Exploration of Medicine

Open Exploration

Open Access Original Article

Body mass, blood pressure, and cognitive functioning among octogenarians and centenarians

Peter Martin[1]*, Rotem Arieli[1], Mai Kabayama[2], Kayo Godai[2], Yasuyuki Gondo[3], Mary Ann Johnson[4], Leonard W. Poon[5]

[1]Department of Human Development & Family Studies, Iowa State University, Ames, IA 50011-1120, USA
[2]Division of Health Sciences, Graduate School of Medicine, Osaka University, Osaka 565-0871, Japan
[3]Clinical Thanatology and Geriatric Behavioral Science, Osaka University, Osaka 565-0871, Japan
[4]Department of Nutrition and Health Sciences, University of Nebraska-Lincoln, Lincoln, NE 68503, USA
[5]Institute of Gerontology, University of Georgia, Athens, GA 30602, USA

***Correspondence:** Peter Martin, Department of Human Development & Family Studies, Iowa State University, 1096 LeBaron Hall, Ames, IA 50011-1120, USA. pxmartin@iastate.edu
Academic Editor: Calogero Caruso, University of Palermo, Italy
Received: February 4, 2023 **Accepted:** April 5, 2023 **Published:** September 15, 2023

Cite this article: Martin P, Arieli R, Kabayama M, Godai K, Gondo Y, Johnson MA, et al. Body mass, blood pressure, and cognitive functioning among octogenarians and centenarians. Explor Med. 2023;4:625–36. https://doi.org/10.37349/emed.2023.00165

Abstract

Aim: The purpose of this study was to examine the association among body mass, blood pressure (BP), and cognitive functioning for octogenarians and centenarians.

Methods: A total of 300 participants (221 centenarians and 79 octogenarians) from the Georgia Centenarian Study were included in this study. Demographic variables included age, gender, and ethnicity. Body mass was measured with the body mass index (BMI), and systolic and diastolic BP, as well as mean arterial pressure (MAP) and the Mini-Mental Status Examination (MMSE) were assessed.

Results: Results showed age differences indicating that centenarians had lower BMI and MMSE scores when compared to octogenarians. Women had lower cognitive functioning scores compared to men. Black Americans had higher BMI and BP as well as lower MMSE scores. Participants with low BMI values (< 18.5 kg/m^2) and normal BP had a significantly lower MMSE score when compared to those with elevated BMI values (≥ 25 kg/m^2 to < 30 kg/m^2) and high BP. Multiple regression analyses determined that age, gender, ethnicity, and BMI were significantly associated with cognitive function in very late life.

Conclusions: The results suggest that extreme values of body mass (low and high) in combination with normal BP (< 130 mmHg) are potential risk factors for compromised cognition.

Keywords

Body mass index, hypertension, cognitive function, centenarians

Introduction

There is no question that excessive body weight and hypertension are not good for optimal health across the lifespan. Excessive body weight has been related to diabetes, cardiovascular disease, and related disorders [1]. Similarly, high blood pressure (BP) is a primary risk factor for cardiovascular disease [2]. However, it is unclear to what extent the two biomarkers are similar risk factors or may even turn out to be protective factors among very old adults. Therefore, the purpose of this study was to explore the association of BP, body mass, and cognitive functioning among the oldest-old adults.

Maintaining high levels of cognitive function is one of the primary concerns in later life. Cognitive decline is specifically noticeable in very old age [3]. Inagaki et al. [4] compared cognitive scores across age groups and reported significantly lower levels of Mini-Mental Status Examination (MMSE) scores among centenarians when compared to younger age groups. There is conflicting evidence about gender differences in dementia prevalence among the oldest-old adults and centenarians. A Chinese study reported that the prevalence of cognitive impairment among women was higher than among men (72.8% and 42.1%, respectively [5]). Similarly, a Greek centenarian study demonstrated that the proportion of women with dementia was significantly higher than that of men (22% and 10%, respectively [6]). Other studies, however, did not reveal gender differences in dementia (e.g., [7]). Ethnic differences have been reported among centenarians, indicating significantly higher dementia rates for Black centenarians when compared to their White counterparts (68% and 45%, respectively; [8]). It is important to find risk and protective factors related to cognitive functioning. Two biomarkers related to cognitive function include body mass and BP. Excessive weight and elevated BP are two recognized metabolic risk factors [9].

Body mass and cognition

Body weight, relative to height, has been related to a number of diseases. Most often, a high body mass index (BMI) is related to diabetes, but also to other diseases [10]. However, inconsistent results have been reported about the association between BMI and cognition when considering age: for younger adults, a high BMI score is associated with impaired cognition, and overweight and obesity in midlife are linked to dementia risk in older age. However, in very late life higher BMI scores appear to be associated with better cognitive function and lower mortality [11].

Therefore, it is not clear to what extent the association between cognitive function and body weight is also true for very old people. For example, Schmeidler et al. [12] recently noted that whereas BMI was associated with somewhat poorer performance in executive functions and language performance among younger old persons, higher BMI values were associated with somewhat better performance among the oldest-old adults (85 +). The authors discussed a protected survivor model as a possible explanation for these effects. This was confirmed by a study of Japanese centenarians whose higher BMI levels were significant predictors of cognitive function, indicating that centenarians with higher BMI levels had higher cognitive scores [13].

