Sarcopenia, Obesity, and Cardiometabolic Risk Factors Among the Elder Population in Taiwan

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Abstract

Background: Sarcopenia and obesity have become important public health and clinical issues worldwide, especially in an aging society like Taiwan. The aim of this study was to evaluate the cardiometabolic risk factors among the different weight status and grip strength status among elder individuals in Taiwan.

Methods: We administered a series of community-based health surveys among the elder population in Chiayi County, Taiwan, from 2017 to 2019. Anthropometric characteristics, handgrip strength, and cardiometabolic risk profiles were measured using standard methods. History of chronic diseases was also asked. The questionnaires, including questions regarding any history of chronic diseases, were administered to the subjects under the assistance of a research technician.

Results: This study recruited 3739 subjects (1600 males and 2139 females). The non-obese group had lower blood glucose (BG) levels compared to the obese group (100.3 ± 32.2 mg/dl vs 109.1 ± 34.3 mg/dl for the male subjects; 102.8 ± 32.1 mg/dl vs. 112.5 ± 40.3 mg/dl for the female subjects). The grip strength was negatively associated with BG in both sexes ($\beta = -0.357$, $p < 0.001$ for the male subjects male and $\beta = -0.385$, $p < 0.05$ for the female subjects). Relationship between the grip strength and the risk of cardiometabolic disease showed that for every 1 kg increase in the grip strength, there was a 4.1% and 4.5% decrease in the risk for developing diabetes in male and female subjects, respectively (OR = 0.959, 95% CI = 0.940–0.979 for males and OR = 0.955, 95% CI = 0.932–0.978 for females).

Conclusions: A higher handgrip strength is associated with a lower BG level and lower risk for developing diabetes mellitus among elder population in Taiwan. Health promotion studies to increase muscle mass along with early rehabilitation programs should focus on the obese and sarcopenic population to prevent cardiometabolic comorbidities.

Background

Sarcopenia, defined as age-related loss of skeletal muscle mass, was first described by Rosenberg in 1988[1,2]. The diagnostic criteria of sarcopenia was defined by the European Working Group on Sarcopenia in Older People (EWGSOP) in 2010 by measuring the muscle mass, grip strength (GS), and gait speed[3]. In addition, the Asian Working Group for Sarcopenia (AWGS) in 2014 set a recommended cutoff for muscle quantity and quality for Asian population[4].

In 2018, the revised EWGSOP2 used handgrip strength to screen for sarcopenia because it better predicted advanced outcomes[5]. Measuring GS is a simple, quick, and inexpensive way to determine the overall muscle strength while also being a good indicator for fragility[6,7]. Many studies have shown that muscle strength is a prognostic factor for all cause death, cardiovascular death, and cardiovascular disease[6,8,9]. Moreover, surveys have also demonstrated the relationship between muscle strength and cardiometabolic risk factors in the elderly[10,11].

Both age-related loss of muscle and increased adipose tissue are important risk factors of cardiometabolic disorders in the elderly[12]. Obesity is associated with the occurrence of many chronic diseases such as hypertension, diabetes mellitus (DM), and dyslipidemia[13]. More recently, the concept of sarcopenic obesity had been established because of their shared association with metabolic disorders, morbidity, and mortality[12,14–16].

Taiwan was transform into an aging society in the past two decades. Approximately 17.09% of Taiwan's population in 2020 was aged 65 years and older. The municipality with the highest population of elderly individuals was Chiayi County, with 20.34% of its population being over the age of 65[17]. This study was to evaluate the cardiometabolic risk factors among different weight and handgrip strength status among elder individuals in Taiwan.

Materials And Methods

Study population

We administered a series of community-based health surveys among Chiayi County's elder individuals from 2017 to 2019. Those who were above 65 years old and have lived in Chiayi County for more than one year were invited to participate in the surveys. The inclusion criteria were individuals 65 to 85 years old who were free from any infectious disease or acute disorders in the past three weeks preceding the start of the surveys.

