ORIGINAL RESEARCH

Prevalence of Metabolic Syndrome and Association with Grip Strength in Older Adults: Findings from the HOPE Study

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Objective: To determine the prevalence of metabolic syndrome (MetS) in older adults and assess the association of MetS and adverse outcomes with handgrip strength (HGS), HGS/body weight (BWT), and HGS/body mass index (BMI).

Methods: A cross-sectional population study in Singapore. Data were collected on demographics, HGS, Timed-Up and Go (TUG), fasting glucose, lipid profile, blood pressure, waist circumference, frailty status, and cognition in 722 older adults ≥65 years old. MetS was defined using the Modified ATP III for Asians where at least three of the following conditions must be fulfilled, central obesity, high blood glucose (or diagnosed diabetes mellitus), high blood pressure (or diagnosed hypertension), low high-density lipoprotein, and high triglycerides. The waist circumference in the Modified ATP III for Asians is ≥90 cm for males or ≥80 cm for females. HGS and HGS normalized by BWT or BMI were used for the association.

Results: The prevalence of MetS in older adults was 41.0%, and those ≥85 years old 50.0%. The prevalence was higher in females ≥70 years old, with 8 in 10 females ≥85 years having MetS. After adjusting for age, years of education, physical exercise, as well as history of smoking and alcohol consumption, higher HGS normalized by BWT or BMI was significantly associated with lower odds of having MetS (OR: 0.51, 95% CI 0.43–0.61, $p<0.01$) and (OR: 0.13, 95% CI 0.07–0.24, $p<0.01$).

Conclusion: Almost 1 in 2 older adults had MetS, with the prevalence in females much higher than that in males over 70 years old. Our findings suggest that both HGS/BWT and HGS/BMI had a significant negative association with MetS, its components, and adverse effects. Further studies are needed to validate the association and to determine optimal cutoffs of HGS/BWT and HGS/BMI for MetS, and the effectiveness of interventions in averting the risk.

Keywords: handgrip strength, metabolic syndrome, prevalence, sarcopenia, older adults

Introduction

The prevalence of metabolic syndrome (MetS) is rapidly increasing in countries with fast-aging populations.[1] MetS is defined as a cluster of cardiometabolic risk factors including diabetes, central obesity, hypertension, elevated fasting plasma glucose, elevated triglycerides, and reduced high-density lipoprotein. It is associated with increased morbidity and mortality including non-alcoholic fatty liver disease, cognitive impairment, cardiovascular disease, and functional decline.[2,3] Skeletal muscle plays a crucial role in the body's glucose metabolism and up to three-quarters of ≥75-year-old people have glucose intolerance.[4] Insulin resistance is increasingly known as a major

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cause of MetS.[5] Several studies have reported that sarcopenia and low muscle mass are risk factors for MetS.[6–8] The current consensus on the diagnosis of sarcopenia includes low muscle strength, low skeletal muscle mass, and/or low physical performance. Handgrip strength (HGS) correlates with total muscle strength and has been shown to predict many adverse outcomes including functional decline, falls, and mortality.[9–11] While there is an association between HGS and MetS, a direct correlation between HGS and MetS is still an ongoing debate.[12–14] It was initially proposed by Ploutz-Snyder et al that correcting muscle strength for bodyweight was a better predictor of functional performance, and more recent findings reported that HGS adjusted for BMI or BWT may better reflect muscle quality.[13,15] Muscle power is thought to decline before muscle strength followed by muscle mass, and is relevant for many daily tasks which in turn could be attributed to muscle quality.[16]

In countries with rapidly aging populations, screening for risk factors, detection, and prevention should be an urgent priority. There are recent studies suggesting HGS/BMI or relative grip strength is better correlated with MetS and adverse outcomes. In addition, to our knowledge, there are no studies on the prevalence of MetS in older adults in Singapore. The aim of our study was to determine the prevalence of MetS in older adults, and assess the association of MetS, components of MetS, and adverse outcomes with HGS, HGS/BWT, and HGS/BMI.