Similar results were reported by Kim et al. [14], suggesting that obesity was associated with a lower risk of cognitive decline in an older South Korean population. This effect was stronger in women when compared to men. Similar results were reported by a Chinese study indicating that higher BMI and overweight were related to slower cognitive decline [15]. However, other research did not show an association between weight and cognition among women whose weight remained stable or who gained weight [16].

Using a comprehensive primary care electronic database from family practices in the United Kingdom, Hazra et al. [17] reported significant gender differences in BMI values for centenarians, indicating that centenarian women had lower BMI values than men. The association between BMI and cognitive function has not been studied widely among centenarian groups. However, researchers of the Georgia Centenarian Study reported that higher body fat was a predictor of survival in centenarians [18].

Hypertension and cognition

Hypertension is another well-known risk factor for health problems and is associated with myocardial infarction and premature mortality [19]. Prevalence rates for hypertension vary across centenarian studies, from 19% among Finnish centenarians and 65% among Hong Kong centenarians [20]. Using data from community-dwelling predominantly male veterans from the United States, Kheirbek et al. [21] noted that octogenarians and nonagenarians were more likely to have hypertension than centenarians. Hazra et al. [17] reported significant gender differences for centenarians, indicating that about 46% of all centenarian men were diagnosed with hypertension compared to 33% of centenarian women. Studies also indicate that in older and very frail individuals, a lower systolic BP (SBP) level (defined as 124 mmHg) predicted clinical events that led to hospitalizations [22].

SBP and diastolic BP (DBP) are important measures of cardiovascular function, but there are age differences in these BP markers. In midlife, SBP and DBP increase with age, but in individuals who are 60 years and older, SBP increases, whereas DBP either remains stable or decreases over time [23]. Therefore, SBP may be a better indicator of cardiovascular risk in older adults, whereas DBP may be a better indicator of cardiovascular risk in younger adults [24, 25]. Studies with older adults typically use high SBP as a marker of hypertension [23].

There is evidence that hypertension relates to cognitive functioning. A meta-analysis of studies including adults 43 to 91 years of age yielded associations between BP, episodic memory, and global cognition, suggesting that high BP is a risk for cognitive function [26]. Hypertension has also been noted as a risk factor for faster cognitive decline in individuals who are at risk for dementia [27]. However, more recent longitudinal results from the Wisconsin Longitudinal Study indicated that self-reported hypertension was only minimally associated with cognition in older adults who were in their sixties and seventies [28].

In very old adults, however, a moderately high level of hypertension may be protective. As some have pointed out, hypertension in older adults may not have a negative effect on cognitive function [29, 30]. One study revealed that high BP was associated with a greater risk of cognitive impairment among individuals who were younger than 75 years, but the effect was reversed with the oldest-old individuals, those 85 years and older [31, 32]. A longitudinal study on a population 85 years of age and older showed a decline in BP for individuals who developed dementia, suggesting that low BP could be an effect of dementia in very old adults [33]. Findings from the Leiden 85-Plus study showed inconsistent results. Some of their findings did not show an association between BP and change in global cognitive function over three years [34]; other research reported from the same study showed that an increase in SBP was associated with better cognitive performance in cognition [31]. Finally, recent findings reported by the Newcastle 85 + study demonstrated that high BP was associated with better global cognitive function over five years [35].

A recent study by Kabayama et al. [36] indicated that a lower SBP was associated with a higher prevalence of physical frailty among 80-year-old adults who were on antihypertensive medication. Whereas SBP was associated with lower cognitive function among 70-year-old study participants, the reverse was true for 90-year-old participants. The authors suggested that the treatment of hypertension should be individualized given the conflicting results.

Results from the Tokyo centenarian study revealed that centenarians with higher BP also scored better on cognitive function than those with lower values. Similar findings were obtained by a study conducted in Poland suggesting that mildly elevated BP is a marker for better health status among centenarians and that centenarians who survived another six months had higher SBP and DBP values at baseline [37]. Finally, Martin et al. [13] reported that centenarians who self-reported high BP levels were more likely to have higher cognitive scores. Higher DBP, however, was related to lower cognitive functioning.

There are also well-documented gender and ethnic group differences that may also directly influence cognitive functioning. There is some evidence suggesting that men typically have higher BP levels than women [38]. However, Evert et al. [39] reported higher prevalence rates of hypertension for female centenarians. The association between hypertension and cognitive function for ethnic subgroups remains unclear. Black Americans show higher prevalence rates and severity of hypertension [40], but Tsang et al. [41] reported for a sample of cognitively intact older Black Americans that BP variability was not associated with global cognitive function. Taken together, there is inconclusive evidence about the impact of hypertension on cognitive function, leading the American Heart Association to conclude that there is insufficient data to make evidence-based recommendations [42].

The current study examined age, gender, and ethnicity as predictors of cognitive functioning. Based on current literature, it is hypothesized that centenarians would have lower BP and BMI levels when compared to octogenarians and that moderate levels of body mass and hypertension would be protective of cognitive function among the oldest-old adults.

