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Association between relative fat mass and cognitive function among US older men: NHANES 2011–2014

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Abstract

Background Relative fat mass (RFM) is a new metric developed to assess the entire body fat proportion in adults. The objective of this study was to examine the correlation between cognitive performance and RFM in older American males.

Methods A total of 1,321 individuals were selected from the National Health and Nutrition Examination Survey (NHANES) that was carried out between the years 2011 and 2014. Specifically, the Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test (CERAD-WL), the Animal Fluency Test (AFT), and the Digit Symbol Substitution Test (DSST) were used in order to achieve the objective of assessing cognitive function. The standardized scores of the three previously mentioned tests were averaged to create the Z-scores, a composite, generalized metric. RFM was ascertained by measuring waist circumference (WC) and height. The relationships that exist between RFM and cognitive performance were investigated using a variety of statistical methods, including multivariate linear regression, threshold effect analyses, smooth curve fitting, and subgroup analyses.

Results The study included 1,321 male volunteers aged 60 years or older, and comprehensive data was provided for each individual. Fully adjusted models indicated a negative correlation between RFM and CERAD-WL scores[-0.17, (-0.32,-0.01)], DSST scores[-0.83, (-1.16,-0.50)] and Z-scores[-0.03, (-0.05, -0.01)]. It was observed that the negative correlation that exists between RFM and Z-scores became more pronounced when RFM exceeded 35.78. Furthermore, subgroup analyses showed that the association between RFM and cognitive function was significantly impacted by education level, poverty-income ratio (PIR), smoking status, and drinking status.

Conclusions A higher RFM was linked to lower cognitive function in older men, suggesting that management of RFM may prove advantageous in mitigating cognitive decline among older male populations.

Keywords Relative Fat Mass(RFM), Cognitive function, NHANES, Obesity, Older men

Introduction

As the global population ages, cognitive dysfunction in older adults is becoming a major threat to health globally. Projections suggest that by 2050, over 130 million people globally will suffer from dementia [1]. Cognitive impairment (CI) pertains to the reduction or weakening of memory, thinking, learning, problem-solving, language, attention, and executive functions. Mild cognitive impairment (MCI) and various types of dementia are both included in the category of CI. Cognitive

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dysfunction impacts not just the well-being of older adults, but also creates significant challenges for their families and society [2]. Research indicates that healthy older women exhibit superior verbal fluency, verbal memory, and processing speed in comparison to their male counterparts [3]. These differences may stem from the positive effects of estrogen on the maintenance of neurocognitive integrity [4, 5]. Identifying the risk factors affecting cognitive function, especially those that can be modified, and developing effective interventions can help alleviate the enormous public health pressures that lie ahead globally. At the global scale, obesity represents a serious obstacle to the improvement of public health [6, 7]. Relative fat mass (RFM) is a unique tool for evaluating obesity since it measures the body's fat reserves and offers a more exact evaluation of the entire body fat proportion in adults than the conventional obesity indicator, Body Mass Index (BMI) [8–12]. RFM is especially applicable in the context of clinical and epidemiological research [8]. Empirical evidence indicates that RFM is correlated with various health conditions, including hypertension, type 2 diabetes, coronary artery disease, and depression [13–16]. This study investigated the connection between RFM and cognitive function in older males using the National Health and Nutrition Examination Survey (NHANES) database from 2011 to 2014 to assist clinical research. The novelty of this research resides in the fact that it fills an absence in the existing research by exploring the association between cognitive performance and the newly developed measure known as RFM.

Materials and methods

Study population

A multifaced, multistage sampling design was employed to collect health examinations and interviews of a sample with national representation of U.S. citizens and civilian populations residing in communities from the NHANES sample. This research analyzed a dataset from the NHANES conducted between 2011 and 2014. Informed permission in writing was acquired from all participants of NHANES. This study was classified as exempt from ethical review due to its use of publicly accessible NHANES data. A comprehensive amount of information on cognitive function assessment and RFM was supplied by the participants. The study's initial recruitment included 19,931 participants. However, after removing participants who were female ($n=10072$), had incomplete data on cognitive function ($n=8431$), missing data on RFM ($n=77$) and covariates ($n=30$), 1321 subjects were ultimately kept in the analyses (Fig. 1).

Variables

Cognitive function

The Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test (CERAD-WL), the Animal Fluency Test (AFT), and the Digit Symbol Substitution Test (DSST) were used to evaluate the cognitive function by NHANES between the years 2011 and 2014 [17–19]. Cohort studies frequently use the aforementioned assessments to estimate language proficiency, memory, and general cognitive function [20–22].

The CERAD-WL is comprised of three Immediate Recall Tests (IRT) and one Delayed Recall Test (DRT) [23]. The IRT measures immediate recall ability, and the DRT measures delayed recall ability [24, 25]. The cumulative sum of the scores received in both the IRT and DRT components of the CERAD-WL is used to calculate the overall score for the test.

The AFT necessitates that participants identify and enumerate as many animal species as they can within a specified time frame. The scores of the AFT are related to the quality of language function [26, 27]. Research showed that the AFT can distinguish between normal elderly and those with cognitive impairment [28, 29].

The DSST involves digit-symbol pairs presented in a digit table. Participants are given instructions to write the symbols that correspond to the numbers in the boxes that are located beneath the numbers within two minutes [30]. The DSST was designed to evaluate attention, concentration, hand–eye coordination, information processing speed, and short-term memory.