Methods
Participants
The population of this study is a subgroup of the Healthy Older People Everyday (HOPE) study, a sub-cohort of the Singapore Population Health Studies – Community Health Study, conducted between April 2015 and August 2016.[17] HOPE was a cross-sectional and nationally representable cohort where 1051 older adults ≥65 years old were recruited from a defined geographical area in the northwest of Singapore. Participants were excluded if baseline information on MetS was incomplete or participants did not agree on fasting blood tests. Complete data were available for only 722 participants. Further details on recruitment, questionnaires, physical and cognitive assessment are elaborated in prior publications.[17,18]

Procedures
The demographic questionnaire included questions on socio-demographics, lifestyle, education level, chronic illness, falls, physical activity including the number of minutes walked or cycled each day, physical and mental health, quality of life, and functional status, which were self-reported by the participants. Mental health was assessed using Mini Mental State Exam (MMSE) and cognitive impairment was defined as MMSE <24.[19] The cognitive level was further adjusted using age and education level.[20] Katz Index for activities of daily living (ADL) was administered to assess participants' functioning level.[21] Participants reported their level of independence in performing six different functions, namely, bathing, dressing, toileting, transferring, and continence. The 5-item FRAIL scale (Fatigue, Resistance, Ambulation, Illness, and Loss of Weight) which has been validated in many countries was used to screen for frailty.[22,23] A score of 0 represents robust, 1–2 represents pre-frail, and 3–5 represents frail. Self-perceived health rating was assessed using the EQ-Visual Analogue Scale (VAS) where participants rate their overall health from a scale of 0 (poorest state of health) to 100 (best state of health) by looking at a 20 cm long scale.[24] These were all conducted during a face-to-face interview at the participant's home or the nearby Resident's Committee center.

Physical and Biochemical Assessment
Following the interview, participants were given an option to undergo a health screening which comprised of physical examination and blood test. The physical examination included measurement of weight, height, blood pressure, and waist circumference. Waist circumference (WC) was measured midpoint between last rib and the iliac crest, blood pressure measured in seating position and the average of two attempts was used. Physical performance screening included the Timed-Up-and-Go (TUG) test[25] and HGS. TUG recorded the time the participant took to raise up from a chair, walk a distance of 3 m and return back to the seat using a stopwatch. HGS was measured three times in a seated position with each arm flexed at a 90° angle using a digital dynamometer (A5401, Takei Scientific Instruments Co., Ltd, Japan). Only the maximum HGS reading for the dominant hand was used in analyses together with HGS normalized with BWT or BMI. Fasting bloods were collected in the morning for lipid profiling which included triglycerides (TG), high-density lipoprotein cholesterol (HDLc), and glucose. Collected blood samples were analyzed on the same day at National University Hospital laboratories.

Metabolic Syndrome

The definition of MetS was based on criteria defined by the Modified ATP III for Asians which includes the presence of 3 or more of the following five components 1) waist circumference ≥90 cm for males or ≥80 cm for females, 2) TG ≥150 mg/dL, 3) HDLc <40 mg/dL in males or <50 mg/dL in females, 4) blood pressure (BP) ≥130/85 mmHg or use of antihypertensive medication, and 5) fasting plasma glucose ≥100 mg/dL or use of pharmacologic treatment for diabetes mellitus.[26]

Statistical Analysis

All analyses were performed using IBM SPSS Statistics 25.0 with statistical significance set at p <0.05. Characteristics of participants were presented as mean and standard deviation for continuous variables while categorical variables were presented as frequencies and percentages. Differences in the numerical variables between those with and without MetS were assessed using 2 sample t-test when normality and homogeneity assumptions were satisfied, otherwise Mann–Whitney U-test was performed. Chi-square test was used for categorical variables. Binary logistic regression was performed to determine the influence of HGS, HGS/BWT, and HGS/BMI on MetS, its individual components, ADL impairment, frailty status, and cognitive impairment. The z-scores of HGS, HGS/BWT, and HGS/BMI were used to obtain a standardized comparison of the odds ratios on MetS. All logistics models had the Hosmer Lemeshow goodness of fit statistic satisfied except for at least prefrail, thus results need to be interpreted with caution. Linear regression was performed to determine the influence of the same predictors on TUG. Regression models were unadjusted in Model 1 and adjusted for age in Model 2 as well as years of education, walking/cycling duration, history of smoking and alcohol consumption in Model 3. The assumptions of constant variance and residual normality were checked.

The study protocol was approved by the National Healthcare Group (NHG) Domain Specific Review Board (DSRB) whose requirements are based on the Declaration of Helsinki and the ethical principles in the Belmont Report, and all participants signed an informed consent form. Any research proposals which involve the National University of Singapore and other restructured hospitals in Singapore can be submitted to NHG DSRB.

