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Cognitive Function in Normal-Weight, Overweight, and Obese Older Adults: An Analysis of the Advanced Cognitive Training for Independent and Vital Elderly Cohort

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Abstract

OBJECTIVES

To assess how elevated body mass index (BMI) affects cognitive function in elderly people.

DESIGN

Cross-sectional study.

SETTING

Data for this cross-sectional study were taken from a multicenter randomized controlled trial, the Advanced Cognitive Training for Independent and Vital Elderly trial.

PARTICIPANTS

The analytic sample included 2,684 normal-weight, overweight, or obese subjects aged 65 to 94.

MEASUREMENTS

Evaluation of cognitive abilities was performed in several domains: global cognition, memory, reasoning, and speed of processing. Cross-sectional association between body weight status and cognitive functions was analyzed using multiple linear regression.
RESULTS
Overweight subjects had better performance on a reasoning task (β = 0.23, standard error (SE) = 0.11, P = .04) and the Useful Field of View (UFOV) measure (β = −39.46, SE = 12.95, P = .002), a test of visuospatial speed of processing, after controlling for age, sex, race, years of education, intervention group, study site, and cardiovascular risk factors. Subjects with class I (BMI 30.0–34.9 kg/m^2) and class II (BMI>35.0 kg/m^2) obesity had better UFOV measure scores (β = −38.98, SE = 14.77, P = .008; β = −35.75, SE = 17.65, and P = .04, respectively) in the multivariate model than normal-weight subjects. The relationships between BMI and individual cognitive domains were nonlinear.
CONCLUSION
Overweight participants had better cognitive performance in terms of reasoning and visuospatial speed of processing than normal-weight participants. Obesity was associated with better performance in visuospatial speed of processing than normal weight. The relationship between BMI and cognitive function should be studied prospectively.
Keywords: cognitive function, body mass index

Overweight and obesity are growing in prevalence among older adults.[1] The prevalence of overweight and obesity is more than 50% in U.S. adults, with the highest prevalence observed in adults aged 50 and older.[1] In association with various cardiovascular risk factors such as hypertension, diabetes mellitus, and heart disease, overweight and obesity are related to a host of adverse health outcomes in older adults and place a severe burden on the U.S. healthcare system.[2]

The relationship between body weight and selected geriatric syndromes has recently attracted significant research interest. Investigators have shown a positive association between body mass index (BMI) and depressive symptoms in elderly people.[3] Studies have demonstrated that, in the elderly population, overweight and obesity were related to self-reported functional limitations,[4] performance-based functional disability,[5] urinary incontinence,[6] and chronic osteoarthritic pain, but controversies still exist regarding the relationship between BMI and cognitive ability in older people. A positive relationship between BMI and cognition has been demonstrated,[7] although some other reports have showed an inverse association between obesity and cognitive performance.[8]

Longitudinally, the relationship between BMI and dementia has not been consistent. One study followed 392 nondemented Swedish adults for 18 years and found that overweight was a risk factor for dementia in women,[9] but the Personnes Agees QUID Study followed 3,646 individuals for 8 years and demonstrated that subjects with a BMI less than 21 had a greater risk of developing dementia than subjects whose BMI was between 23 and 26. The relationship was no longer significant after excluding individuals who developed dementia early during the follow-up.[10]

Therefore, the overarching goal of this study was to elucidate the relationship between body weight and cognitive function in late life by examining data from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial.

METHODS

Study Design and Participants

The ACTIVE trial, a randomized, controlled study, was designed to evaluate the effectiveness and durability of three cognitive training interventions (memory training, reasoning training, and speed-of-processing training) on mental abilities and daily functioning in older, independent-living adults. The trial is described in greater detail elsewhere.[11] Briefly, persons aged 65 to 94 were enrolled across six field sites in the United States using various sampling frames and recruitment strategies (state driver's license and identification card registries, medical clinic rosters, senior center and community organization rosters, senior housing sites, local churches, and roster of assistance and service programs for low-income elderly persons) from March 1998 to October 1999. Persons were excluded if they were cognitively impaired (score <22 on the Mini-Mental State Examination (MMSE)); had a known diagnosis of Alzheimer's disease; were functionally impaired (requiring assistance in dressing, personal hygiene, or bathing three or more times in the previous 7 days); were medically unstable, predisposing them to imminent functional decline or death; participated currently or recently in other cognitive training; were unavailable during the study; or were impaired in vision, hearing, or communicative ability, making participation in the study impossible. All participants were randomized into three cognitive intervention groups and a no-contact control group. The cohort consists of 2,802 independent-living, otherwise normal older adults.