Cognitive function among the elderly population exhibits considerable variability, characterized by both ceiling and floor effects [31]. Therefore, this study averaged the standardized scores [(subject's test score-average score) / standard deviation] of CERAD-WL, AFT, and DSST scores to create a new metric called Z-scores, providing a comprehensive indicator of cognitive function among the individuals in this research [32, 33]. Z-scores is calculated as

$$\text{Z-scores} = \frac{\frac{Score\ (CERAD-WL)-Mean\ (CERAD-WL)}{SD(CERAD-WL)} + \frac{Score(AFT)-Mean(AFT)}{SD(AFT)} + \frac{Score(DSST)-Mean(DSST)}{SD(DSST)}}{3}$$

There is a lack of cutoff point to determine different cognitive function statuses according to these tests. Referring to the published research, the lowest quartile

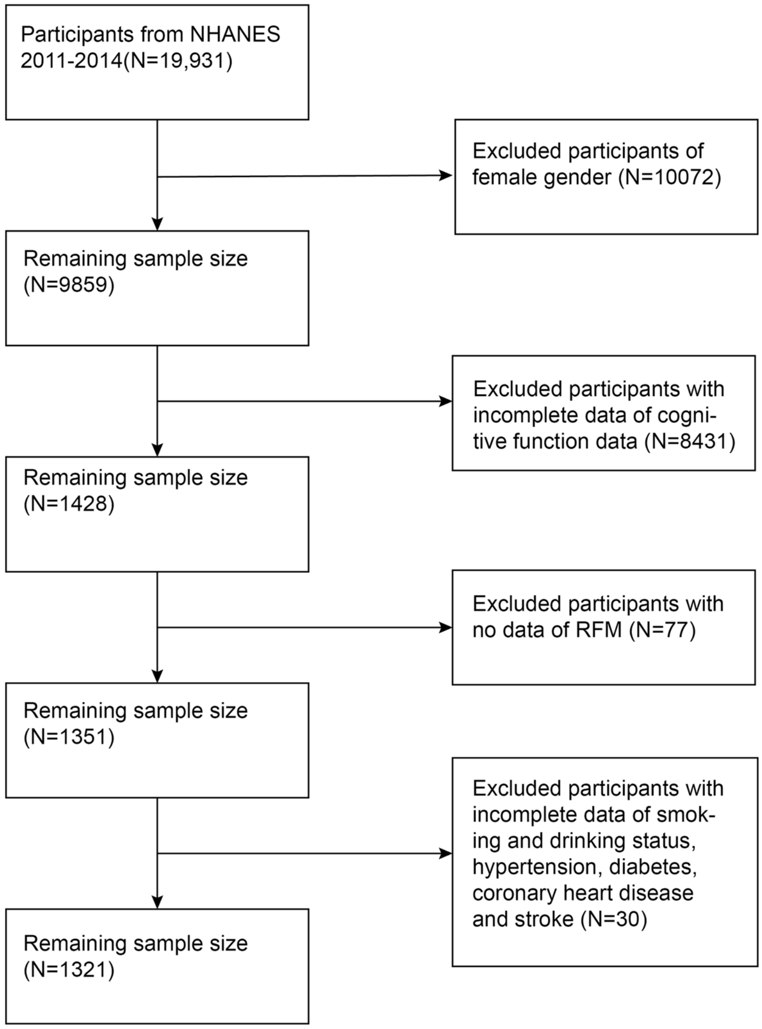

Fig. 1 Flow diagram showing the participants' selecting step

value was used as the cutoff point, categorizing the individuals into two groups: normal cognitive performance and low cognitive performance. The cutoff point of CERAD-WL, AFT, DSST, and Z-scores was 19, 12, 32, and -0.55, respectively [34–36].

Relative Fat Mass(RFM)

Professionals at the Mobile Examination Center (MEC) took height and waist circumference (WC) measurements. The equation utilized for determining the RFM in males is expressed as follows [18]:

$$\text{RFM} = 64 - (20 \times \text{Height} \div \text{WC})$$

Covariates

This study incorporated the following covariates: age, race, education level, Poverty Income Ratio (PIR), BMI (kg/m^2), smoking and drinking status, as well as the presence of hypertension, diabetes, coronary heart disease, and stroke. When it came to drinking status, the threshold for either drinking or not drinking was set at 12 drinks per year. On the other hand, smoking status was defined as smoking more than 100 cigarettes in lifetime. Hypertension, diabetes, coronary heart disease, and stroke were based on participants' self-reported replies to the questions, "Have you ever been told by a doctor or other health professional that you had hypertension/diabetes/coronary heart disease/stroke".

Statistical analysis

R software (version 4.2) and EmpowerStats (version 4.2) were utilized in order to carry out statistical studies. Categorical variables were represented as percentages (%), while continuous variables were expressed as mean ± standard deviations (SD). RFM was additionally employed to examine both continuous variables and quartile distributions.

Multivariate linear regression was used to examine the relationship between RFM and cognitive test results. To remove the impact of confounding variables, three models were developed. A trend test was conducted to assess the linear progression of cognitive test scores across RFM quartiles. Smooth curve fitting was used in order to explore the nonlinear relationship that exists between RFM and cognitive test results. Threshold effect analyses were applied to identify the inflection point during the investigation process. In addition, subgroup analyses were carried out to evaluate the consistency of the association. Statistical significance was determined using a P-value < 0.05.