Results

The prevalence of MetS in the sampled population was 41.0%. Table 1 presents the demographic differences between MetS and no-MetS older adults. There was no significant age or gender difference between the two groups. There were significant ethnic differences in the prevalence of MetS with one in two of the Indian ethnic group, compared to one in three amongst the Chinese ethnic group. The MetS group had significantly higher BMI (26.5 ± 3.8 kg/m^2 vs 23.0 ± 3.5 kg/m^2) and higher systolic blood pressure (138 ± 20 mmHg vs 131 ± 19 mmHg) than the no-MetS group. The MetS group was also less active, on average walking or cycling for 34 ± 74 minutes compared with no-MetS 40 ± 50 minutes. The prevalence of frailty amongst the MetS group was almost double (7.2% vs 4.5%), with almost 1 in 7 having difficulty walking 50 metres and 1 in 10 having more than 5 illnesses. Although non-significant, there were more older adults with MetS who were separated/divorced or widowed and had lower education.

Those with MetS had significantly longer TUG of 11.9 ± 3.7 compared with 10.8 ± 4.1 seconds and worse cognition based on the MMSE score (26.2 ± 4.5 vs 27.2 ± 3.1). Though not statistically significant, maximum HGS was lower, and after normalizing for BWT and BMI, respectively, significant differences between the groups were observed.

Figure 1 shows the prevalence of MetS across gender and the 5-year age groups. The overall prevalence increased from 65 to 74 years old from 40.5% to 44.7%, reduced to 32.0% between 75 and 79 years, and increased again to 50% for the ≥85-year-old participants with MetS. The prevalence of MetS amongst females was higher than for males ≥ 70 years old, although the confidence interval overlapped, with 8 in 10 females ≥85 years having MetS.

Figure 2 shows the prevalence of individual MetS components across age, with hypertension being most prevalent across gender and age groups. As age increased, prevalence of hypertension was observed to increase. Generally, more females had central obesity as compared to men, regardless of age groups, and prevalence increased with age. The prevalence of elevated fasting glucose and/or diabetes remained relatively stable between 25% and 45% across gender and age group. A slightly lower proportion of females had high TG as compared to males below 75 years old, where the trend reversed after the age of 75 years with a greater difference in prevalence with increasing age. The prevalence of low HDL in men

Table 1 Characteristics of Participants in Mean ± Standard Deviation or Frequency (Percentage) in 722 Elderly in the HOPE Study (2015–2016)

	All 722 (100.0)	No Metabolic Syndrome 426 (59.0)	Has Metabolic Ssyndrome 296 (41.0)	P-value
Age, years	71 ± 5	71 ± 5	71 ± 5	0.970
Gender,n				0.119
Male	325 (45.0)	202 (47.4)	123 (41.6)	
Female	397 (55.0)	224 (52.6)	173 (58.4)	
Ethnicity,n^				0.017
Chinese	592 (82.0)	365 (61.7)	227 (38.3)	
Malay	41 (5.7)	19 (46.3)	22 (53.7)	
Indian	44 (6.1)	19 (43.2)	25 (56.8)	
Body weight, kg	61.3 ± 11.0	57.9 ± 9.9	66.3 ± 10.7	<0.01
BMI, kg/m^2	23.4 ± 4.1	23.0 ± 3.5	26.5 ± 3.8	<0.01
Education, years	6.3 ± 4.4	6.5 ± 4.4	6.0 ± 4.3	0.133
Systolic pressure, mmHg	134 ± 20	131 ± 19	138 ± 20	<0.01
Diastolic pressure, mmHg	70 ± 10	69 ± 9	71 ± 10	<0.01
Physical activity, n				
Engage in vigorous activity	26 (3.6)	18 (4.2)	8 (2.7)	0.280
Engage in moderate activity	221 (30.6)	136 (31.9)	85 (28.7)	0.358
Walk/bike per day (mins)	38 ± 59	40 ± 51	36 ± 69	0.191
History of smoking,n	212 (29.4)	123 (28.9)	89 (30.1)	0.729
History of alcohol consumption,n	421 (58.3)	264 (62.0)	157 (53.0)	0.017
MetS components, n				
Central obesity	436 (60.4)	168 (39.4)	269 (90.5)	<0.01
Hypertension	538 (74.5)	264 (62.0)	274 (92.6)	<0.01
Elevated fasting glucose	223 (30.9)	48 (11.3)	175 (59.1)	<0.01
High triglycerides	193 (26.7)	34 (8.0)	159 (53.7)	<0.01
Low high-density lipoprotein	219 (30.3)	48 (11.3)	171 (57.8)	<0.01
Frail status, n				0.015
Robust	420 (58.6)	267 (62.8)	153 (52.4)	
Pre-frail	257 (35.8)	139 (32.7)	118 (40.4)	
Frail	40 (5.6)	19 (4.5)	21 (7.2)	
Fatigue, n	182 (25.4)	97 (22.8)	85 (29.1)	0.057
Resistance, n	77 (10.7)	41 (9.6)	36 (12.3)	0.254
Aerobic, n	82 (11.4)	41 (9.6)	41 (14.0)	0.069
Illnesses, n	34 (4.7)	10 (2.4)	24 (8.2)	<0.01
Loss Of Weight, n	83 (11.6)	46 (10.8)	37 (12.7)	0.447
At least one ADL impairment, n	118 (16.3)	59 (13.8)	59 (19.9)	0.030
One or more falls, n	86 (11.9)	48 (11.3)	38 (12.8)	0.522
Timed-up and go, s	11.3 ± 4.0	10.8 ± 4.1	11.9 ± 3.7	<0.01
Grip strength, kg	22.5 ± 6.9	22.8 ± 6.7	22.1 ± 7.1	0.165
Grip strength/weight	0.4 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	<0.01
Grip strength/BMI	1.0 ± 0.3	1.0 ± 0.3	0.9 ± 0.3	<0.01
Health rating, score	80.8 ± 14.4	81.4 ± 14.0	80.1 ± 14.9	0.294
MMSE, score	26.8 ± 3.7	27.2 ± 3.1	26.2 ± 4.5	<0.01
Poor cognition (MMSE 0-23), n	64 (8.9)	33 (7.7)	31 (10.5)	0.205
Poor cognition by age and education, n	45 (6.2)	21 (4.9)	24 (8.1)	0.082

