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Association between upper leg length and metabolic syndrome among US elderly participants—results from the NHANES (2009–2010)

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Abstract

Objective To examine the relationship between upper leg length (ULL) and metabolic syndrome (MetS) in older adults. **Methods** Data was collected from National Health and Nutritional Examination Survey (NHANES, 2009–2010). 786 individuals (385 males and 401 females) who were 60 years of age or older were included in this analysis. MetS was defined as having at least three of following conditions, i.e., central obesity, dyslipidemia, insulin resistance, and hypertension based on National Cholesterol Education Program guidelines. ULL was grouped into gender-specific tertiles. **Results** 328 (41.7%) of participants were categorized as having MetS (38.7% in men and 49.1% in women, P = 0.002). Compared to individuals in the 1st tertile (T1) of ULL, those in the 3rd tertile (T3) had lower levels of triglycerides (120.8 *vs*. 153.1 mg/dL, P = 0.045), waist circumference (100.7 *vs*. 104.2 cm, P = 0.049), and systolic blood pressure (126.7 *vs*. 131.4 mmHg, P = 0.005), but higher levels of high-density-lipoprotein cholesterol (58.1 *vs*. 52.4 mg/dL, P = 0.024). The odds ratios (95% CI) of MetS from multivariate logistic regression were 0.57 (0.32–1.03) for individuals in the T2 of ULL and 0.39 (0.24–0.64) for individuals in the T3 of ULL, respectively (P-value for the trend 0.022). **Conclusions** ULL was negatively associated with MetS in older adults. Further research is needed to identify potential mechanisms.

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Keywords: Metabolic syndrome; Older adults; Upper leg length

1 Introduction

Metabolic syndrome (MetS), a clustering of cardiometabolic risk factors consisting of central obesity, hypertension, dyslipidemia, and insulin resistance (IR),[1] is associated with an increased risk of cardiovascular disease (CVD) and type 2 diabetes (T2D).[2] The risk factors are more prevalent among older adults, and it is estimated that over 40% of older adults in the USA aged 60 years and above have MetS.[3,4] The prevalence of MetS is higher in women compared to men and Hispanics and blacks compared to non-Hispanic whites.[3] The prevalence of MetS has been reported to be increased with lower levels of education[5] and poor lifestyles, such as a lack of physical activity,[6] increased alcohol intake,[7,8] and increased cigarette smoking.[9] Further, those born with high or low compared normal birth weights,[10] and post-menopausal compared to pre-menopausal women have higher rates of MetS.[11]

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Interestingly, stature measurements, such as height, leg length, and femur length, have been found to be inversely associated with the risk of CVD and T2D in adults.[12–18] Leg length is also inversely associated with systolic blood pressure (SBP), obesity, and IR.[19,20] Shorter stature is considered as a proxy indicator of poor nutritional status during early childhood, which may alter metabolism pattern that increases the risk for CVD in later life.[21,22] However, osteoporosis leads to a decrease in stature among elderly individuals.[23,24] For example, men and women may lose an average of 1 cm in standing height every 10 years after the age of 40.[23] The shrinkage of stature in the elderly is mainly due to the osteoporosis occurring in the spine, which affects trunk length dramatically.[25,26] Compared to trunk length, femur bone length is less likely to be affected by osteoporosis and, therefore, a more reliable indicator of early life nutritional status when examining its relationship with cardiovascular disease among seniors.[25,26] A shorter femur bone, leg length, or leg length-to-height ratio has been linked to IR, T2D, high blood pressure, and higher body fat.[19,20]

It would be interesting to examine whether or not there is a risk association of stature components with MetS among elderly adults. This may provide knowledge of the disease mechanism and direction of prevention and/or intervention for future research. Therefore, using data from a National Health and Nutritional Examination Survey (NHANES, USA),[27] we investigate the relationship between upper leg length (ULL) and MetS among seniors, and we hypothesized that ULL will be negatively associated with MetS.