Materials and methods

Participants

Participants of the Georgia Centenarian Study [43] were included in this study. Two participants were excluded because they did not have global cognitive function (MMSE) scores. Major demographic variables are summarized in Table 1. A total of 300 participants were included in this study. The average age of the participants was 96.0 years, and almost 80% were women. About 24% of the sample were Black Americans, the average MMSE score was 19.48, and the BMI was 23.80 kg/m^2. Average BP was 128.76 mmHg (systolic) and 74.17 mmHg (diastolic). Thirty-nine percent reported to be on medication for hypertension, and most (75.6%) described their health as "good" or "excellent."

Table 1. Sample characteristics

Variables	Octogenarians (*n* = 79)				Centenarians (*n* = 221)			
	M	SD	*n*	Freq	M	SD	*n*	Freq
Age	84.40	2.86			100.17	1.96		
Gender								
Male			28	(35.4)			39	(17.6)
Female			51	(64.6)			182	(82.4)
Ethnicity								
White/Caucasian			65	(82.3)			162	(73.3)
Black Americans			14	(17.7)			59	(26.7)
Self-rated health								
Poor			2	(2.7)			9	(4.8)
Fair			11	(14.7)			42	(22.5)
Good			44	(58.7)			97	(51.9)
Excellent			18	(24.0)			39	(20.9)
BMI (kg/m^2)	25.92	4.92			22.96	4.79		
BP (mmHg)								
Systolic	131.76	18.28			127.55	15.54		
Diastolic	75.34	10.96			73.70	9.11		
MAP	94.15	11.83			91.65	9.14		
Hypertension medication								
No			43	(54.4)			140	(63.3)
Yes			36	(45.6)			81	(36.7)
Mental status	25.04	7.13			17.47	8.99		

M: mean; SD: standard deviation; *n*: number; Freq: frequency; MAP: mean arterial pressure. Only means (standard deviations) or frequencies are shown

Measures

Next to the demographic variables of age group, gender, and ethnicity, the analyses included the BMI, SBP, DBP, MAP [DBP + (SBP – DBP) × 1/3] and a measure of cognitive function (MMSE). A person was diagnosed to have hypertension if the SBP was ≥ 130 mmHg, or the DBP was ≥ 90 mmHg, or if he/she reported current use of antihypertensive medication. The BMI was calculated as a person's weight in kilograms divided by his or her height in meters squared (kg/m^2).

To explore different risk group typologies, participants were divided into four different BMI groups: low BMI (malnourished, < 18.5 kg/m^2), normal BMI (18.5–24.9 kg/m^2), overweight BMI (25.0–29.9 kg/m^2), and obese BMI (≥ 30 kg/m^2). BP was also separated into two groups: normal BP (SBP < 130 mmHg) and high BP (SBP ≥ 130 mmHg). Four subgroups were formed: Low BMI & Normal BP, Low BMI & High BP, High BMI & Normal BP, and High BMI & High BP. However, to obtain a more fine-grained assessment, continuous data were used for the association analyses.

Cognitive functioning was assessed with the MMSE [44]. The measure includes five components of cognitive functioning with 30 items: orientation, registration, attention and calculation, recall, and language (0 = incorrect, 1 = correct). MMSE scores range from 0 to 30. Higher scores indicate higher cognitive functioning. The reliability for MMSE in this study is $\alpha = 0.88$.

Analyses

Mean group comparisons using analysis of variance (ANOVAS) with post-hoc subgroup mean comparisons were computed to examine mean differences. In addition, bivariate correlations and hierarchical regression analyses were computed. The first block included age group, gender, and ethnicity. The second block included the BMI score and the squared BMI score. The third block added the SBP score as a continuous variable. Additional analyses substituting SBP with DBP and MAP were computed. Finally, quadratic terms for systolic and DBP were added in an additional block. The dependent variable was the MMSE or global cognitive functioning. Taking hypertension medication was included as a covariate.

Additionally, configural frequency analyses (CFAs) were computed. This person-centered analysis allows for the examination of underlying configurations (e.g., high BP, high BMI levels, low cognitive function) that occur significantly more or less than would be expected by chance [45]. CFA [46] detects underlying configurations by comparing observed to expected frequencies for each combination in a cross-tabulation [47], resulting in patterns that occur significantly more or less than would be expected by chance [45]. Configurations that occur more often than would be expected by chance are referred to as "types," whereas configurations that occur less often than would be expected by chance are referred to as "antitypes." CFAs were conducted with the extension in statistical product and service solutions (SPSS) version 29. CFAs require variables to be categorized, and participants were divided into high and low BP groups, with the group division at 130 mmHg SBP, with the four categories of BMI, and with an MMSE group division at 23.