Notes: Figures presented as means ± SD for continuous variables or frequencies (%) for categorical variables. *P*-value for continuous variables (Mann–Whitney *U*-test) and for categorical variables (Chi-square). ^Percentages within ethnic group.
Abbreviations: BMI, body mass index; ADL, activities of daily living; MMSE, mini-mental state examination.
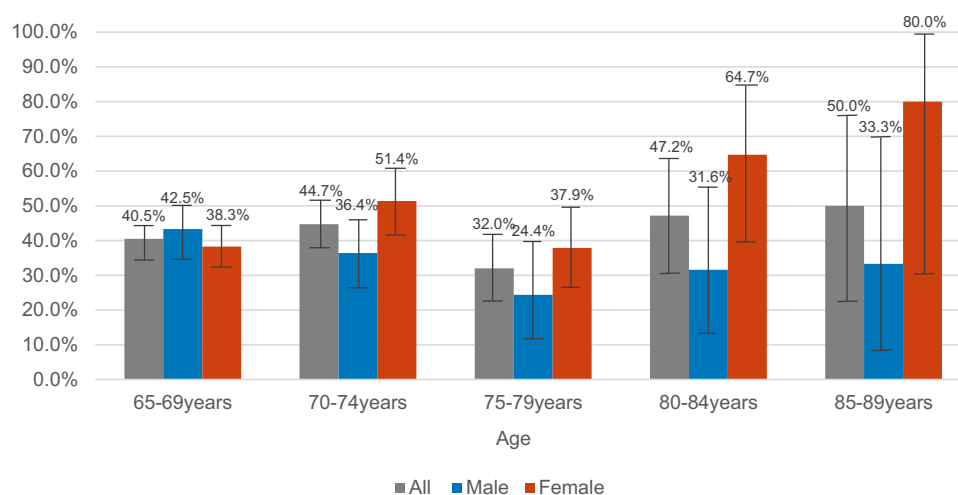
Figure 1 Prevalence of MetS by gender and age groups.

remained between 15% and 30%, while that of females was higher, especially above 80 years old.