Results

Baseline characteristics

A total of 1,321 individuals took part in the research investigation. A mean age of 69.23 ± 6.71 years and a mean RFM of 30.41 ± 4.41 were observed in this study. The RFM levels from Q1 to Q4 were 24.82 ± 2.63, 29.63 ± 0.77, 31.89 ± 0.69, and 35.78 ± 1.98, respectively. The mean CERAD-WL score was 23.80 ± 6.13, and CERAD-WL levels from Q1 to Q4 were 25.66 ± 6.28, 24.40 ± 5.96, 25.21 ± 5.91, 25.12 ± 5.77, respectively. The mean AFT score was 16.90 ± 5.50, and AFT levels from Q1 to Q4 were 19.15 ± 6.18, 18.16 ± 5.77, 18.23 ± 5.60, 18.86 ± 5.44, respectively. The mean DSST score was 43.88 ± 16.14, and DSST levels from Q1 to Q4 were 52.69 ± 16.57, 51.31 ± 15.29, 50.19 ± 14.07, 49.03 ± 15.06, respectively. The mean Z-scores was 0 ± 0.79, and Z-scores levels from Q1 to Q4 were 0.42 ± 0.87, 0.26 ± 0.79, 0.29 ± 0.74, 0.30 ± 0.76, respectively. Individuals in the Q4 group had poorer results on cognitive tests in comparison to those in the Q1 group (Table 1).

Association of RFM with cognitive function

RFM was negatively correlated with DSST scores and Z-scores in all three models. In Model 3, for every unit increase in RFM, there was a 0.17-point decrease in CERAD-WL scores (P < 0.05), a 0.83-point decrease in DSST scores (P < 0.05), and a 0.03-point decrease in Z-score (P < 0.05). However, the negative relationship between RFM and AFT scores was not significant (P > 0.05) (Table 2).

Comparisons between participants in the Q4 and Q1 of RFM showed a 5.51-point reduction in DSST scores (P for trend < 0.05). Significant relationships between RFM quartiles and CERAD-WL, AFT, and Z-score were not identified (P for trend > 0.05).

Smooth curve fitting was employed to identify the nonlinear correlation between cognitive test results and RFM (Fig. 2). In the CERAD-WL, the inflection point was identified at 35.51, indicating that the negative correlation between RFM and CERAD-WL scores became more noticeable when RFM > 35.51. For every unit increase in RFM up to 35.51, CERAD-WL scores decreased by 0.25 points (P < 0.05); however, for every unit increase in RFM above 35.51, CERAD-WL scores decreased by 1.17 points (P < 0.05). In the AFT, the inflection point was identified at 37.16, indicating that the negative correlation between RFM and AFT scores is not significant when RFM ≤ 37.16; however, for every unit increase in RFM above 37.16, AFT scores decreased by 1.26 points (P < 0.05). In the DSST, the inflection point was identified at 33.01, indicating that the negative correlation between RFM and DSST scores became more noticeable when RFM > 33.01. For every unit increase in RFM up to 33.01, DSST scores decreased by 0.92 points (P < 0.05); however, for every unit increase in RFM above 33.01, DSST scores decreased by 2.45 points (P < 0.05). In Z-scores, the inflection point was identified at 35.78, indicating that the negative correlation between RFM and Z-scores became more noticeable when RFM > 35.78. For every unit increase in RFM up to 35.78, Z-scores decreased by 0.04 points (P < 0.05); however, for every unit increase in RFM above 35.78, Z-scores decreased by 0.17 points (P < 0.05) (Table 3).

Subgroup analyses

Further subgroup analyses revealed variation in the association between RFM and cognitive function, as seen in Table 4. Significant interactions emerged in the interaction analyses for education level, PIR, smoking and drinking status when Z-scores was used to assess cognitive function (P < 0.05). No significant interactive effects were detected in other variables (P > 0.05).

Discussion

This research demonstrated a statistically significant negative correlation between RFM and CERAD-WL, DSST, and Z-scores. Comparisons between participants in the Q4 and Q1 of RFM revealed a reduction in DSST scores. Smooth curve fitting revealed a nonlinear relationship between RFM and cognitive function (Log-likelihood ratio < 0.05). The negative correlation between RFM and CERAD-WL scores, DSST scores, and Z-scores became more pronounced when RFM > 35.51, 33.01 and 35.78, respectively.