2 Methods

The NHANES 2009–2010 data were used for this analysis. The information regarding the background and design can be found elsewhere.[27] In brief, 10,537 individuals aged 2–80 years were surveyed during 2009–2010. A total of 2,005 individuals aged 60 years or older participated this survey. After excluding those who were not in the morning laboratory sample (n = 1,032) there were 973 participants. After further excluding those with missing information for defining MetS, i.e., waist circumference, high density lipoprotein cholesterol, triglycerides, blood pressure, and fasting blood glucose, 786 individuals (385 men and 401 women) were included in this study.

Venous blood samples collected after an overnight fasting for at least 9 h was completed and processed, stored (frozen at −20°C), and shipped to Fairview Medical Center Laboratory at the University of Minnesota, Minneapolis for analysis. The laboratory analysis follows the NHANES laboratory protocol.[27] Fasting blood glucose (FBG) was measured using an enzymatic method while triglycerides and high density lipoprotein cholesterol (HDL-C) were measured using the Roche modular P chemistry analyzer. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken at the mobile exam centers by research assistants using a sphygmomanometer to the nearest 1 mmHg. Participants were instructed to rest in a sitting position quietly for 5 min prior to measurement. Three measurements were recorded, and the average of these three was used for both SBP and DBP in this analysis. Waist circumference (WC) was measured by a trained research assistant using a measuring tape estimating the distance around the participant's waist. It was reported to the nearest 0.1 cm. Furthermore, MetS, was defined as having at least three of the following components based on National Cholesterol Education Program guidelines: central obesity (WC ≥ 102 cm in men and ≥ 88 cm in women), high triglycerides (serum triglyceride level ≥ 150 mg/dL), low HDL-C (serum HDL-C < 40 mg/dL for men and < 50 mg/dL for women), hypertension (BP ≥ 130/85 mmHg or currently taking medication for hypertension), and IR (FBG ≥ 110 mg/dL).[28]

ULL was measured to the nearest 0.1 cm following the NHANES protocol as the horizontal distance between the distal end of the femur and the inguinal crease (just below the anterior superior iliac spine). Metal, sliding calipers were used to mark the distal end of the femur while participants were instructed to sit on a bench with a 90 degree bend in the knee. In the analysis, ULL (in cm) was first examined as a continuous variable and then categorized into gender-specific tertiles (Ts). The cut-off points of these tertiles (T1–T3) are: 0–37.52, 37.52–40.38, and > 40.38, respectively for men, and 0–32.87, 32.87–35.71, and > 35.71, respectively for women.

Covariates considered in this study were: gender (men/ women), ethnicity (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, or other race), age (years), education [having at least partially completed college or having an AA degree; (yes/no)], moderate physical activity (yes/no), diabetes (yes/no), myocardial infarction (MI) history (yes/no), family history of heart attack (yes/no), alcohol intake [consumed at least 12 alcoholic drinks in the past year (yes/no)], and cigarette smoking (current, ex-smoker, or never). Physical activity information was collected using a validated Global Physical Activity Questionnaire.[29] Moderate physical activity was defined as regularly engaging in any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate. Diabetes status was defined as either diagnosed diabetes by a physician or currently taking medication for diabetes. MI history was defined as being told by a physician that he or she had an MI. A family history of heart attack was defined as having a close relative, either alive or deceased, who has been diagnosed of a heart attack by a physician.

All analyses were conducted using survey procedures in SAS 9.3 (SAS Institute Inc., Cary, NC, USA), which take into account the weighted and clustered sampling design of the NHANES. Student t tests or analysis of variance was used for comparison of continuous variables and chi-square or Fisher's exact was used for categorical variables when appropriate. The age and gender adjusted means were calculated for MetS components (FBG, HDL-C, triglycerides, WC, SBP and DBP) across tertiles of ULL. Logistic regression was performed to assess the relationship between ULL and MetS after adjusting for all the covariates. Multi-collinearity among predictor variables was checked using variance inflation factor. The gender-ULL interaction was examined in the related analyses. All tests were conducted in two-tailed with an alpha set at 0.05 for statistical significance.