The odds ratios of individual HGS indices on the risk of MetS are summarized in Table 2. Only after normalizing for BWT and BMI, respectively, HGS was observed to be associated with decreased odds of having MetS by almost 50% and 90%, respectively (OR 0.51,95% CI 0.43–0.61, p<0.01, and OR 0.13, 95% CI 0.07–0.24, p<0.01). Similar associations were also found for HGS/BWT and HGS/BMI on all other components of MetS. Additionally, the unadjusted model using Z scores showed that the measure of grip strength alone was associated with a reduction in risk of having MetS by 17% as compared to a reduction of 34% and 32% in risk associated with HGS/BWT and HGS/BMI, respectively. This suggests that the normalized grip measures were twice as effective as grip strength in predicting a reduction in risk of MetS. Similarly, HGS/BWT and HGS/BMI better predicted adverse outcomes compared with HGS alone for cognitive impairment, frailty/pre-frailty, TUG, and ADL impairment.
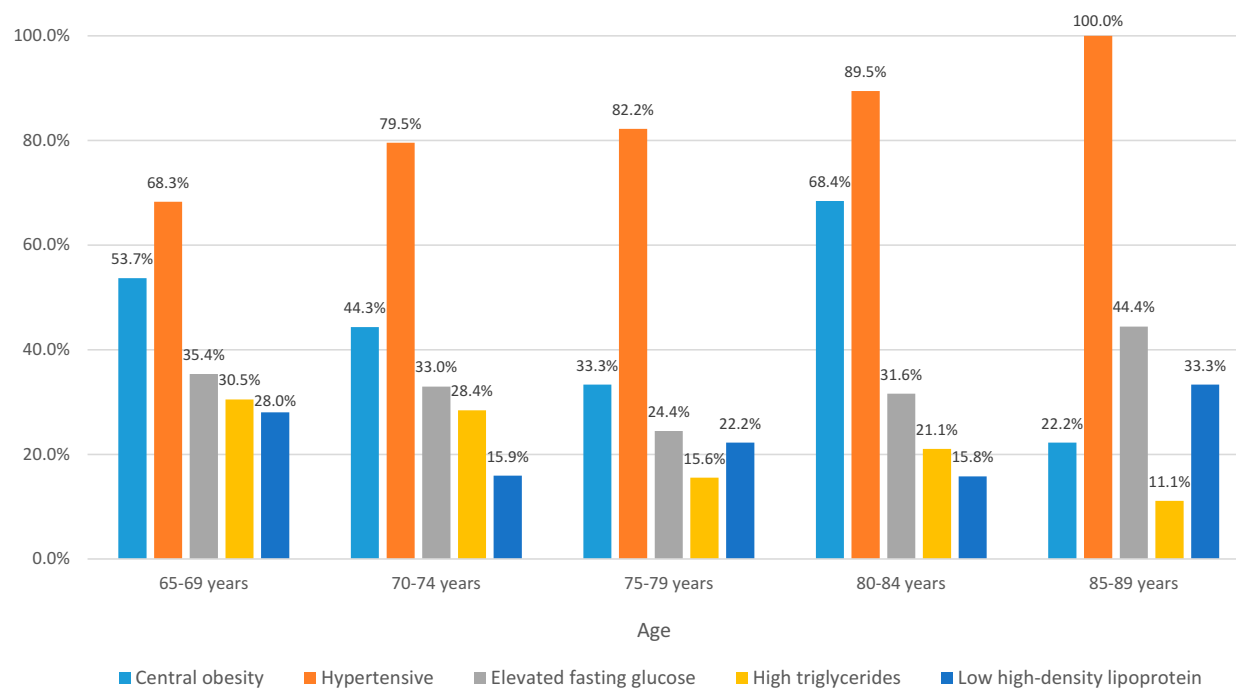
Discussion

The prevalence of MetS varies depending on the criteria used and age, and the worldwide prevalence of MetS is known to be between 22% and 44%.[27] The prevalence of MetS in our population increased up to the age of 70 years, took a sharp decline, and increased again. One of the hypotheses is that a subgroup with very high-risk cardiovascular risk factors may die, and the subsequent increase may be related to a sedentary lifestyle, mobility limitation, and lack of physical activity.[28–30] The participants in the MetS group walked or cycled less. A combination of health education and walking exercise has

been shown to reduce risk factors for MetS and lead to an improved lifestyle.[31] Given that prevalence of MetS increases with age, and almost all of the subjects had high waist circumference, efforts to increase awareness must begin early, and should be a public health priority for every country. Studies have shown that exercise can reduce or improve most parameters associated with MetS.[32] The higher prevalence of MetS in females after the age of 70 years is linked with menopause, where females with 20 years or more since menopause are more likely to have MetS and elevated blood pressure compared with those for whom menopause was 10 years ago or less.[33] The changes in lipid profile including increasing TG, total cholesterol, and low HDL levels are known to occur during the menopausal transition and post-menopause.[34] An interesting aspect of our study was that the prevalence of low HDL almost doubled in females after the age of 80 years old.