Table 1 Weighted baseline characteristics of participants in RFM quartiles

Characteristics	Relative Fat Mass(RFM)				*P*-value
	Q1 11.93–27.90	**Q2 27.90–30.66**	**Q3 30.66–33.20**	**Q4 33.20–43.21**	
	***N*=330**	***N*=329**	***N*=331**	***N*=331**	
Age(years)	67.49±6.23	69.11±6.99	69.84±6.21	68.20±6.27	<0.0001
Race(%)					0.0064
Mexican American	2.21	3.40	4.43	4.47	
Other Hispanic	2.66	4.00	3.81	3.17	
Non-Hispanic White	75.66	78.65	83.02	82.65	
Non-Hispanic Black	10.78	6.94	5.79	6.76	
Other Race	8.69	7.00	2.95	2.94	
Education level(%)					<0.0001
Less than 9th grade	5.72	6.53	5.97	5.78	
9-11th grade	5.15	10.33	9.21	12.78	
High school graduate/GED or equivalent	20.58	19.53	18.98	18.63	
Some college or AA degree	23.90	21.48	32.02	35.30	
College graduate or above	44.64	42.13	33.83	27.50	
PIR(%)					0.2115
<1	6.94	6.83	4.34	8.26	
≥1	93.06	93.17	95.66	91.74	
BMI(kg/m^2)					<0.0001
<25	78.40	17.10	1.28	8.68	
25–30	21.60	77.03	60.97	91.32	
≥30	0	5.87	37.75	0	
RFM	24.82±2.63	29.36±0.77	31.89±0.69	35.78±1.98	<0.0001
Smoking (%)					0.0235
Yes	57.00	56.71	64.43	65.70	
No	43.00	43.29	35.57	34.30	
Drinking(%)					0.6463
Yes	83.93	86.86	86.84	84.96	
No	16.07	13.14	13.16	15.04	
Hypertension (%)					<0.0001
Yes	31.75	57.11	59.53	72.25	
No	68.25	42.89	40.47	27.75	
Diabetes (%)					<0.0001
Yes	8.99	13.21	22.26	38.31	
No	91.01	86.79	77.74	61.69	
Coronary heart disease (%)					0.0100
Yes	7.85	13.41	13.69	16.55	
No	92.15	86.59	86.31	83.45	
Stroke (%)					0.0062
Yes	5.54	5.11	3.28	9.37	
No	94.46	94.89	96.72	90.63	
CERAD-WL scores	25.66±6.28	24.40±5.96	25.21±5.91	25.12±5.77	0.0677
CERAD-WL Cognitive Function (%)					0.0198
Normal cognitive performance	87.24	78.45	82.87	85.26	
Low cognitive performance	12.76	21.55	17.13	14.74	
AFT scores	19.15±6.18	18.16±5.77	18.23±5.60	18.86±5.44	0.0799
AFT Cognitive Function (%)					0.4202
Normal cognitive performance	85.66	83.51	87.71	87.05	
Low cognitive performance	14.34	16.49	12.29	12.95	

Table 1 (continued)

Characteristics	Relative Fat Mass(RFM)				*P*-value
	Q1 11.93–27.90	Q2 27.90–30.66	Q3 30.66–33.20	Q4 33.20–43.21	
	N = 330	*N* = 329	*N* = 331	*N* = 331	
DSST scores	52.69 ± 16.57	51.31 ± 15.29	50.19 ± 14.07	49.03 ± 15.06	0.0159
DSST Cognitive Function (%)					0.6897
Normal cognitive performance	89.11	87.93	88.18	86.12	
Low cognitive performance	10.89	12.07	11.82	13.88	
Z-scores	0.42 ± 0.87	0.26 ± 0.79	0.29 ± 0.74	0.30 ± 0.76	0.0596
Z-scores Cognitive Function (%)					0.9161
Normal cognitive performance	87.29	86.46	85.37	86.38	
Low cognitive performance	12.71	13.54	14.63	13.62	

Mean ± SD for continuous variables: the *P*-value was calculated by the weighted linear regression model

(%) for categorical variables: the *P*-value was calculated by the weighted chi-square test

Abbreviations: *RFM* Relative fat mass, *CERAD-WL* Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test, *AFT* Animal Fluency Test, *DSST* Digit Symbol Substitution Test, *PIR* Poverty Income Ratio, *BMI* Body Mass Index

Table 2 Associations between RFM and cognitive function

Cognitive function	Model 1 β(95%CI) *P*-value	Model 2 β(95%CI) *P*-value	Model 3 β(95%CI) *P*-value
CERAD-WL	-0.06(-0.14,0.01)0.0995	-0.05(-0.12,0.02)0.1630	-0.17(-0.32,-0.01)0.0422
Q1	Ref	Ref	Ref
Q2	-1.26(-2.20,-0.32)0.0086	-0.75(-1.63,0.12)0.0923	-0.54(-1.49,0.40)0.2563
Q3	-0.45(-1.36,0.47) 0.3414	0.25(-0.61,1.11) 0.5704	0.45(-0.60, 1.51) 0.3998
Q4	-0.54(-1.46,0.37) 0.2469	-0.38(-1.23,0.47)0.3827	0.13(-1.33, 1.60) 0.8578
P for trend	0.620	0.914	0.397
AFT	-0.04(-0.11,0.03) 0.2633	-0.05(-0.12,0.02)0.1562	-0.08(-0.23,0.07) 0.2852
Q1	Ref	Ref	Ref
Q2	-0.98(-1.88,-0.08)0.0329	-0.70(-1.55,0.14)0.1043	-0.39(-1.27,0.49) 0.3863
Q3	-0.92(-1.80,-0.04)0.0409	-0.61(-1.44,0.23)0.1574	-0.13(-1.11,0.86) 0.8020
Q4	-0.29(-1.17,0.59) 0.5205	-0.36(-1.19,0.47)0.3911	0.61 (-0.76,1.98) 0.3830
P for trend	0.624	0.499	0.458
DSST	-0.30(-0.49,-0.11)0.0019	-0.28(-0.44,-0.12)0.0008	-0.83(-1.16,-0.50) < 0.0001
Q1	Ref	Ref	Ref
Q2	-1.38(-3.78,1.01) 0.2568	-0.11(-2.14,1.93) 0.9174	-0.96 (-2.92, 0.99) 0.3340
Q3	-2.50(-4.84,-0.16)0.0364	-0.70(-2.71,1.32)0.4982	-2.13 (-4.32, 0.06) 0.0573
Q4	-3.67(-6.00,-1.33)0.0021	-3.33(-5.32,-1.34)0.0011	-5.51 (-8.55,-2.47) 0.0004
P for trend	0.001	< 0.001	< 0.001
Z-scores	-0.01(-0.02,-0.00)0.0156	-0.01(-0.02,-0.00)0.0084	-0.03(-0.05, -0.01) 0.0006
Q1	Ref	Ref	Ref
Q2	-0.16(-0.28,-0.03)0.0130	-0.09(-0.19,0.02) 0.1147	-0.07 (-0.18, 0.03) 0.1719
Q3	-0.13(-0.25,-0.01)0.0328	-0.04(-0.14,0.07) 0.4857	-0.03 (-0.14, 0.09) 0.6539
Q4	-0.12(-0.24,-0.00)0.0462	-0.11(-0.22,-0.01)0.0359	-0.07 (-0.23, 0.09) 0.4041
P for trend	0.088	0.089	0.632