Results

First, separate age group, gender, and ethnicity analyses of variance were computed for BMI, systolic, DBP, MAP, and global cognitive function (Table 2). For BMI, age differences, F (1,299) = 18.55, P <0 .05, $\eta^2 = 0.07$ and ethnicity differences, F (1,299) = 6.25, P < 0.05, $\eta^2 = 0.03$, were obtained. Centenarians' BMI was significantly lower (M = 22.96 kg/m^2) than the BMI of octogenarians (M = 25.92 kg/m^2). For SBP, DBP, and MAP, ethnic differences were obtained, F (1,247) = 7.10, P < 0.001, $\eta^2 = 0.03$, F (1,247) = 5.13, P < 0.05, η^2 = 0.02, and F (1,247) = 8.62, P < 0.01, $\eta^2 = 0.03$, respectively. All BP measures were higher for Black Americans (M = 134.37, M = 76.86, and M = 96.03) when compared to White participants (M = 127.07, M = 73.36, and M = 91.27, respectively). Finally, age and ethnic differences were obtained for global cognitive functioning, F (1,299) = 45.57, P < 0.001, $\eta^2 = 0.13$ and F (299) = 20.12, P < 0.01, $\eta^2 = 0.06$, respectively. Centenarians had significantly lower MMSE scores than octogenarians (M = 17.47 and M = 25.04, respectively) and Black Americans had significantly lower MMSE scores than their White counterparts (M = 15.39 and M = 20.78, respectively).

The mean group differences for the combination of BMI and BP groups are summarized in Table 3. The lowest BMI group (i.e., BMI < 18.5 kg/m^2) with normal BP had significantly lower MMSE scores when compared to the elevated BMI group with relatively high SBP. Having normal BP in combination with extremely low values of BMI appears to be a risk factor for low MMSE scores in very late life.

Table 2. Mean group differences in BMI, BP, MAP, and cognitive function

Variables	Age				Gender				Ethnicity			
	80s	100s	*F*	η^2	Male	Female	*F*	η^2	White	Black	*F*	η^2
BMI (kg/m^2)	25.92	22.96	18.55^{***}	0.07	24.86	23.53	2.80^{+}	0.01	23.37	25.25	6.25^{*}	0.03
SBP	131.76	127.55	2.91^{+}	0.01	129.28	128.63	0.16	0.00	127.07	134.37	7.10^{**}	0.03
DBP	75.34	73.70	1.30	0.01	73.50	74.34	0.24	0.00	73.36	76.86	5.13^{*}	0.02
MAP	94.15	91.65	2.79^{*}	0.01	92.09	92.44	0.01	0.00	91.27	96.03	8.62^{**}	0.03
Cognitive function	25.04	17.47	45.57^{***}	0.13	22.70	18.54	11.08^{**}	0.04	20.78	15.39	20.12^{**}	0.06

Age, gender, and ethnicity differences for BMI, SBP, DBP, MAP, and cognitive function after controlling for hypertension medication; $^{+}$ $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; *F*: *F*-test; η^2: eta-squared

Table 3. Mean group differences in cognitive functioning for body mass and BP groups

BMI (kg/m^2)	Cognitive score for normal BP	Cognitive score for high BP	*F*
< 18.5	12.59 (n = 22)[a]	17.80 (n = 5)	1.09
18.5–24.9	19.25 (n = 73)	20.38 (n = 48)	0.48
25–29.9	21.43 (n = 30)	21.80 (n = 39)[b]	0.87
≥ 30	15.88 (n = 8)	20.67 (n = 12)	1.79

Total N = 237. Means with different superscripts are significantly different. *F*: *F*-test; [a] lowest group; [b] highest group

The results of the CFA are summarized in Table 4. They confirm the ANOVA results by yielding two specific types. Participants with low BMI and normal SBP were more likely to belong to the low cognitive functioning group than would have been expected by chance. The second type demonstrated that participants with moderately high BMI and high SBP were more likely to belong to the high cognitive functioning group than would have been expected by chance.

Table 4. Configuration of cognition, BP, and BMI

Cognition	BMI	SBP	Count	Expected count	Test statistic for asymptotic binomial test	Type
1	1	1	19	7.98	3.78^{***}	Type
1	1	2	2	6.46	−1.98	
1	2	1	40	36.88	0.56	
1	2	2	29	29.86	−0.17	
1	3	1	14	20.36	−1.47	
1	3	2	13	16.49	−0.89	
1	4	1	6	5.50	0.00	
1	4	2	5	4.46	0.26	
2	1	1	5	8.04	−1.27	
2	1	2	3	6.51	−1.59	
2	2	1	37	37.16	−0.03	
2	2	2	28	30.10	−0.41	
2	3	1	19	20.52	−0.35	
2	3	2	28	16.62	2.89^{**}	Type
2	4	1	2	5.55	−1.74	
2	4	2	7	4.49	1.19	

Blank spaces in the last column reflect neither types nor antitypes. The corresponding configurations are not different from expected values; ** $P < 0.01$; *** $P < 0.001$. Cognition (1: < 23; 2 ≥ 23), BMI (1: < 18.5 kg/m^2; 2: ≥ 18.5 kg/m^2 and < 23.0 kg/m^2; 3: ≥ 23.0 kg/m^2 and < 30.0 kg/m^2; 4: ≥ 30.0 kg/m^2), SBP (1: < 130 mmHg; 2: ≥ 130 mmHg)

Bivariate correlations of all variables are summarized in Table 5. Body mass was significantly associated with age, ethnicity, BP, and cognitive function. Younger participants, Black Americans, those with relatively high BP, and participants with higher cognitive function scores were more likely to show higher BMI values. BP was related to ethnicity, indicating that Black Americans had higher BP levels. Finally, cognitive function was associated with all variables, except medications, DBP, and MAP. Older participants and Black Americans had lower cognitive function scores, whereas men and those with higher BMI scores had higher cognitive function levels.