In addition to low relative HGS, our MetS group also had longer TUG. In a most recent study, longer TUG with or without low HGS was associated with increased short-term mortality.[35] Similar to other studies, our MetS group had significantly lower MMSE scores and a higher prevalence of cognitive impairment.[36] Persons with MetS are more likely to have vascular dementia related to hypertension, elevated fasting glucose, and hypertriglyceridemia. Similarly, frail persons are more likely to have elevated fasting glucose, and have a higher prevalence of cognitive impairment too.[37–40]

Of the MetS components, obesity and insulin resistance are known to be associated with sarcopenia. Sarcopenia and insulin resistance share a common pathway where the loss of skeletal muscle mass gives rise to insulin resistance, impaired suppression of gluconeogenesis, and reduced protein
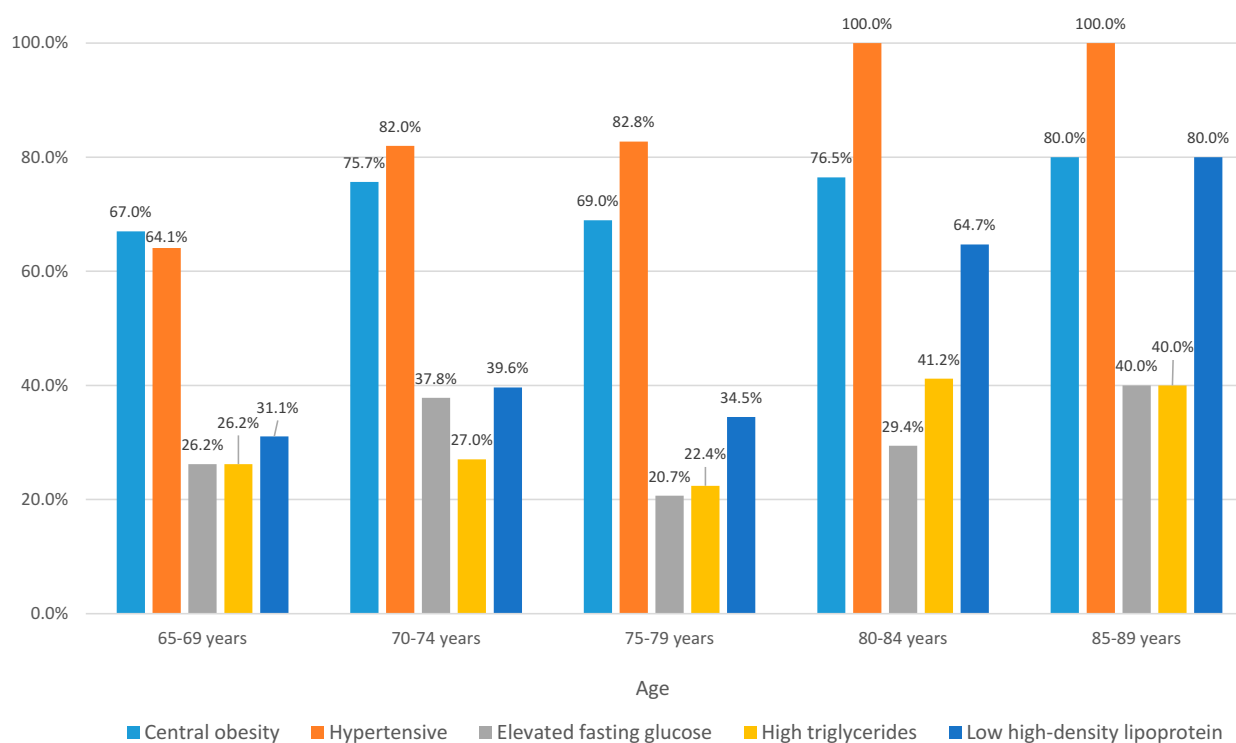
A

B

Figure 2 (**A**) Prevalence of MetS components across age groups (for males). (**B**) Prevalence of MetS components across age groups (for females).

