}$, there is also still the possibility that some age or disease-related weight-loss has begun to occur in this sample, which may bias downward the association of current BMI and disability. Given the uniformly strong association between higher BMI and functional limitations observed and the strong reductions in the strength of associations between BMI at age 25 years and limitations controlling for current BMI, we do not think this concern is substantively significant in this analysis.

Our findings are consistent with the idea that long-term obesity may contribute to greater physiological wear and tear over time and thus negatively impact functioning beyond current obesity but that high levels of current BMI appear to be a more salient risk factor. Although this finding could be considered a positive news in light of the dramatic increase in the probability of being obese by age 25 years in recent US cohorts,[1] it should be remembered that overweight and obesity at age 25 years remains risky due to their associations with even more severe obesity later in life. Although long-term obesity did not emerge as a statistically significant independent risk factor in overall measures of being limited, severely limited or the total number of limitations, the point estimates in all of those cases were in the direction of elevated risk. The smaller but still significant associations between long-term obesity and several measures of individual functional tasks also suggest that we may see an increase in disability associated with aging cohorts who have a longer average lifetime exposure to obesity but that dramatic changes in disability associated with these aging cohorts due to duration of obesity is less likely. Overall, these results thus highlight the importance of maintaining a healthy weight and preventing additional weight gain throughout the life course to reduce the risks of disability and loss of physical functioning.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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