Questionnaire

General demographic data including gender, age, residency, education level, occupation, and the need for a caregiver were collected using a standard questionnaire. History of chronic diseases including DM, hypertension, cardiovascular disease, chronic kidney disease, any type of cancer, and cerebrovascular disease as well as medication history were recorded by research technician. Lifestyle patterns such as dietary habits, cigarette smoking, alcohol intake, and daily activity were also collected from the study participants.

Anthropometric measurements

The anthropometric characteristics including body weight (BW), height, waist circumference (WC), hip circumference (HIP), and body fat (BFAT) were measured using standard methods. The height was measured in meters using a digital stadiometer that recorded to the nearest 0.5 cm and the subjects were barefoot and wore only light indoor clothing. BW was measured to an accuracy of 0.1 kg using a standard beam balance scale. The BFAT was obtained using a segmental body composition analyzer (TBF-410, Tanita Corp., Tokyo, Japan) and was expressed as percentages. The WC and HIP were measured using standard methods suggested by the WHO (World Health Organization). The WC was measured to the nearest 0.1 cm at the midpoint between the margin of the last rib and the iliac crest of the ilium. The HIP was measured to the widest diameter of the pelvic region. We calculated the body

mass index (BMI) as BW (kg) divided by the square of the height (m^2), while the waist-to-hip ratio was calculated by WC (cm) divided by the HIP (cm).

Grip strength measurement

The GS was measured using digital dynamometers (TKK5101). All subjects were in a seated position while fully extending their elbows. After two to three minutes of rest, we measured the GS on either the right or left hand for two times. Two values for the GS were recorded, and the mean value of the two recordings was used for analysis[18]. The subjects were divided into four subgroups according to their BW classification and GS. Non-obese (OB-) subjects were defined as those with a BMI < 27, while obese (OB+) individuals were defined as those with a BMI ≥ 27. A normal grip strength (GS+) was defined as GS ≥ 30kg in males and GS ≥ 20 kg in females, and a weak GS (GS-) was defined as GS ≤ 30 kg in males and GS ≤ 20 kg in females[3].

Blood pressure measurement

Blood pressure was obtained after the subjects had rested for five to ten minutes. In a seated position, the subjects' arms were positioned at the same height as the heart and inserted into cuffs of appropriate sizes. Two measurements were recorded, and the mean value of the two recordings was used for data analysis.

Blood specimen collection

After 10–12 hours of overnight fasting, 10 ml of venous blood was collected from the subjects using a venous container. The plasma and serum were separated from the blood within one hour and stored at −80°C until analysis.

Plasma glucose and lipid profile measurement

The plasma glucose concentration of each subject was analyzed immediately after blood sampling and was determined by the glucose oxidase method using the Beckman Glucose Analyzer II (Beckman Instruments, Fullerton, CA)[19]. We measured the total cholesterol (CHOL) level using an esterase oxidase method[20] and the triglyceride (TG) level using an enzymatic procedure[21] using a Hitachi 7150 auto-analyzer (Hitachi, Tokyo, Japan). Levels of high-density lipoprotein (HDLC) and low-density lipoprotein (LDLC) were measured using an enzymatic method[22].

Approval of the IRB

All participants provided written informed consent and agreed to have their general demographic data, questionnaire, anthropometric data, and blood samples taken for this study. The institutional review board of the Tri-Service General Hospital approved this study (Number: TSGHIRB-1-108-05-073).

Statistical Methods

We used SPSS ver. 22 to conduct all statistical analyses. Continuous variables, such as anthropometric measures, grip strength, and cardiometabolic risk profile, were presented as sample mean and SD. The student's t-test was used to compare the differences between the groups. The analysis of variance (ANOVA) test was used to compare more than three groups. The categorical variables were described as numbers and percentages. The chi-square test was used to compare the differences among two or more groups. We used multivariate regression analyses and logistic regression analyses for further statistical inference. A two-tailed p value less than 0.05 was considered statistically significant.