Table 2 Odds Ratio and Beta-Coefficients (95% Confidence Interval) of Individual Grip Strength Indices on Risk of Metabolic Syndrome, Its Components, Cognition, and Physical Decline in 722 Older adults in the HOPE Study (2015–2016)

	Model 1 OR/Beta-Coefficient (95%CI)	Model 2 OR/Beta-Coefficient (95%CI)	Model 3 OR/Beta-Coefficient (95%CI)
Grip strength			
Metabolic syndrome	0.99 (0.97-1.01)	0.99 (0.96-1.01)	0.99 (0.96-1.01)
Central obesity	0.95 (0.93-0.97)**	0.95 (0.93-0.97)**	0.96 (0.94-0.99)**
Hypertension	0.99 (0.97-1.02)	1.01 (0.98-1.03)	1.02 (0.99-1.05)
Elevated fasting glucose	0.99 (0.97-1.01)	0.99 (0.97-1.01)	0.98 (0.96-1.01)
High triglycerides	1.01 (0.99-1.03)	1.01 (0.98-1.03)	1.01 (0.98-1.03)
Low high-density lipoprotein	0.97 (0.94-0.99)**	0.97 (0.95-0.99)**	0.98 (0.96-1.01)
Poor cognition (MMSE 0-23)	0.89 (0.85-0.93)**	0.89 (0.85-0.94)**	0.90 (0.85-0.95)**
Poor cognition adjusted by age and education	0.85 (0.80-0.90)**	1.03 (1.02-1.06)**	0.86 (0.80-0.92)**
At least 1 ADL impairment	0.95 (0.92-0.98)**	0.86 (0.80-0.91)**	0.96 (0.93-1.00)*
Pre-frail or frail	0.97 (0.95-0.99)**	0.97 (0.95-1.00)*	0.98 (0.95-1.01)
Timed up and go[#]	-0.15 (-0.20 - -0.11)**	-0.12 (-0.16–0.08)**	-0.13 (-0.18–0.09)**
Grip strength/body weight			
Metabolic syndrome	0.55 (0.47-0.64)**	0.54 (0.46-0.64)**	0.51 (0.43-0.61)**
Central obesity	0.30 (0.24-0.36)**	0.29 (0.23-0.35)**	0.28 (0.22-0.35)**
Hypertension	0.72 (0.61-0.84)**	0.75 (0.64-0.88)**	0.75 (0.63-0.90)**
Elevated fasting glucose	0.74 (0.64-0.87)**	0.74 (0.63-0.86)**	0.71 (0.59-0.85)**
High triglycerides	0.81 (0.69-0.95)**	0.80 (0.68-0.94)**	0.76 (0.64-0.90)**
Low high-density lipoprotein	0.69 (0.59-0.81)**	0.69 (0.59-0.81)**	0.73 (0.61-0.86)**
Poor cognition (MMSE 0-23)	0.52 (0.39-0.69)**	0.53 (0.40-0.71)**	0.58 (0.43-0.80)**
Poor cognition adjusted by age and education	1.08 (0.94-1.25)	0.44 (0.31-0.63)**	0.50 (0.34-0.73)**
At least 1 ADL impairment	0.43 (0.30-0.61)**	0.75 (0.61-0.92)**	0.77 (0.62-0.96)*
Pre-frail or frail	0.78 (0.68-0.90)**	0.80 (0.69-0.92)**	0.83 (0.71-0.97)*
Timed up and go[#]	-1.02 (-1.29 - -0.77)**	-0.88 (-1.11 - -0.64)**	-0.90 (-1.16 - -0.65)**
Grip strength/BMI			
Metabolic syndrome	0.19 (0.11-0.31)**	0.19 (0.11-0.31)**	0.13 (0.07-0.24)**
Central obesity	0.03 (0.02-0.06)**	0.03 (0.02-0.05)**	0.02 (0.01-0.04)**
Hypertension	0.35 (0.21-0.57)**	0.40 (0.24-0.67)**	0.38 (0.21-0.69)**
Elevated fasting glucose	0.50 (0.30-0.82)**	0.49 (0.30-0.81)**	0.39 (0.22-0.71)**
High triglycerides	0.57 (0.37-0.95)*	0.54 (0.32-0.92)*	0.43 (0.23-0.78)**
Low high-density lipoprotein	0.28 (0.17-0.48)**	0.29 (0.17-0.49)**	0.34 (0.18-0.61)**
Poor cognition (MMSE 0-23)	0.06 (0.02-0.17)**	0.07 (0.02-0.19)**	0.08 (0.03-0.28)**
Poor cognition adjusted by age and education	0.03 (0.01-0.12)**	0.03 (0.01-0.13)**	0.05 (0.01-0.20)**
At least 1 ADL impairment	0.37 (0.19-0.70)**	0.42 (0.21-0.82)*	0.42 (0.20-0.90)*
Pre-frail or frail	0.49 (0.31-0.78)**	0.53 (0.33-0.85)**	0.62 (0.36-1.06)
Timed up and go[#]	-3.26 (-4.12 - -2.40)**	-2.77 (-3.56 - -1.99)**	-3.02 (-3.91 - -2.14)**