3 Results

Overall the prevalence of MetS was 41.7%. MetS was more prevalent in women than in men (49.1% *vs*. 38.7%, P < 0.05). The characteristics of participants by gender are shown in Table 1. Both genders had a similar characteristic profile, except for women with lower proportions of alcohol intake (5.4% *vs*. 21.5%, $P < 0.0001$) and MI history (4.7% *vs*. 14.0%, $P < 0.0001$).

There was no interaction between gender and ULL tertiles ($\chi^2 = 0.52$, $P = 0.47$). The gender combined characteristics of participants by tertiles of ULL are shown in Table 2. Individuals in T3 compared to T1 were more likely to be white (84.7% *vs*. 65.8%, $P < 0.0001$), with a higher education (65.2% *vs*. 42.3%, $P < 0.0001$), higher moderate physical activity (48.0% *vs*. 35.8%, $P = 0.002$), but less likely to have diabetes (12.9% *vs*. 27.1%, $P = 0.003$) or MetS (30.6% *vs*. 55.0%, $P < 0.0001$).

Table 1. Characteristics of participants aged 60 years and above in the NHANES (2009–2010) by gender.

	Men (*n* = 385)	Women (*n* = 401)
Age, yrs	69.5 ± 0.3	70.5 ± 0.4
White race, %	80.0	80.0
Some college education, %	51.8	51.0
#Current smoker, %	10.7	6.7
#Ex-smoker, %	50.4	33.8
#At least 5 alcoholic drinks/day, %	21.5	5.4*
Moderate physical activity, %	44.4	36.6
#BP medication, %	95.1	97.5
Diabetes, %	21.9	18.0
#MI history, %	13.0	4.7*
#Family history of heart attack, %	13.9	18.2
#Upper leg length, cm	39.4 ± 0.3	35.2 ± 0.2*

Data are presented as mean ± SE or percent. *Indicates a statistically significant difference ($P < 0.05$) in comparing T3 to T1 and T2 to T1; #Indicates a sample size decrease. BP: blood pressure; MI: myocardial infarction; NHANES: National Health and Nutritional Examination Survey; T1–T3: upper leg length tertiles.

Table 2. Characteristics of participants aged 60 years and above in the NHANES (2009–2010) by tertiles of upper leg length (*n* = 786).

	T1	T2	T3
N	258	258	270
Male, %	46.7	46.7	42.1
Age, yrs	70.9 ± 0.5	70.7 ± 0.6	69.0 ± 04*
White race, %	65.8	85.5*	84.7*
Some college education, %	42.3	45.2	65.2*
#Current smoker, %	8.2	8.5	8.7
#Ex-smoker, %	43.2	43.9	37.8
#At least 5 alcoholic drinks/day, %	12.8	15.7	11.6
Moderate physical activity, %	35.8	34.0	48.0*
#BP medication, %	96.5	98.4	97.5
Diabetes, %	27.1	22.3	12.9*
#MI history, %	9.7	7.4	8.4
#Family history of heart attack, %	19.6	15.8	13.5

Data are presented as mean ± SE or percent. #Indicates a sample size decrease; *Indicates a statistically significant difference in comparing T3 to T1 and T2 to T1 ($P < 0.05$). BP: blood pressure; MI myocardial infarction; NHANES: National Health and Nutritional Examination Survey; T1–T3: upper leg length tertiles.

Figures 1–3 show the gender and age adjusted means of each MetS component by tertiles of ULL. The statistically significant differences were observed in mean levels of triglycerides, SBP, and HDL-C ($P < 0.01$ for trends). Age and gender adjusted prevalence of MetS was almost two times higher in T1 compared to T3 individuals (Figure 4).