Model 1: variables were not adjusted

Model 2: adjustments were made to age and race

Model 3: adjustments were made for age, race, education level, PIR, BMI, smoking status, drinking status, hypertension, diabetes, coronary heart disease, stroke

Abbreviations: *RFM* Relative Fat Mass, *CERAD-WL* Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test, *AFT* Animal Fluency Test, *DSST* Digit Symbol Substitution Test, *PIR* Poverty Income Ratio, *BMI* Body Mass Index

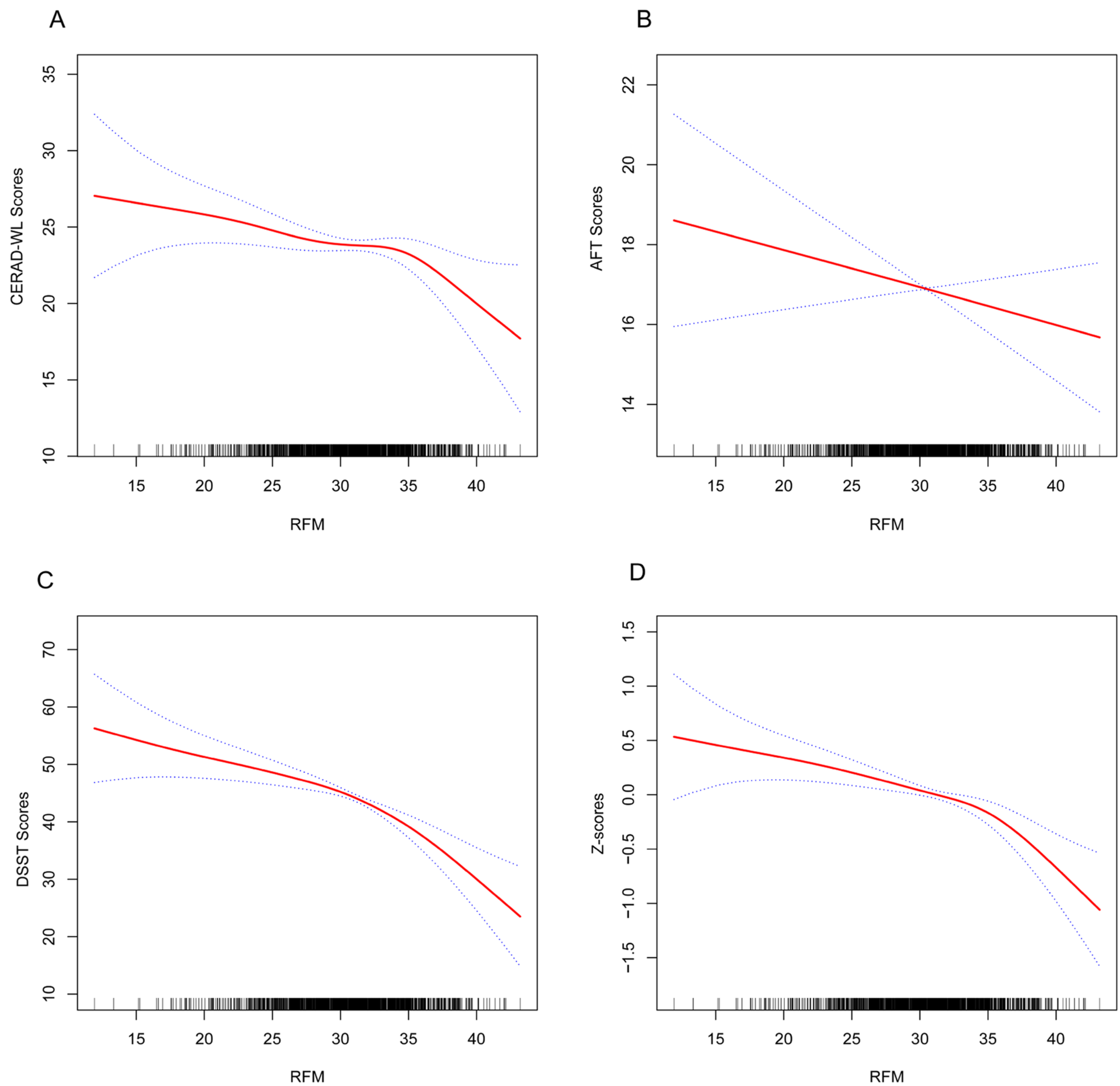

Fig. 2 The nonlinear negative relationship between RFM and cognitive function. The solid line represents the smooth curve fit between variables. Dotted line represents the 95% of confidence interval (CI) from the fit. **A** RFM and CERAD-WL scores; **B** RFM and AFT scores; **C** RFM and DSST scores; **D** RFM and Z-scores. Age, race, education level, PIR, BMI, smoking status, drinking status, hypertension, diabetes, coronary heart disease, stroke were adjusted

The possible mechanisms that connect obesity and cognitive function are intricate and varied. Although the precise processes are still under investigation, several have been proposed [37]. The first mechanism is the inflammatory response. The consistent and ongoing presence of inflammation is a hallmark of obesity. Adipose tissue secretes pro-inflammatory cytokines and inflammation-related proteins, both of which are crucial in facilitating systemic inflammation [38]. The resultant inflammatory condition may induce oxidative stress and subsequent neuronal damage, thereby impairing cognitive function [39]. The second mechanism is insulin resistance. Insulin resistance frequently occurs alongside obesity, resulting in cells becoming less sensitive to insulin's effects. Disruptions in insulin signaling may lead to diminished neuronal

Table 3 Threshold effect analyses of RFM on cognitive function

Models	CERAD-WL	AFT	DSST	Z-scores
Model I				
One line slope	-0.17(-0.32,-0.01) 0.0422	-0.08(-0.23,0.07) 0.2852	-0.83(-1.16,-0.50) < 0.0001	-0.03(-0.05,-0.01) 0.0006
Model II				
Turning point(K)	35.51	37.16	33.01	35.78
< K	-0.25(-0.41,-0.08) 0.0033	-0.16(-0.31,0.00) 0.0526	-0.92(-1.25,-0.59) < 0.0001	-0.04(-0.06,-0.02) < 0.0001
> K	-1.17(-1.74,-0.59) < 0.0001	-1.26(-2.08,-0.43) 0.0028	-2.45(-3.24,-1.67) < 0.0001	-0.17(-0.24,-0.10) < 0.0001
OR between < K and > K	-0.92(-1.42,-0.41) 0.0004	-1.10(-1.86,-0.34) 0.0045	-1.53(-2.20,-0.86) < 0.0001	-0.13(-0.19,-0.07) < 0.0001
Log-likelihood ratio	< 0.001	0.004	< 0.001	< 0.001

Age, race, education level, PIR, BMI, smoking status, drinking status, hypertension, diabetes, coronary heart disease, stroke were adjusted