Notes: Model 1 – Unadjusted, Model 2 – Adjusted for age, Model 3 – Adjusted for age, years of education, duration of exercise, history of smoking and alcohol consumption. *$p<0.05$, **$p<0.01$, [#]Not standardized coefficient.
Abbreviations: MMSE, mini-mental state examination; ADL, activities of daily living; BMI, body mass index.

synthesis. Diabetes and insulin resistance are associated with a decline in skeletal muscle mass.[41] Mitochondrial dysfunction which is prevalent in obesity is also associated with other age-related diseases including sarcopenia, cancers, and neurodegenerative disease.[42] Low muscle mass is a known cause for the development of MetS.[6,7,43] MetS has been shown to be positively associated with appendicular lean mass and forearm cross-sectional area and negatively correlated with muscle quality, especially in obese and overweight older adults with MetS.[44] There is a positive feedback loop between MetS and sarcopenia, where sarcopenia may also be exacerbated by obesity with excessive intramuscular fat deposition affecting muscle strength, quality, and contractility.[43,45] MetS with sarcopenia have worse outcomes

including weakness, functional impairment, increased morbidity, and mortality compared with either alone.[46] The diagnosis of sarcopenia requires measurement of muscle strength where HGS is recommended. The participants in our study had no significant difference in HGS between the MetS and no-MetS groups. However, there were significant differences between the 2 groups when HGS was adjusted for BMI and BWT, respectively. HGS adjusted for BMI or BWT was a better predictor for MetS and its components than HGS alone. HGS adjusted for BMI or BWT revealed a significantly better dose–response relationship with adverse outcomes including ADL assistance and cognition. Our findings further support an earlier finding that adjusting muscle strength for BWT or BMI was a better predictor of functional performance, MetS, dyslipidemia, cardiovascular risks, or prediabetes.[14,15,47–49] There are various theories which require further validation in obese or overweight participants with MetS, including the altered oxidative capacity of muscle fibers, intramuscular fat accumulation, and muscle quality accounting for reduced muscle strength despite larger fat-free mass.[50]

Our study has several strengths, including being a population-level study and including the old (70 to 79 years old) and old-old (≥80 years old). Most studies on MetS are limited to ≤70 years old. In addition to self-reported data, we have objective laboratory results to classify MetS and no-MetS. There are several limitations to our study. Firstly, participation in the health screening including blood tests was optional and those who did not agree to blood tests were younger, had lower cognition and education level, as well as a higher prevalence of hypertension; hence the prevalence of MetS may in fact be higher than observed. Secondly, the sample size of participants aged ≥80 years was small, resulting in a wider 95% confidence interval. Thirdly, the higher prevalence of cognitive impairment in the MetS group could have affected recall and physical performance, including HGS and TUG. Lastly, our study did not collect sleep data including sleep quality and duration, which have been reported to be associated with MetS.[51] More studies are needed to determine the prevalence and effect of MetS in the old-old and to identify biomarkers linking MetS to cancer, fatty liver, chronic diseases, and sarcopenia. In addition, further studies are needed to determine if interventions including resistance exercise and a high protein diet to improve muscle strength will lead to a lower prevalence of MetS.

Conclusion

The prevalence of MetS is on the rise in countries with aging population and it is associated with many negative outcomes including cardiovascular disease, functional decline, and cognitive impairment. Early detection of at-risk individuals is crucial as exercise programs have been shown to delay or reverse risks associated with MetS. HGS is a recommended assessment for muscle strength and diagnosis of sarcopenia. However, HGS adjusted for BWT or BMI is a better predictor for MetS, its components, and associated adverse outcomes. Further studies are needed prospectively to determine optimal cutoffs of HGS/weight and HGS/BMI to assess the risk of having MetS among community-dwelling older adults, if those with lower HGS/BMI are at greater risk of MetS and the effectiveness of interventions in averting the risk.

Acknowledgment

Disclosure

The authors declare no conflicts of interest for this work.

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