The adjusted odds ratios of MetS for tertiles of ULL from three logistic regression models are shown in Table 3. After adjustment for age and gender (Model 1), compared to the reference group T1 the odds ratio (95% CI) of MetS were significantly lower for individuals in T2 [0.61 (0.38–0.97), $P < 0.0001$] and T3 [0.37 (0.24–0.59), $P < 0.0001$]. The further

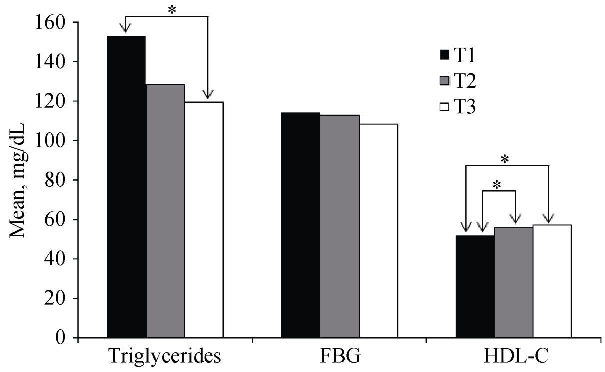

Figure 1. Mean differences of triglycerides, FBG, HDL-C between the tertiles of upper leg length in elderly adults after adjusting for age and gender. *$P < 0.05$, $n = 786$. FBG: fasting blood glucose; HDL-C: high density lipoprotein cholesterol; T1–T3: upper leg length tertiles.

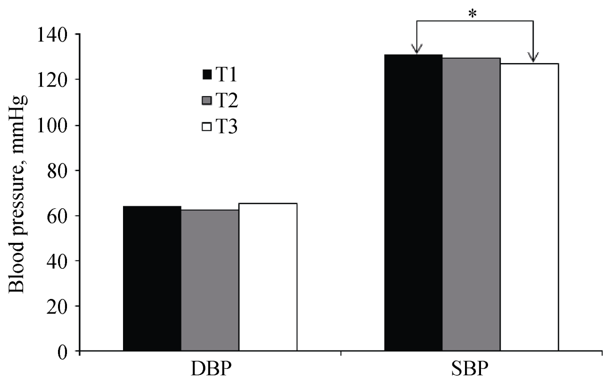

Figure 2. Mean differences of SBP and DBP (mmHg) between the tertiles of upper leg length in elderly adults after adjusting for age and gender. DBP: diastolic blood pressure; SBP: Systolic blood pressure; T1–T3: upper leg length tertiles. *$P < 0.05$, $n = 786$.

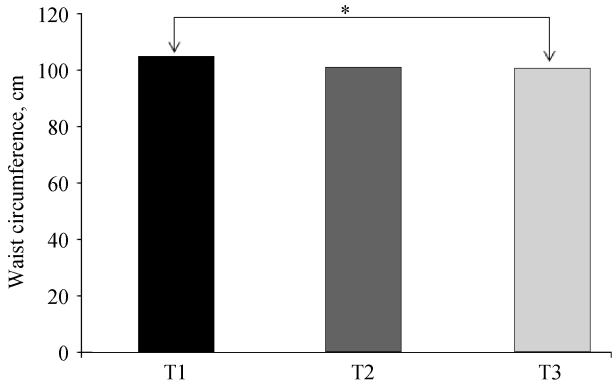

Figure 3. Mean difference of waist circumference (cm) between the tertiles of upper leg length in elderly adults after adjusting for age and gender. T1–T3: upper leg length tertiles. *$P < 0.05$; $n = 786$.

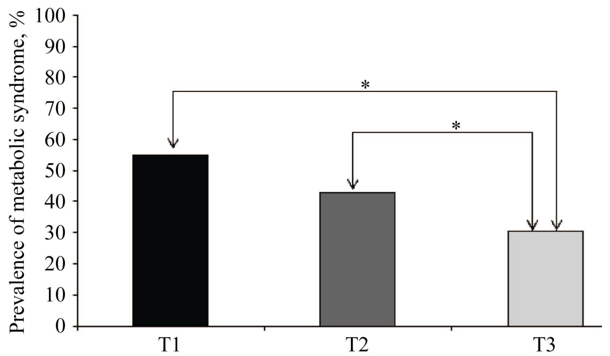

Figure 4. Age and gender adjusted prevalence of metabolic syndrome (n = 786). T1–T3: upper leg length tertiles.