Table 5. Bivariate correlations of demographic and health variables

Variables	1	2	3	4	5	6	7	8	9
Age	1.0								
Gender (Women)	0.19**	1.00							
Ethnicity (Black Americans)	0.09	0.02	1.00						
BMI (kg/m^2)	–0.27**	–0.11	0.16*	1.00					
Medications	–0.08	0.08	0.07	0.11	1.00				
SBP	–0.12	–0.02	0.19*	0.25**	0.19**	1.00			
DBP	–0.08	0.04	0.15*	0.21**	0.09	0.41**	1.00		
MAP	–0.11	0.01	0.20**	0.27**	0.16*	0.81**	0.87**	1.00	
Cognitive function	–0.37**	–0.19**	–0.25**	0.16*	0.10	0.13*	–0.06	0.03	1.00

* $P < 0.05$; ** $P < 0.01$

Table 6. Predictors of cognitive functioning

Variables	*B*	SE	*β*	*F*	R^2
Block 1					0.19
Age	–6.45	1.24	–0.31	–5.21***	
Gender (women)	–2.96	1.30	–0.14	–2.27*	
Ethnicity (Black Americans)	–4.86	1.25	-0.23	–3.90***	
Hypertension medication	1.94	1.10	0.10	1.77+	
Block 2					0.21*
Age	–5.81	1.27	–0.28	–4.57***	
Gender (women)	–2.58	1.30	–0.12	–1.99*	
Ethnicity (Black Americans)	–5.12	1.26	–0.24	–4.08***	
Hypertension medication	1.48	1.11	0.08	1.34	
BMI (kg/m^2)	1.16	0.51	0.63	2.27*	
BMI^2	–0.02	0.01	–0.54	–1.96*	
Block 3					0.21
Age	–5.69	1.27	–0.27	–4.48***	
Gender (Women)	–2.61	1.30	–0.12	–2.01*	
Ethnicity (Black Americans)	–5.43	1.27	–0.26	–4.28*	
Hypertension medication	1.25	1.11	0.07	1.13	
BMI (kg/m^2)	1.02	0.52	0.56	1.98*	
BMI^2	–0.02	0.01	–0.48	–1.74+	
BP (systolic)	0.05	0.03	0.09	1.49	

B: unstandardized coefficient; SE: standard error; *β*: standardized coefficient; *F*: *F*-test value; *R2*: explained variance; + $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

The results of the hierarchical multiple regression analyses are summarized in Table 6. The first block contained the three demographic variables age, gender, and ethnicity, as well as medication for hypertension. Age, gender, and ethnicity were significantly associated with cognitive function, indicating that older adults, women, and Black American participants had lower scores on cognitive function. The model predicted 19% of the variance. In block 2, the BMI and its squared value were added to the equation. The model was a significant improvement over the demographic model, F_{Δ} (2,233) = 3.23, $P < 0.05$. Finally, SBP was added but did not explain any additional variance, F_{Δ} (2,232) = 2.22, $P > 0.05$. The analyses were repeated by exchanging SBP with DBP and then with MAP, but those variables did not explain additional variance. Finally, the multiple regression analyses were computed once more to assess the influence of quadratic BP terms, but those analyses did not yield significant results for the additional variables.

Discussion

The purpose of this study was to examine the associations among body mass, BP, and cognitive function. The study uncovered four important results. First, there were age and ethnicity differences for BMI. Second, there were ethnic differences in BP. Third, there were age, gender, and ethnic differences in cognitive function. Finally, the analyses identified one specific risk group for low levels of cognitive function: participants with low BMI and normal BP had the lowest cognitive scores compared to the group with moderately high BMI values and high BP.

Age differences in BMI, BP, and cognitive function have been well documented in past research, indicating that centenarians are more likely to have lower BP levels, lower BMI [21, 48], and lower cognitive function [4]. In this study, centenarians showed significantly lower global cognition levels. The results also indicate that centenarians did not differ from octogenarians when comparing systolic and DBP, but centenarians did have lower MAP and BMI values than octogenarians did, with the mean value within a healthy range. It is unclear whether the BMI and MAP values have consistently been low or whether there were recent changes for centenarians.

That the cognitive function score is significantly lower when compared to octogenarians is not surprising, as most population-based centenarian studies have reported relatively low cognitive function scores (e.g., [4]). There is also previous evidence that Black Americans have lower MMSE scores [8] and higher BP values [40] when compared to White Americans.

Another aim was to examine the combination of BP and BMI values for the oldest-old adults. Elevated levels for both are components of the metabolic syndrome [9]. The results suggest that there is one specific risk group for low cognitive functioning. The lowest group includes the oldest-old adults with very low levels of BMI and normal BP values. The results suggest that BMI values between 23.0 kg/m^2 and 29.9 kg/m^2 and with higher BP readings are associated with higher levels of cognitive function. The results were confirmed with the CFA. Although normal BP by itself was not associated with better or worse cognitive functioning, the combination of normal BP with very low BMI levels signifies a risk group for cognitive function. Perhaps elevated BP compensates for low weight in very late life. Unfortunately, the sample was quite small and some of the cell sizes were marginal. It is difficult to recruit large samples of centenarians, and most centenarian studies have to rely on small participant numbers.