Results

The distributions of anthropometric variables and cardiometabolic risk factors among study population by quartile grip strength subgroups with gender-specification were presented in Table 1. A total of 3739 subjects (1600 males and 2139 females) were recruited. The mean GS was 32.8 ± 7.2 kg for the males and 21.6 ± 4.8 kg for the females. The subjects were divided into four subgroups based on the quartile distribution of GS (Q1–Q4, lowest to highest). For both sexes, the subgroup with the highest GS also had the largest BMI, WC, HIP, and BFAT ($p < 0.001$).

Table 1

Distributions of anthropometric variables and cardiometabolic risk factors among study population by quartile grip strength subgroups with gender-specification (n = 3,739) (mean ± SD)

	Grip strength(kg)								
	Q1(lowest)		Q2		Q3		Q4(highest)		p-value
Male	< 28		28-32.85		32.85–37.4		> 37.4		
(n = 1,600)	(n = 399)		(n = 401)		(n = 397)		(n = 403)		
BHT(cm)	159.0	± 5.7	161.2	± 5.5	163.4	± 5.2	165.7	± 5.6	< 0.001
BWT(kg)	61.7	± 9.8	63.9	± 9.4	66.8	± 9.0	70.8	± 9.8	< 0.001
BMI(kg/m^2)	24.3	± 3.5	24.6	± 3.4	25.0	± 3.3	25.8	± 3.3	< 0.001
BWC(cm)	87.6	± 9.3	87.1	± 9.2	88.4	± 8.7	90.4	± 8.7	< 0.001
BHIP(cm)	93.7	± 6.9	94.0	± 6.1	95.2	± 6.1	97.2	± 6.2	< 0.001
WHR	0.93	± 0.06	0.93	± 0.06	0.93	± 0.06	0.93	± 0.06	0.214
BFAT(%)	22.3	± 6.8	22.1	± 6.8	22.5	± 5.9	24.0	± 5.8	< 0.001
SBP(mmHg)	138.4	± 19.3	139.5	± 18.6	137.7	± 17.7	139.2	± 17.0	0.489
DBP(mmHg)	78.7	± 11.4	81.1	± 10.5	82.3	± 11.0	84.6	± 10.5	< 0.001
BG(mg/dl)	105.9	± 33.3	104.7	± 30.6	106.4	± 30.7	101.7	± 23.9	0.119
TC(mg/dl)	177.6	± 36.9	179.6	± 33.7	184.6	± 35.1	186.4	± 34.5	0.001
TG(mg/dl)	115.5	± 66.6	116.3	± 82.3	120.0	± 75.5	125.2	± 73.1	0.033
LDLC(mg/dl)	97.7	± 30.7	98.7	± 28.2	103.0	± 29.2	106.0	± 30.7	< 0.001
HDLC(mg/dl)	50.9	± 13.7	52.5	± 14.1	52.3	± 13.3	51.5	± 13.3	0.315
Female	< 18.2		18.2–21.7		21.7–24.7		> 24.7		
(n = 2,139)	(n = 531)		(n = 544)		(n = 544)		(n = 520)		
BHT(cm)	148.3	± 5.8	149.9	± 5.4	151.7	± 5.1	153.6	± 5.2	< 0.001
BWT(kg)	54.2	± 9.3	55.7	± 9.0	57.8	± 8.9	61.0	± 9.1	< 0.001
BMI(kg/m^2)	24.6	± 4.0	24.8	± 3.9	25.1	± 3.7	25.9	± 3.8	< 0.001

Abbreviations: BHT, body height; BWT, body weight; BMI, Body mass index; BWC, body waist circumference; BHIP, body hip circumference; WHR, body waist to hip ratio; BFAT, body fat; SBP, systolic blood pressure; DBP, diastolic blood pressure; BG, blood glucose; TC, total cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol; HDLC, high-density lipoprotein cholesterol.