Abbreviations: *RFM* Relative Fat Mass, *CERAD-WL* Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test, *AFT* Animal Fluency Test, *DSST* Digit Symbol Substitution Test, *PIR* Poverty Income Ratio, *BMI* Body Mass Index

activity and cognitive impairments [39]. The third mechanism is vascular factors. As we know, obesity is associated with hypertension, dyslipidemia, and atherosclerosis [40]. It is possible that these disorders lead to cognitive impairment by lowering the amount of blood that flows through the cerebrovascular system and by causing the blood–brain barrier to become compromised [40–43]. The fourth mechanism is hormonal dysregulation. Obesity leads to changes in leptin and adiponectin levels, affecting brain function and synaptic plasticity [44, 45]. These mechanisms are interrelated and have a combined impact.

BMI is a prominent method that is used to evaluate obesity. Enhanced cognitive performance has been shown to be correlated with a decreased BMI, according to some study results [46–48]. Conversely, the opposite results have been observed in multiple studies [49–51]. This phenomenon is called "obesity paradox" [52–54]. Since the BMI is incapable of distinguishing between muscle and adipose mass, the paradox of obesity may have a viable resolution. As a result, two individuals possessing identical BMI values may exhibit significantly divergent body compositions and experience varying health outcomes [55–58].

As a predictor of obesity, RFM is superior to BMI in terms of its accuracy, making it a more reliable instrument for evaluating body fat percentage [8, 15, 59, 60]. Research indicates that the RFM metric demonstrates enhanced predictive accuracy for dyslipidemias and metabolic syndrome (MetS) in comparison to BMI [61]. Based on the results of a cohort research, elderly people who kept their weight at a reasonable level but had abdominal obesity demonstrated a higher propensity to acquire dementia than those without the condition [62]. The findings of this research indicate that early screening for negative RFM in older men could be a useful method for identifying at-risk groups, and that properly managing RFM might help postpone cognitive decline.

Strengths and limitations

This research used a dataset from NHANES comprising 1,321 older men, which improved the credibility and applicability of the results. To guarantee the study's rigor, a range of statistical techniques were used. The study findings indicated a substantial negative correlation between RFM and CERAD-WL scores, DSST scores, and Z-scores in older men. Early identification of adverse RFM is conducive to identifying high-risk groups for cognitive dysfunction.