Table 3. Logistic regression analyses of upper leg length on metabolic syndrome in participants aged 60 years and over in the NHANES (2009–2010).

	OR	95% CI	*P*-values for trends
Model 1			
T1	1.00		< 0.0001
T2	0.61	(0.38–0.97)	
T3	0.37	(0.24–0.59)	
Model 2			
T1	1.00		< 0.0001
T2	0.57	(0.36–0.91)	
T3	0.36	(0.24–0.55)	
Model 3			
T1	1.00		< 0.0001
T2	0.57	(0.32–1.03)	
T3	0.39	(0.39–0.64)	

Model 1: ULL with gender and age; Model 2: further adjusted for ethnicity and education; Model 3: further adjusted for moderate physical activity, smoking status, alcohol intake, diabetes, MI history, and family history of heart attack. MI: myocardial infarction; NHANES: National Health and Nutritional Examination Survey; T1–T3: upper leg length tertiles. ULL: upper leg length.

adjustment for ethnicity and education (Model 2) and physical activity, smoking status, alcohol intake, diabetes, MI history, and family history of heart attack (Model 3) did not change the relationship though the odds ratio in T2 was not statistically significant.

4 Discussion

Using the NHANES 2009–2010 data, we examined the association between ULL and MetS and also each individual component of MetS among older US adults. We found that compared to those with longer ULL individuals with shorter ULL had significantly higher levels of triglycerides, WC, and SBP, but lower levels of HDL-C. Therefore, MetS was more prevalent among those with shorter ULL.

The relationship between short stature and risk of CVD has been repeatedly observed.[19,20] Short stature or short stature components have been also linked to the risk factors of CVD, including IR, T2D, high blood pressure, and higher body fat.[19,20] A recent study indicates that shorter leg length-to-height ratio was even positively associated with the risk of MetS in children.[30] However, no studies have examined the association between ULL and MetS in elderly adults. We decided to use ULL instead of total stature because the shrinkage of stature in the elderly is mainly due to the osteoporosis occurring in the spine, which affects trunk length dramatically, rather than femur length.[25,26] This study brings knowledge to the literature surrounding the relationship between stature measurements and MetS. As predicted, ULL was negatively associated with MetS in elderly adults. Future studies should investigate potential mechanisms for this relationship. One potential mechanism for the protective effect of longer femurs may be related to elevated levels of osteocalcin. This hormone is involved in stimulating pancreatic β-cells and adipocytes to release insulin and adiponectin thereby ameliorating IR and decreasing the risk of T2D and CVD.[31,32] Another potential mechanism is poor early nutrition.[21] Since short stature (shorter femur) is positivity associated with disenfranchised childhood environment, this association could be reflective of early nutrition risk to cardiovascular diseases later in life.[21,22] Knowing that stature is the result of an interaction between genetic and environmental factors, it is also important to capture genetics. Nelson, *et al*.[33] examined the association between genetically determined height and the risk of coronary artery disease via an analysis of height-associated genes. The authors found an association between genetically determined shorter stature and an elevated risk of coronary artery disease, which is partially explained by the relationship between height and an undesirable lipid profile (triglycerides and HDL-C). Further, in the present study, a shorter stature

(ULL) was negatively linked to the same lipid components of MetS.

The prevalence of MetS was 41.7% which was similar to other studies.[3,4] The prevalence in males and females was 38.7% and 49.1%, respectively. The gender difference observed in this study was similar to a study by Yaffe, *et al*.[4] Post-menopausal status in women and birth weight data were not available, and future studies should consider them because they are associated with MetS.[10,11] A key strength of this study was using weighted analyses since it improves generalizability. Further, the groupings of ULL were created using gender-specific tertiles. The other strength was controlling for many important covariates related to MetS, such as diabetes, smoking, family history of MI, previous MI, and others.

In conclusion, there was a negative relationship between ULL and MetS in older adults. Future studies need to examine potential mechanisms. It is possible that ULL could be used clinically as a predictive stature measurement of MetS in older adults.

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