† ANOVA F test was to compare the anthropometric variables and cardiometabolic risk factors among these four subgroups with gender specifications; TG using log transformation to test.

	Grip strength(kg)								
BWC(cm)	82.6	± 9.4	82.5	± 9.3	83.1	± 9.5	84.5	± 8.8	0.001
BHIP(cm)	94.2	± 8.0	95.0	± 7.5	95.7	± 7.3	97.4	± 7.1	< 0.001
WHR	0.88	± 0.07	0.87	± 0.07	0.87	± 0.07	0.87	± 0.06	0.071
BFAT(%)	31.1	± 7.6	31.8	± 7.3	32.6	± 7.4	34.1	± 6.8	< 0.001
SBP(mmHg)	139.9	± 18.9	140.8	± 17.8	139.4	± 17.8	140.9	± 17.7	0.414
DBP(mmHg)	77.4	± 10.5	78.8	± 10.5	78.4	± 10.0	80.2	± 9.8	< 0.001
BG(mg/dl)	105.7	± 32.7	105.3	± 36.6	106.4	± 35.2	104.5	± 30.8	0.850
TC(mg/dl)	194.5	± 38.7	198.6	± 36.3	199.2	± 37.0	205.0	± 38.4	< 0.001
TG(mg/dl)	124.3	± 72.7	122.9	± 63.0	123.6	± 70.1	127.8	± 74.9	0.763
LDLC(mg/dl)	104.6	± 31.7	108.8	± 30.1	107.3	± 30.0	112.9	± 31.1	< 0.001
HDLC(mg/dl)	59.4	± 15.0	59.7	± 14.7	60.5	± 14.3	60.1	± 13.9	0.627

Abbreviations: BHT, body height; BWT, body weight; BMI, Body mass index; BWC, body waist circumference; BHIP, body hip circumference; WHR, body waist to hip ratio; BFAT, body fat; SBP, systolic blood pressure; DBP, diastolic blood pressure; BG, blood glucose; TC, total cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol; HDLC, high-density lipoprotein cholesterol.

† ANOVA F test was to compare the anthropometric variables and cardiometabolic risk factors among these four subgroups with gender specifications; TG using log transformation to test.

Table 2 shows the distribution of cardiometabolic risk profiles among the study population according to their obese status and GS status with gender specification. The non-obese (OB-) groups had lower blood glucose (BG) levels, lower systolic blood pressure (SBP), and TG levels, and higher HDLC levels compared to the obese (OB+) groups. Among the females, the OB- groups had a lower diastolic blood pressure (DBP) than the OB + groups. Among the OB- groups, the BG levels and SBP were lower in the normal grip strength (GS+) subgroups than the weak grip strength (GS-) subgroups. For example, the mean BG level for the male subjects was 100.3 ± 32.2 mg/dl and 109.9 ± 45.2 mg/dl in the OB-/GS + and the OB-/GS- subgroups, respectively ($p < 0.001$). The mean BG level for females was 102.8 ± 32.1 mg/dl and 103.3 ± 31.4 mg/dl in the OB-/GS + and the OB-/GS- subgroups, respectively ($p < 0.001$). The mean SBP for males was 137.2 ± 17.8 mmHg and 137.7 ± 19.5 mmHg in the OB-/GS + and the OB-/GS- subgroups, respectively ($p < 0.001$). The mean SBP for females was 138.6 ± 17.5 mmHg and 138.7 ± 18.5 mmHg in the OB-/GS + and the OB-/GS- subgroups, respectively ($p < 0.001$).