The current study analyzed the baseline association between body weight and cognitive function in the ACTIVE participants.

Classification of Body Weight

Body weight status was categorized based on BMI, calculated from baseline objective height and weight measurement, as weight in kilograms divided by height in square meters (kg/m^2). BMI was categorized according to the National Institutes of Health obesity standards: BMI less than 18.5, underweight; BMI 18.5–24.9, normal weight, BMI 25.0–29.9, overweight; BMI 30.0–34.9, class I obesity; and BMI equal to and greater than 35.0, class II obesity.[12] Of the 2,802 subjects in the ACTIVE cohort, there were 30 subjects who were underweight, 609 normal weight, 1,067 overweight, 642 class I obesity, 366 class II obesity, and 88 missing BMI. Because there were small numbers of underweight subjects (n = 30) and subjects with missing BMI (n = 88), they were excluded from analysis.

Cognitive Function Assessment

Evaluation of cognitive abilities was performed in several domains: global cognition, memory, reasoning, and speed of processing. Global cognitive function was measured using the MMSE. For memory, a composite score was created from three test scores that were standardized to a common mean of zero and summed: the Hopkins Verbal Learning Test Related Word Lists,[13] the Rey Auditory-Verbal Learning Test Unrelated Word Lists,[14] and the Rivermead Behavioral Memory Test Paragraph Recall task.[15] These measures include an immediate and delayed learning condition, critical for the detection of anterograde memory disorders. These properties are also associated with loss of newly presented information.[16] A higher memory composite score indicates better memory function.

For the reasoning domain, three outcomes were assessed: Word Series, Letter Series, and Letter Sets. A reasoning composite was similarly created from scores of the three tests. A higher reasoning composite score indicates better performance. Word Series and Letter Series tasks consisted of a list of months or letters forming increasingly complex repetitive patterns, requiring the subject to scan the list, generate and reject hypotheses regarding the nature of the pattern, and then select the next stimulus in a list of possible answers. Letter Set task required subjects to find a rule common to four of five letter sets, marking the set inconsistent with the rule. These reasoning tests require strategy formation, behavioral spontaneity, and retrieval ability from long-term memory.[16] It is critical that these tasks do not substantially require the learning of new information (as is the case in the tests of memory) but rather such cognitive abilities as concept formation, response generation, and cognitive flexibility.

For speed of processing, the ACTIVE battery included the Useful Field of View (UFOV)[17] measure and the Digit Symbol Substitution (DSS) test. The computer-administered UFOV was a visual divided-attention measure requiring speeded visual processing and focused on measures of visual search skills. The DSS test focused on the ability to identify and locate visual information quickly in a divided-attention format. Lower scores on the UFOV and higher scores on the DSS test indicate better performance. These tasks measure visual and motor speed of processing.

Other Covariates

The ACTIVE protocol included assessments of smoking status and history of diabetes mellitus, stroke, myocardial infarction, and hypercholesterolemia by self-report. A trained research assistant assessed blood pressure after 5 minutes of quiet sitting twice, with 2 minutes between each measure. The average systolic blood pressure and diastolic blood pressure were obtained. Blood pressure was categorized into four groups according to the Seventh Report of the Joint National Committee (normotensive, prehypertension, stage 1 hypertension, and stage 2 hypertension[18]) and was adjusted as a categorical variable. Other covariates included age, sex, race or ethnicity, study site, and years of education.

Analysis

The analytic sample consisted of 2,684 normal-weight, overweight, or obese ACTIVE participants. Distributions of memory composites, reasoning composites, UFOV scores, and DSS scores were normal. Therefore, normality assumption was tenable for linear regression analyses with these cognitive performances as dependent variables. Distribution of MMSE was only mildly left-skewed. The association between BMI and MMSE was unchanged whether transformed or untransformed MMSE scores were used. Therefore, untransformed MMSE scores were used in the analyses to have interpretable beta coefficients.