The results of the multiple regression analyses indicated that the association between BMI and cognitive function is important to consider. Higher BMI values were associated with better cognitive function. This result is consistent with previous studies [11, 12] pointing to the importance of maintaining a healthy weight rather than losing too much weight and becoming a nutritional risk. BP, on the other hand, was not significantly associated with cognitive function, a result somewhat inconsistent with previous research. A number of researchers [31, 32] had noted that for people 85 years and older relatively high BP was associated with a lower risk of cognitive impairment. The results suggest that BP alone may not be important in predicting cognitive function, but that it is relevant in combination with other biomarkers, such as BMI.

Finally, the relationship between BMI and cognitive function appears to be curvilinear. Very low levels of BMI may be a risk factor for low cognitive function, and with increasing BMI levels, higher levels of cognitive function were noted. However, extreme BMI values reversed the positive effect of BMI on cognitive function. These results are consistent with previous research indicating that among very old persons who were overweight the mortality risk was lower when compared to very old persons who were of normal weight, even after controlling for weight change and multi-morbidity [49]. The findings are consistent with the overall classification of BMI values, indicating that values too high or too low may have negative effects on cognitive function.

The study has a number of limitations. First, the sample is from a small geographic area in the Southeast of the United States, and centenarians are still very rare. The overall sample size, therefore, is somewhat compromised. Second, the study included very general measures. As some have argued, the BMI is a limited anthropometric measure, and additional assessments, such as waist-to-hip ratio and skin folds, as well as comprehensive nutritional measures, such as the percentage of fat mass or muscle strength should be considered. For BP, the cutoff value was set to 130 mmHg for SBP. Others might have used higher or lower cutoffs. Finally, the cognitive measure was only a mental status questionnaire that did not distinguish different components of cognitive functioning.

The study also is limited in its cross-sectional design, which does not allow antecedent-consequence relationship or a causal ordering of variables. For example, it is not clear whether BMI affects cognitive function or a decline in cognitive function affects BMI. Suemoto et al. [50] reported that greater decline in BMI over four years was associated with lower memory scores and lower memory scores were associated with a decline in BMI, pointing to a reverse causation effect.

In spite of these limitations, the current study provides useful information for researchers and practitioners. Keeping weight and BP in normal range is an important task for older individuals and their care providers, so that their level of cognitive functioning is maintained at the highest possible levels.

Abbreviations

BMI: body mass index

BP: blood pressure

CFAs: configural frequency analyses

DBP: diastolic blood pressure

MAP: mean arterial pressure

MMSE: Mini-Mental Status Examination

SBP: systolic blood pressure

Declarations

Acknowledgments

Authors acknowledge the valuable recruitment and data acquisition effort by M. Burgess, K. Grier, E. Jackson, E. McCarthy, K. Shaw, L. Strong, and S. Reynolds, data acquisition team manager; S. Anderson, E. Cassidy, M. Janke, and J. Savla, data management; M. Poon, project fiscal management.

Author contributions

PM: Conceptualization, Formal analysis, Writing—original draft, Writing—review & editing. RA: Formal analysis, Writing—review & editing. MK: Conceptualization, Writing—review & editing. KG: Conceptualization, Writing—review & editing. YG: Writing—review & editing. MAJ: Conceptualization, Formal analysis, Writing—review & editing. LWP: Supervision Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflict of interest.

Ethical approval

The study was approved by the Institutional Review Boards (IRB) at the University of Georgia and Iowa State University (XX-026) and complied with Declaration of Helsinki.

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Not applicable.

Availability of data and materials

Data are available from the principal investigator of the study Leonard W. Poon (lpoon8122@gmail.com).

Funding

The Georgia Centenarian Study was funded by [1P01AG17553] from the National Institute on Aging, a collaboration among The University of Georgia, Tulane University Health Sciences Center, Boston University, University of Kentucky, Emory University, Duke University, Wayne State University, Iowa State University, Temple University, and University of Michigan. Additional investigators of the Georgia Centenarian Study include S. M. Jazwinski, R. C. Green, M. MacDonald, M. Gearing, W. R. Markesbery (deceased), J. L. Woodard, M. A. Johnson, J. S. Tenover, I. C. Siegler, W. L. Rodgers, D. B. Hausman, C. Rott, A. Davey, and J. Arnold. The first author's work on the project was supported by the Fulbright Commission and by United States Department of Agriculture, Hatch Project Grant, [IOW04116]. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright

References

1. Bays HE, Chapman RH, Grandy S; SHIELD Investigators' Group. The relationship of body mass index to diabetes mellitus, hypertension and dyslipidaemia: comparison of data from two national surveys. Int J Clin Pract. 2007;61:737–47.
2. Rapsomaniki E, Timmis A, George J, Pujades-Rodriguez M, Shah AD, Denaxas S, et al. Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1·25 million people. Lancet. 2014;383:1899–911.
3. Schaie KW. Individual differences in rate of cognitive change in adulthood. In: Bengston VL, Schaie KW, editors. The course of later life: research and reflections. New York: Springer; 1989. pp. 65–85.
4. Inagaki H, Gondo Y, Hirose N, Masui Y, Kitagawa K, Arai Y, et al. Cognitive function in Japanese centenarians according to the Mini-Mental State Examination. Dement Geriatr Cogn Disord. 2009;28:6–12.
5. Wang B, He P, Dong B. Association between family functioning and cognitive impairment among Chinese nonagenarians/centenarians. Geriatr Gerontol Int. 2015;15:1135–42.
6. Stathakos D, Pratsinis H, Zachos I, Vlahaki I, Gianakopoulou A, Zianni D, et al. Greek centenarians: assessment of functional health status and life-style characteristics. Exp Gerontol. 2005;40:512–8.
7. Ravaglia G, Forti P, De Ronchi D, Maioli F, Nesi B, Cucinotta D, et al. Prevalence and severity of dementia among northern Italian centenarians. Neurology. 1999;53:416–8.
8. Poon LW, Woodard JL, Stephen Miller L, Green R, Gearing M, Davey A, et al. Understanding dementia prevalence among centenarians. J Gerontol A Biol Sci Med Sci. 2012;67:358–65.
9. Cornier MA, Dabelea D, Hernandez TL, Lindstrom RC, Steig AJ, Stob NR, et al. The metabolic syndrome. Endocr Rev. 2008;29:777–822.
10. Knight JA. Diseases and disorders associated with excess body weight. Ann Clin Lab Sci. 2011;41:107–21.
11. García-Ptacek S, Faxén-Irving G, Cermáková P, Eriksdotter M, Religa D. Body mass index in dementia. Eur J Clin Nutr. 2014;68:1204–9.
12. Schmeidler J, Mastrogiacomo CN, Beeri MS, Rosendorff C, Silverman JM. Distinct age-related associations for body mass index and cognition in cognitively healthy very old veterans. Int Psychogeriatr. 2019;31:895–9.
13. Martin P, Gondo Y, Arai Y, Ishioka Y, Johnson MA, Miller LS, et al. Cardiovascular health and cognitive functioning among centenarians: a comparison between the Tokyo and Georgia centenarian studies. Int Psychogeriatr. 2019;31:455–65.
14. Kim S, Kim Y, Park SM. Body mass index and decline of cognitive function. PLoS One. 2016;11:e0148908.

15. Liang F, Fu J, Moore JB, Zhang X, Xu Y, Qiu N, et al. Body mass index, waist circumference, and cognitive decline among chinese older adults: a nationwide retrospective cohort study. Front Aging Neurosci. 2022;14:737532.
16. Driscoll I, Espeland MA, Wassertheil-Smoller S, Gaussoin SA, Ding J, Granek IA, et al.; Women's Health Initiative Study of Cognitive Aging. Weight change and cognitive function: findings from the Women's Health Initiative Study of Cognitive Aging. Obesity (Silver Spring). 2011;19:1595–600.
17. Hazra NC, Dregan A, Jackson S, Gulliford MC. Differences in health at age 100 according to sex: population-based cohort study of centenarians using electronic health records. J Am Geriatr Soc. 2015;63:1331–7.
18. Poon LW, Johnson MA, Davey A, Dawson DV, Siegler IC, Martin P. Psycho-social predictors of survival among centenarians. In: Martin P, Rott C, Hagberg B, Morgan K, editors. Centenarians: autonomy versus dependence in the oldest old. New York: Springer; 2000. pp. 77–89.
19. Pedrinelli R, Ballo P, Fiorentini C, Denti S, Galderisi M, Ganau A, et al. Gruppo di Studio Ipertensione e Cuore, Societa' Italiana di Cardiologia. Hypertension and acute myocardial infarction: an overview. J Cardiovasc Med (Hagerstown). 2012;13:194–202.
20. Rasmussen SH, Andersen-Ranberg K. Health in centenarians. In: Pachana N, editor. Encyclopedia of Geropsychology. Singapore: Springer; 2017. pp. 1005–18.
21. Kheirbek RE, Fokar A, Shara N, Bell-Wilson LK, Moore HJ, Olsen E, et al. Characteristics and incidence of chronic illness in community-dwelling predominantly male U.S. veteran centenarians. J Am Geriatr Soc. 2017;65:2100–6.
22. Koujiya E, Kabayama M, Yamamoto M, Akiyama M, Higami Y, Kodama K, et al. Associations of blood pressure levels with clinical events in older patients receiving home medical care. Hypertens Res. 2021;44:197–205.
23. Benetos A, Petrovic M, Strandberg T. Hypertension management in older and frail older patients. Circ Res. 2019;124:1045–60.
24. Franklin SS, Larson MG, Khan SA, Wong ND, Leip EP, Kannel WB, et al. Does the relation of blood pressure to coronary heart disease risk change with aging? The framingham heart study. Circulation. 2001;103:1245–9.
25. Khattar RS, Swales JD, Dore C, Senior R, Lahiri A. Effect of aging on the prognostic significance of ambulatory systolic, diastolic, and pulse pressure in essential hypertension. Circulation. 2001;104:783–9.
26. Gifford KA, Badaracco M, Liu D, Tripodis Y, Gentile A, Lu Z, et al. Blood pressure and cognition among older adults: a meta-analysis. Arch Clin Neuropsychol. 2013;28:649–64.
27. Goldstein FC, Levey AI, Steenland NK. High blood pressure and cognitive decline in mild cognitive impairment. J Am Geriatr Soc. 2013;61:67–73.
28. Moll AC, Woodard JL. Hypertension and cognition are minimally associated in late life. Hypertens Res. 2022;45:1622–31.
29. Kuyumcu ME, Yesil Y, Yavuz BB, Halil M, Cankurtaran M, Arıoğul S. Relationship between blood pressure and physical and cognitive function in the oldest old. J Am Geriatr Soc. 2013;61:828–9.
30. Ogliari G, Sabayan B, Mari D, Rossi PD, Lucchi TA, de Craen AJ, et al. Age- and functional status–dependent association between blood pressure and cognition: the Milan geriatrics 75+ cohort study. J Am Geriatr Soc. 2015;63:1741–8.
31. Euser SM, van Bemmel T, Schram MT, Gussekloo J, Hofman A, Westendorp RG, et al. The effect of age on the association between blood pressure and cognitive function later in life. J Am Geriatr Soc. 2009;57:1232–7.
32. Sabayan B, Oleksik AM, Maier AB, van Buchem MA, Poortvliet RK, de Ruijter W, et al. High blood pressure and resilience to physical and cognitive decline in the oldest old: the Leiden 85-plus study. J Am Geriatr Soc. 2012;60:2014–9.