On the other hand, it is necessary to point out the constraints of this research. Firstly, as a cross-sectional survey, it could not demonstrate a causal link. Consequently, more investigation with an expanded sample size needs to be performed to verify the causal relationship. Secondly, the study was limited to the years from 2011 to 2014. Therefore, cohort studies might be necessary to validate the current results. Furthermore, the study's sample was restricted to older males, without considering the women; thus, additional studies are required to ascertain whether the findings can be applied to other demographics. Future studies should incorporate older women to enhance the generalizability of the results and explore whether the management of RFM has an advantage in mitigating cognitive decline. Finally, although RFM is a new metric for obesity, further studies are needed to validate its advantage over conventional metrics.

Conclusion

A substantial negative connection between RFM and cognitive function in older men in the United States is revealed in the present study. Elevated RFM levels

Table 4 Subgroup analysis of the associations between RFM and cognitive function

Subgroup	CERAD-WL β(95%CI)	*P* for interaction	AFT β(95%CI)	*P* for interaction	DSST β(95%CI)	*P* for interaction	Z-scores β(95%CI)	*P* for interaction
Age		0.2901		0.0130		0.7817		0.1176
< 70	-0.25(-0.42,-0.08) 0.0033		-0.18(-0.34,-0.02) 0.0242		-0.98(-1.33,-0.63) < 0.0001		-0.04(-0.06, -0.03) < 0.0001	
70–79	-0.15(-0.35,0.04) 0.1220		0.04(-0.14,0.22) 0.6787		-1.07(-1.48, -0.66) < 0.0001		-0.03(-0.05, -0.01) 0.0112	
≥ 80	-0.09(-0.37,0.19) 0.5321		-0.06(-0.32,0.21) 0.6695		-0.88(-1.47, -0.28) 0.0038		-0.03(-0.06, 0.01) 0.0999	
Race		0.5479		0.0160		0.8654		0.1193
Mexican American	-0.16(-0.58,0.27) 0.4695		-0.20(-0.59,0.19) 0.3172		-0.81 (-1.68, 0.06) 0.0678		-0.04 (-0.08, 0.01) 0.1166	
Other Hispanic	0.02(-0.51,0.54) 0.9538		-0.17(-0.65,0.32) 0.5067		-0.34 (-1.43, 0.74) 0.5346		-0.02 (-0.07, 0.04) 0.5827	
Non-Hispanic White	-0.19(-0.36,-0.03) 0.0234		-0.12(-0.28, 0.03) 0.1217		-0.87 (-1.21, -0.52) < 0.0001		-0.04 (-0.05, -0.02) 0.0001	
Non-Hispanic Black	-0.16(-0.42,0.09) 0.2167		-0.08(-0.32, 0.15) 0.4887		-0.73 (-1.26, -0.20) 0.0070		-0.03 (-0.06, -0.00) 0.0455	
Other Race	0.03(-0.27,0.32) 0.8539		0.32 (0.04, 0.59) 0.0230		-0.79 (-1.40, -0.18) 0.0113		0.00 (-0.03, 0.04) 0.7856	
Education level		0.0919		0.8706		0.0089		0.0494
Less than 9th grade	-0.20 (-0.52, 0.12) 0.2278		0.02 (-0.28, 0.32) 0.8899		-0.83 (-1.50, -0.16) 0.0148		-0.03 (-0.06, 0.01) 0.1450	
9-11th grade	0.12 (-0.16, 0.39) 0.4140		-0.04(-0.30, 0.22) 0.7549		-0.01 (-0.59, 0.56) 0.9620		0.00(-0.03,0.03) 0.8239	
High school graduate/GED or equivalent	-0.09(-0.31, 0.13) 0.4146		-0.07(-0.28, 0.14) 0.4976		-0.68 (-1.14, -0.22) 0.0036		-0.02(-0.05,0.00) 0.0620	
Some college or AA degree	-0.13(-0.33, 0.08) 0.2179		-0.05(-0.24, 0.14) 0.6281		-0.88 (-1.30, -0.46) < 0.0001		-0.03(-0.05,-0.01) 0.0154	
College graduate or above	-0.25(-0.42,-0.07) 0.0055		-0.11 (-0.28, 0.05) 0.1715		-1.02 (-1.38, -0.66) < 0.0001		-0.04(-0.06,-0.02) < 0.0001	
PIR		0.0759		0.1907		0.0074		0.0102
< 1	0.01 (-0.24, 0.26) 0.9457		0.04 (-0.20, 0.27) 0.7462		-0.29 (-0.81, 0.23) 0.2697		-0.00(-0.03,0.02) 0.8214	
≥ 1	-0.19(-0.36,-0.03) 0.0197		-0.10(-0.25, 0.05) 0.1947		-0.92 (-1.26, -0.59) < 0.0001		-0.04(-0.05,-0.02) 0.0001	
BMI		0.0026		0.0797		0.0301		0.1313
< 25	-0.34(-0.54, -0.14) 0.0010		-0.21(-0.40,-0.02) 0.0275		-0.42 (-0.84, -0.01) 0.0475		-0.04(-0.06,-0.02) 0.0005	
25–30	0.18 (-0.05, 0.41) 0.1298		0.03 (-0.19, 0.24) 0.8183		-1.11 (-1.60, -0.63) < 0.0001		-0.01(-0.04,0.01) 0.3783	
≥ 30	-0.18 (-0.37, 0.02) 0.0778		0.06 (-0.12, 0.25) 0.4905		-0.33 (-0.74, 0.07) 0.1077		-0.01(-0.03,0.01) 0.2594	
Smoking		0.0013		0.0908		0.0127		0.0007
Yes	-0.08 (-0.24, 0.09) 0.3704		-0.04(-0.19, 0.12) 0.6406		-0.69 (-1.04, -0.34) 0.0001		-0.02(-0.04,-0.00) 0.0293	
No	-0.30(-0.48, -0.12) 0.0010		-0.15(-0.32, 0.02) 0.0826		-1.06 (-1.43, -0.68) < 0.0001		-0.05(-0.07,-0.03) < 0.0001	
Drinking		0.9107		0.0052		0.2296		0.0666
Yes	-0.16(-0.33, -0.00) 0.0501		-0.13(-0.28, 0.02) 0.0998		-0.88 (-1.22, -0.54) < 0.0001		-0.03(-0.05,-0.02) 0.0002	