Cross-sectional association between body weight status and cognitive functioning was examined by using multiple linear regression while controlling for the influence of other covariates. Indicator variables were created for overweight subjects and those with class I and class II obesity, whereas normal-weight participants were categorized as the reference group. In Model 1, age, sex, race, years of education, and study site were controlled for. In Model 2, all covariates in Model 1 plus smoking status; blood pressure; and history of diabetes mellitus, myocardial infarction, hypercholesterolemia, and stroke were controlled for. The standardized effect sizes in different models were also calculated based on the standard deviation of the cognitive performance of the reference group (normal-weight subjects). In considering the issue of multiple comparisons, *P* = .05 was allocated across 15 comparisons (3 hypotheses in 5 models) using Bonferroni correction, resulting in a corrected alpha level of 0.0033.

Interaction effects between sex, blood pressure, diabetes mellitus, and categories of body weight were separately assessed in the multivariate model. The linear trend between body weight and cognitive functions was also tested by performing a trend test and plotting the adjusted mean cognitive scores against body weight status.

- Other Sections▼
  - Abstract
  - METHODS
  - RESULTS
  - DISCUSSION
  - References

RESULTS

The baseline characteristics of the ACTIVE participants based on body weight status are provided in Table 1. The majority of the ACTIVE participants were female and white.

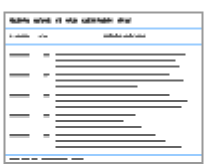


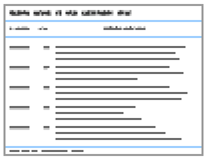
Table 1

Baseline Characteristics of Participants (N = 2,684)*

After controlling for age, sex, race, years of education, intervention group, and study site, overweight subjects showed better performance on memory tests (β = 0.24, *P* = .03, effect size = 0.09) than normal-weight subjects (Table 2), although cardiovascular risk factors confounded the positive relationship between overweight and memory, and the association vanished after cardiovascular risk factors were added to the multivariate model. Memory performance of obese subjects was not statistically different from that of normal-weight subjects.

Table 2

Cross-Sectional Analysis of Body Weight on Cognitive Functions



Overweight subjects demonstrated better performance on the reasoning tests than normal-weight participants after multivariate adjustment for age, sex, race, years of education, intervention group, study site, and cardiovascular risk factors (β = 0.23, *P* = .04, effect size = 0.08). This association remained marginally significant for comparison between class I obesity and normal-weight subjects (β = 0.24, *P* = .06, effect size = 0.09). In addition, overweight and obese subjects exhibited better performance on the visuospatial speed of processing (UFOV) than normal-weight subjects (β = −39.46, *P* = .002, effect size = 0.13; β = −38.98, *P* = .008, effect size = 0.13, respectively). There were no significant differences in global cognition between overweight/obese and normal-weight subjects. Although the effect sizes were small, in keeping with Cohen's taxonomy, overweight subjects demonstrated a significantly better score on the UFOV measure than normal-weight subjects when the corrected alpha level (0.0033) was taken into consideration.

The interactions between sex, diabetes mellitus, blood pressure, and body weight were then examined, but no evidence was found for statistically significant interactions between these risk factors. To examine effects of restricted range of measurement using conventional scoring of the MMSE, ability scores derived from MMSE item responses were examined using an item response theory scoring method (one-parameter normal ogive): substantively equivalent results were obtained regarding the relationship between BMI and cognitive function.

There was no linear relationship between body weight categories and global cognition, memory, reasoning task, and the DSS test score, as reflected by nonsignificant *P*-values in trend test (Table 2) and inverted-U relationship between cognitive scores and weight status (Figure 1). Although the *P*-value of trend test between weight status and UFOV measure was 0.04, the graph of UFOV and BMI categories demonstrated a J-shaped, not linear, relationship.