Table 2
Distributions of cardiometabolic risk factors among study population by different weight status and grip strength with gender-specification (n = 3739) (mean ± SD)

	Obesity status and grip strength				
	OB(-),GS(-)	OB(-),GS(+)	OB(+),GS(+)	OB(+),GS(-)	p-value
Male (n = 1,600)	(n = 431)	(n = 772)	(n = 289)	(n = 108)	
SBP(mmHg)	137.7 ± 19.5	137.2 ± 17.8	142.6 ± 16.7	143.3 ± 17.2	< 0.001
DBP(mmHg)	78.7 ± 11.2	82.3 ± 10.7	84.7 ± 10.4	81.1 ± 11.7	< 0.001
BG(mg/dl)	104.3 ± 33.3	102.7 ± 25.6	109.1 ± 34.3	109.1 ± 29.1	0.007
TC(mg/dl)	179.3 ± 36.4	184.3 ± 34.3	182.3 ± 36.3	176.1 ± 33.0	0.029
TG(mg/dl)	108.4 ± 62.7	114.3 ± 75.1	144.1 ± 86.5	131.4 ± 65.3	< 0.001
LDLC(mg/dl)	99.1 ± 29.8	102.9 ± 29.5	102.6 ± 31.0	96.3 ± 28.7	0.046
HDLC(mg/dl)	53.0 ± 14.1	53.3 ± 13.7	47.7 ± 11.9	47.1 ± 11.7	< 0.001
Female (n = 2,139)	(n = 573)	(n = 969)	(n = 408)	(n = 189)	
SBP(mmHg)	138.7 ± 18.5	138.6 ± 17.5	144.5 ± 18.0	143.8 ± 17.5	< 0.001
DBP(mmHg)	76.7 ± 10.2	78.4 ± 10.0	81.1 ± 10.0	80.9 ± 11.1	< 0.001
BG(mg/dl)	103.3 ± 31.4	102.8 ± 30.1	112.5 ± 40.3	110.4 ± 41.5	< 0.001
TC(mg/dl)	194.4 ± 37.1	202.2 ± 37.9	199.7 ± 35.7	198.4 ± 42.1	0.001
TG(mg/dl)	120.0 ± 66.1	118.0 ± 67.6	139.1 ± 70.7	141.1 ± 86.2	< 0.001
LDLC(mg/dl)	104.7 ± 30.4	110.3 ± 31.1	109.6 ± 28.6	107.0 ± 34.6	0.005
HDLC(mg/dl)	59.7 ± 15.1	61.6 ± 14.9	57.2 ± 11.9	58.5 ± 14.3	< 0.001

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; BG, blood glucose; TC, total cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol; HDLC, high-density lipoprotein cholesterol.

Obesity status and grip strength
† ANOVA F test was to compare the cardio-metabolic risk factors among these four subgroups with gender specifications; TG using log transformation to test.
OB(-): non-obese, BMI < 27,
OB(+): obese, BMI > = 27
GS(-): weak grip strength, GS < 30 for male and GS < 20 for female
GS(+): normal grip strength, GS > = 30 for male and GS > = 20 for female

The multivariate regression analyses for the GS in relation to the cardiometabolic risk profiles before and after adjusting for the potential confounders with genders specifications were presented in Table 3. In both genders, the GS was negatively associated with BG ($\beta = -0.357$, $p < 0.001$ for males and $\beta = -0.385$, $p < 0.05$ for females) and positively associated with CHOL ($\beta = 0.658$, $p < 0.001$ for males and $\beta = 0.792$, $p < 0.001$ for females) and LDLC ($\beta = 0.489$, $p < 0.001$ for males and $\beta = 0.604$, $p < 0.001$ for females). For males, the GS was positively associated with DBP ($\beta = 0.167$, $p = 0.005$) and HDLC ($\beta = 0.180$, $p = 0.001$). For females, the GS was positively associated with SBP ($\beta = 0.305$, $p = 0.001$) only.