33. Molander L, Gustafson Y, Lövheim H. Longitudinal associations between blood pressure and dementia in the very old. Dement Geriatr Cogn Disord. 2010;30:269–76.
34. van Vliet P, Westendorp RG, van Heemst D, de Craen AJ, Oleksik AM. Cognitive decline precedes late-life longitudinal changes in vascular risk factors. J Neurol Neurosurg Psychiatry. 2010;81:1028–32.
35. Harrison SL, Stephan BC, Siervo M, Granic A, Davies K, Wesnes KA, et al. Is there an association between metabolic syndrome and cognitive function in very old adults? the Newcastle 85+ study. J Am Geriatr Soc. 2015;63:667–75.
36. Kabayama M, Kamide K, Gondo Y, Masui Y, Nakagawa T, Ogawa M, et al.; SONIC study group. The association of blood pressure with physical frailty and cognitive function in community-dwelling septuagenarians, octogenarians, and nonagenarians: the SONIC study. Hypertens Res. 2020;43:1421–9.
37. Szewieczek J, Dulawa J, Francuz T, Legierska K, Hornik B, Włodarczyk-Sporek I, et al. Mildly elevated blood pressure is a marker for better health status in Polish centenarians. Age (Dordr). 2015;37:4.
38. de Munter JS, Agyemang C, van Valkengoed IG, Bhopal R, Stronks K. Sex difference in blood pressure among South Asian diaspora in Europe and North America and the role of BMI: a meta-analysis. J Hum Hypertens. 2011;25:407–17.
39. Evert J, Lawler E, Bogan H, Perls T. Morbidity profiles of centenarians: survivors, delayers, and escapers. J Gerontol A Biol Sci Med Sci. 2003;58:232–7.
40. Zhao B, Jose PO, Pu J, Chung S, Ancheta IB, Fortmann SP, et al. Racial/ethnic differences in hypertension prevalence, treatment, and control for outpatients in northern California 2010–2012. Am J Hypertens. 2015;28:631–9.
41. Tsang S, Sperling SA, Park MH, Helenius IM, Williams IC, Manning C. Blood pressure variability and cognitive function among older African Americans: introducing a new blood pressure variability measure. Cogn Behav Neurol. 2017;30:90–7.
42. Iadecola C, Yaffe K, Biller J, Bratzke LC, Faraci FM, Gorelick PB, et al.; American Heart Association Council on Hypertension; Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Quality of Care and Outcomes Research; Stroke Council. Impact of hypertension on cognitive function: a scientific statement from the American Heart Association. Hypertension. 2016;68:e67–94.
43. Poon LW, Jazwinski M, Green RC, Woodard JL, Martin P, Rodgers WL, et al. Methodological considerations in studying centenarians: lessons learned from the Georgia centenarian studies. Annu Rev Gerontol Geriatr. 2007;27:231–64.
44. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12:189–98.
45. Schrepp M. The use of configural frequency analysis for explorative data analysis. Br J Math Stat Psychol. 2006;59:59–73.
46. von Eye A. Introduction to configural frequency analysis: the search for types and antitypes in cross-classifications. Cambridge: Cambridge University Press; 1990.
47. Martin P, Baenziger J, Macdonald M, Siegler IC, Poon LW. Engaged lifestyle, personality, and mental status among centenarians. J Adult Dev. 2009;16:199–208.
48. Arai Y, Hirose N, Nakazawa S, Yamamura K, Shimizu K, Takayama M, et al. Lipoprotein metabolism in Japanese centenarians: effects of apolipoprotein E polymorphism and nutritional status. J Am Geriatr Soc. 2001;49:1434–41.
49. Dahl AK, Fauth EB, Ernsth-Bravell M, Hassing LB, Ram N, Gerstof D. Body mass index, change in body mass index, and survival in old and very old persons. J Am Geriatr Soc. 2013;61:512–8.
50. Suemoto CK, Gilsanz P, Mayeda ER, Glymour MM. Body mass index and cognitive function: the potential for reverse causation. Int J Obes (Lond). 2015;39:1383–9.