Table 4 (continued)

Subgroup	CERAD-WL β(95%CI)	*P* for interaction	AFT β(95%CI)	*P* for interaction	DSST β(95%CI)	*P* for interaction	Z-scores β(95%CI)	*P* for interaction
No	-0.17 (-0.39, 0.04) 0.1189		0.12 (-0.09, 0.32) 0.2641		-0.65 (-1.10, -0.20) 0.0050		-0.02(-0.04,0.01) 0.2014	
Hypertension		0.1266		0.0223		0.0025		0.4522
Yes	-0.08 (-0.27, 0.11) 0.4084		0.04 (-0.14, 0.22) 0.6938		-1.18 (-1.58, -0.78) < 0.0001		-0.03(-0.05,-0.01) 0.0151	
No	-0.20(-0.36, -0.03) 0.0195		-0.12(-0.28, 0.03) 0.1136		-0.71 (-1.05, -0.37) < 0.0001		-0.03(-0.05,-0.01) 0.0004	
Diabetes		0.1349		0.2991		0.3237		0.8595
Yes	-0.32(-0.58, -0.06) 0.0155		0.02 (-0.22, 0.26) 0.8807		-0.62 (-1.16, -0.09) 0.0219		-0.03(-0.06,-0.00) 0.0464	
No	-0.17(-0.33, -0.01) 0.0358		-0.08(-0.23, 0.07) 0.3078		-0.83 (-1.16, -0.50) < 0.0001		-0.03(-0.05,-0.01) 0.0006	
Coronary heart disease		0.1665		0.0591		0.6971		0.1357
Yes	-0.02 (-0.28, 0.23) 0.8592		0.10 (-0.14, 0.34) 0.4170		-0.92 (-1.45, -0.38) 0.0008		-0.01(-0.04,0.01) 0.3320	
No	-0.17(-0.33, -0.01) 0.0329		-0.09(-0.24, 0.06) 0.2252		-0.83 (-1.16, -0.50) < 0.0001		-0.03(-0.05,-0.01) 0.0004	
Stroke		0.5754		0.2258		0.9226		0.3522
Yes	-0.08 (-0.41, 0.24) 0.6095		0.08 (-0.22, 0.39) 0.5999		-0.81 (-1.48, -0.13) 0.0192		-0.02(-0.05,0.02) 0.3761	
No	-0.17(-0.33, -0.01) 0.0400		-0.09(-0.23, 0.06) 0.2623		-0.84 (-1.17, -0.51) < 0.0001		-0.03(-0.05,-0.01) 0.0005	

Age, race, education level, PIR, BMI, smoking status, drinking status, hypertension, diabetes, coronary heart disease, stroke were adjusted

Abbreviations: *RFM* Relative Fat Mass, *CERAD-WL* Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test, *AFT* Animal Fluency Test, *DSST* Digit Symbol Substitution Test, *PIR* Poverty Income Ratio, *BMI* Body Mass Index

correlated with diminished scores on cognitive assessments, particularly the CERAD-WL and DSST. The potential benefit of preventing cognitive impairment by managing RFM levels is underscored by these results. This serves as a reminder that strategies to lower RFM, such as dietary adjustments, exercise regimens, and other lifestyle adjustments, may be helpful in preventing cognitive impairment in older male populations. Additional research is required to confirm the validity of the results.

Abbreviations

RFM	Relative fat mass
U.S.	United States
NHANES	National Health and Nutrition Examination Survey
CERAD-WL	Consortium to Establish a Registry for Alzheimer's Disease Word Learning Test
AFT	Animal Fluency Test
DSST	Digit Symbol Substitution Test
WC	Waist circumference
CI	Cognitive impairment
MCI	Mild cognitive impairment
IRT	Immediate Recall Test
DRT	Delayed Recall Test
MEC	Mobile Examination Center
PIR	Poverty Income Ratio
BMI	Body mass index
SD	Standard deviation
NCHS	National Center for Health Statistics
MetS	Metabolic syndrome

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Authors' contributions
LL designed the study, collected and analyzed data, and completed the first draft of the paper. AW supervised the entire study and helped revise the paper. SY assisted with data analysis and paper writing. All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All participants submitted written informed consent and were approved by the National Ethics Board.

Consent for publication
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Competing interests
The authors declare no competing interests.

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