Table 3
Multivariate regression analyses of grip strength on anthropometric variables and cardiometabolic risk factors in different models with gender-specification

Dependent	Model I†			Model II‡		
variables	β	se β	p-value	β	se β	p-value
Male (n = 1,600)						
SBP(mmHg)	0.200	0.071	0.005	0.118	0.077	0.123
DBP(mmHg)	0.254	0.043	< 0.001	0.167	0.127	0.005
BG(mg/dl)	-0.228	0.118	0.052	-0.357	0.074	< 0.001
TC(mg/dl)	0.514	0.138	< 0.001	0.658	0.151	< 0.001
TG(mg/dl)	0.234	0.293	0.424	-0.081	0.313	0.797
Log TG(mg/dl)	0.001	0.001	0.259	0.000	0.001	0.737
LDLC(mg/dl)	0.442	0.117	< 0.001	0.489	0.128	< 0.001
HDLC(mg/dl)	0.043	0.054	0.427	0.180	0.056	0.001
Female (n = 2,139)						
SBP(mmHg)	0.395	0.085	< 0.001	0.305	0.088	0.001
DBP(mmHg)	0.152	0.049	0.002	0.088	0.051	0.087
BG(mg/dl)	-0.143	0.164	0.382	-0.385	0.170	0.024
TC(mg/dl)	0.569	0.181	0.002	0.792	0.190	< 0.001
TG(mg/dl)	0.252	0.339	0.458	-0.172	0.350	0.623
Log TG(mg/dl)	0.001	0.001	0.252	0.000	0.001	0.814
LDLC(mg/dl)	0.458	0.148	0.002	0.604	0.156	< 0.001
HDLC(mg/dl)	-0.030	0.070	0.672	0.122	0.072	0.089

Abbreviations: β, regression coefficient; se, standard error; SBP, systolic blood pressure; DBP, diastolic blood pressure; BG, blood glucose; TC, total cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol; HDLC, high-density lipoprotein cholesterol.

† Model I: adjusting for age.

‡ Model II: further adjusting for body height, body weight, waist to hip ratio, and body fat.

Table 4 demonstrates the GS in relation to the risk for cardiometabolic diseases. For every 1 kg increase in the GS, there was a decrease of 4.1% and 4.5% in the risk for DM in males and females, respectively (OR = 0.959, 95% CI = 0.940–0.979 for males and OR = 0.955, 95% CI = 0.932–0.978 for females). But, a

higher GS seems to be associated with an increased risk for dyslipidemia in females (OR = 1.029, 95% CI = 1.006–1.053).

Table 4
Multivariate logistic regression analyses of grip strength on cardiometabolic diseases in different models with gender-specification

Dependent	Model I†		Model II‡	
variables	OR	95% CI	OR	95% CI
Male				
Hypertension	1.021	1.004–1.038	1.011	0.992–1.030
Diabetes mellitus	0.971	0.954–0.989	0.959	0.940–0.979
Dyslipidemia	1.011	0.995–1.027	1.006	0.988–1.023
Female				
Hypertension	1.016	0.995–1.037	0.997	0.975–1.020
Diabetes mellitus	0.972	0.951–0.995	0.955	0.932–0.978
Dyslipidemia	1.036	1.014–1.058	1.029	1.006–1.053
Abbreviations: OR, odds ratio; CI, confidence interval.				
†Model I: adjusting for Age.				
‡Model II: further adjusting for body height, body weight, waist to hip ratio, and body fat.				

Discussion

In the present study, we found that the non-obese subjects had lower BG levels compared with the obese subjects. Those who had a higher GS had lower BG levels than the subjects with a lower GS. Our results revealed that the GS may be a protective factor against DM among the elder population in Taiwan.

This was a well-conducted and large community-based study to evaluate the relationship of the GS with cardiometabolic risk profiles among the elder population in Taiwan. However, there are some limitations in our study. First, the cross-section design limits its ability to evaluate the causal relationships between the GS and the cardiometabolic risk profiles. Second, we did not measure the muscle mass in the study. Although the GS was a convenient and effective way to detect and screen for sarcopenia among the elder individuals, the muscle mass and GS should have been measured at the same time to properly assess for the presence of sarcopenia[4,5]. Finally, information bias regarding the history of chronic diseases in the subjects could not be excluded by using a survey questionnaire. Despite this, the association between the GS and the cardiometabolic risk factors were still reliably explored in this study.