Figure 1

Mean cognitive scores with 95% confidence intervals were obtained according to body weight status after controlling for age, sex, race, years of education, intervention group, study site, and cardiovascular risk factors. A nonlinear relationship between (more ...)

- Other Sections▼
  - Abstract
  - METHODS
  - RESULTS
  - DISCUSSION
  - References

DISCUSSION

The ACTIVE study offers several advantages for the investigation of the relationship between BMI and cognitive function, including a large and diverse sample of healthy older adults, objective measures of height and weight to determine BMI, tests of several cognitive abilities, and measures of several covariates that might confound the relationship between BMI and cognitive function. The results indicate a nonlinear relationship between cognitive performance and BMI in normal-weight, overweight, and obese older adults. Overweight subjects demonstrated better cognitive performance on tests of reasoning and visuospatial speed of processing than normal-weight participants. Obese subjects, unlike their overweight counterparts, did not demonstrate compelling cognitive superiority in memory and reasoning tasks than normal-weight subjects, yet similar to overweight subjects, obese subjects demonstrated better performance in visuospatial speed of processing than normal-weight subjects. There was no interactive effect of sex, blood pressure, diabetes mellitus, or body weight on cognitive performance. The findings support a recent longitudinal study that found that subjects with a BMI greater than 23 kg/m^2 had lower risk of developing cognitive impairment after 5 years of follow-up.[19] In addition, the researchers described a U-shaped relationship between BMI and risk of impairment in instrumental activities of daily living, which are cognition-dependent abilities.

The following mechanisms can explain these findings. First, in older people, BMI is a strong predictor of skeletal muscle mass,[20] which seems positively related to cognitive abilities.[21] Second, greater BMI is associated with better cardiac output and stroke volume and may thus improve cerebral blood flow and cognition.[22] Finally, BMI has an inverted-U relationship with serum levels of insulin-like growth factor (IGF-1), with highest IGF-1 levels observed in those BMI between 25 kg/m^2 and 27 kg/m^2.[23] Higher IGF-1 levels exert beneficial cognitive effects in terms of better frontal-executive functions (set shifting and psychomotor speed)[24] and less cognitive decline[25] in elderly people. Such evidence supports the findings of this study regarding the nonlinear inverted-U relationship between body weight status and cognition.

These results have potential public health implications. U-shape or J-shape phenomena have been widely discussed in elderly people, including the relationships between blood pressure and cognition,[26] blood pressure and mortality,[27] and cholesterol levels and quality of life.[28] This nonlinearity could also account for inconsistent findings in different studies regarding the relationship between body weight and cognitive ability.[7–10] Based on the results of the current study, there is some evidence to suggest that even normal BMI may not represent a desirable state for cognition in older adults.

In addition to the cross-sectional nature of the analysis, which precludes establishing a causal relationship between BMI and cognitive abilities, this study has the following limitations that deserve comment. First, the exclusion of subjects with BMIs less than 18.5 kg/m^2 precludes any conclusions regarding the relationship between low BMI and cognitive function. Second, the measures of health conditions as adjusted variables in the analysis were limited to self-report and were not validated through medical record review. Third, the ACTIVE study used a volunteer, not a population-based, sample recruited for cognition-enhancing interventions. The cognition screening scores of the study population represented neither the general population nor a truly cognitively intact sample. Last, although the findings suggest some potential, although small, benefit of elevated BMI in specific cognitive function, it could certainly be due to random effect, and the clinical importance of these findings should be explored prospectively.

In conclusion, being overweight was associated with better cognitive performance in terms of reasoning tasks and visuospatial speed of processing than being normal weight. Being obese was associated with better performance in visuospatial speed of processing than being normal weight. This investigation provides a good rationale to examine the longitudinal effect of BMI on cognition.

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Footnotes

Author Contributions: study concept and design (Kuo, Jones, Milberg, and Lipsitz), acquisition of subjects (Tennstedt, Talbot, and Morris), analysis and interpretation of data (Kuo and Jones), preparation of manuscript (Kuo and Jones), critical revision (Jones, Milberg, Tennstedt, Talbot, Morris, and Lipsitz).

- Other Sections▼
    - Abstract
    - METHODS
    - RESULTS
    - DISCUSSION
    - References

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