In distributing the study population into quartiles based on the grip strength, there was no significant difference in the blood glucose level and blood pressure among the different quartile subgroups. It was possible that the increased BMI, WC, and BFAT negated the effect of GS on the BG level since obesity itself plays an important role in the development of hyperglycemia, insulin resistance, and metabolic syndrome[23,24]. This was also observed in the subjects that were distributed by GS and BW classification. The levels of the metabolic syndrome indicators (BG, SBP, TG, and HDLC) in the non-obese subjects were ideal compared to those of the obese subjects.

The associations between the GS, lipid profiles, and risk for dyslipidemia were not consistent in our study. A higher GS was associated with higher levels of CHOL and LDLC, but the risk for dyslipidemia was only increased in the female subjects. This result was similar to a Switch study wherein the GS only showed a moderate association with the cardiovascular risk markers. Their results also suggest that the GS has a complex association with the lipid profile since low GS values might be associated with a “deleterious low” lipid profile[25].

After adjusting for age and body composition, the GS had an inverse association with the BG level in our study. It was similar to previous results that demonstrated favorable correlation of GS to the fasting glucose and glycohemoglobin (HbA1c) level in women[26]. Our results were also similar to the findings of the Korea National Health and Nutrition Examination Survey (KNHANES), which demonstrated the inverse association between the relative GS and fasting glucose/HbA1c levels[7]. In another study among Asian population, Liang et al. reported the inverse dose-response association between the GS and fasting BG level[27]. In our study, the GS is a protective factor against the development of DM for both genders. This result was consistent with several studies that have evaluated the relationship between the GS and cardiometabolic diseases. The results of the Healthy Life in an Urban Setting (HELIUS) study, which included six ethnic groups, also revealed the inverse correlation between the GS and DM prevalence[28]. Similarly, the Helsinki Birth Cohort Study (HBCS), found that the GS was lower in those with known and newly diagnosed DM compared to those with normal BG levels[29]. Further studies conducted by the KNHANES also showed that the GS was negatively associated with the development of type 2 DM and insulin resistance[30,31].

Although there were several studies that have demonstrated the association between the GS and DM, their causal relationship remains unclear. Long-term exercise and training that might be related to higher muscle strength attenuates lipid-induced insulin resistance[32]. In contrast, a lower muscle strength might be caused by inflammation, which is also an important factor caused by insulin resistance[33]. However, further studies and trials are needed to determine the causal relationship between the GS and BG levels.

Conclusions

In general, the obese subjects had higher BG levels than the non-obese subjects. Furthermore, after adjusting for age and body composition, a higher GS was associated with a lower BG level and decreased

risk for developing DM among the elder population in Taiwan. Additional health promotion studies to increase muscle mass along with early rehabilitation programs should focus on the obese and sarcopenic population to prevent cardiometabolic comorbidities in later life.

Declarations

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No potential conflict of interest relevant to this article was reported.

Consent to publish;

Not applicable.

Availability of data and material:

The datasets used and analyzed during the current study available from the corresponding authors on reasonable request.

Authors' contributions:

CCY prepared data, analyzed data, wrote manuscript and discussed draft.

LMS prepared data, prepared Tables 1-2 and discussed draft.

KCC prepared Tables 3-4: data discussed and formatted manuscript.

LCH corrected draft and discussed draft.

WDM prepared data, analyzed data, formatted tables and manuscript.

TMK instructed manuscript and discussed draft.

CNF formatted design, analyzed data, discussed manuscript and corrected final manuscript.

All authors read and approved the final manuscript.

Ethics declaration:

This study was approved by the Tri-Service General Hospital Ethical committee (Number: TSGHIRB-1-108-05-073) and was performed in accordance with the ethical standards.

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