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Association between hand-grip strength and risk of stroke among Mongolian adults: Results from a population-based study

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Abstract: Mongolia ranks third in the world in stroke-related deaths. Loss of skeletal muscle mass and function, known as sarcopenia, is associated with a higher risk of various metabolic disorders such as stroke. Thus, screening of sarcopenia is important. Hand-grip strength (HGS) can be used to predict sarcopenia in the short term. In this cross-sectional study, we used data (n=1180, mean age of 39.2 ± 15.2 and 33.2% males) from the Mon-Timeline cohort study, a multidisciplinary, prospective, population-based cohort study in Mongolia. A digital grip strength dynamometer (TKK 5401 GRIP D; Takei, Japan) was used to measure HGS. We performed binary logistic regression analysis between HGS and stroke risk. Suspected sarcopenia was defined when HGS is less than the 25th percentile of HGS. In this study, 3.3% of all participants had a stroke. The incidence of stroke was significantly higher (5.2% and 1.9%) in people with suspected sarcopenia. According to body composition, the incidence of stroke was more frequent in sarcopenic obese people: 1.3%, 2.4%, 2.8% and 6.2% in normal (non-obese and non-sarcopenic), sarcopenic (non-obese), obese (non-sarcopenic) and sarcopenic obese groups, respectively. In regression analysis, the OR (95% CI) was 2.84 (1.44; 5.59) for sarcopenic compared with non-sarcopenic. The adjustments for age, gender, education, body mass index, waist circumference and hypertensive status attenuated the associations, but lower HGS remained significantly associated with a higher risk of stroke. In conclusion, lower HGS was significantly associated with a higher risk of stroke independent of adiposity and hypertensive status in Mongolian adults.

Keywords: hand-grip strength; stroke; sarcopenia; sarcopenic obesity; hypertension;

1.0 INTRODUCTION

Stroke continues to be one of the leading causes of morbidity and mortality in the world. According to the World Health Organization, 15 million people suffer stroke worldwide each year. Of these, 5 million dies and another 5 million are permanently disabled (Lindsay et al., 2019). The prevalence of stroke is not decreasing due to the increasing prevalence of other metabolic diseases such as obesity, high blood pressure, and diabetes (Field et al., 2001; Lindsay et al., 2019; Narayan et al., 2007; Willey et al., 2014). High blood pressure contributes to more than 12.7 million strokes worldwide (Lindsay et al., 2019). The population attributable risk resulting from hypertension (HTN) was 29.9% (95% CI, 12.5 to 47.4) for stroke (Willey et al., 2014). Because obese people are more likely to have cardiovascular disease and diabetes, they are more likely to have a stroke than non-obese people (Field et al., 2001; Willey et al., 2014). Although the increase of adiposity has been proven to cause cardiovascular disease and diabetes, in recent years, sarcopenia (the loss of skeletal muscle mass and function) has attracted as much attention as obesity (Roh & Choi, 2020; Xia et al., 2021). A recent study (n= 2432) found that people with sarcopenia had a higher risk of myocardial infarction and atrial fibrillation even without clinical heart failure (Xia et al., 2021). In particular, the combination of obesity and sarcopenia has been shown to increase the risk of various metabolic disorders rather than an increase in adiposity (Roh & Choi, 2020).

Because sarcopenia is more common in people with hypertension, the risk of stroke is higher in people with high blood pressure and muscle weakness (Bai et al., 2020). In this regard, the screening of sarcopenia in obese and elderly people is essential. However, the most widely used clinical method for calculating body mass index (BMI), the waist circumference measurement method, does not distinguish between body fat and muscle size (Frankenfield et al., 2001; Oterdoom et al., 2009). Also, with the waist circumference measurement, it is impossible to estimate muscle size (Wang et al., 2003). Because radiological and laboratory methods for accurately measuring the proportions and size of the body composition are relatively expensive and time-consuming (Houtkooper et al., 1996), scientists continue to use low-cost methods for detecting muscle failures in a relatively short period (Al Snih et al., 2004; Lera et al., 2018). Numerous studies have shown that estimating the amount of hand-grip strength can be used to predict sarcopenia in the short term (Al Snih et al., 2004; Wannamethee et al., 2007).

In Mongolia, the prevalence of lifestyle-related diseases has steadily increased for the last 30 years (Center for Health Development, 2020; World Health Organization, 2020). The prevalence of overweight and obesity was 17.3% in 1992, 26.5% in 1999, 41.4% in 2006, 54.3% in 2013, and as of 2020, it has increased to 64% (World Health Organization, 2020). As a result, obesity-related diseases are on the rise. For instance, the prevalence of diabetes increased from 3.2% in 1999 to 8.3% in 2020 (Suvd et al., 2002; World Health Organization, 2020). Cardiovascular disease has been the leading cause of death since 1992, with 32.1% of all deaths being due to cardiovascular disease in 2019 (Center for health development, 2020). The incidence of stroke has been increasing rapidly in recent years. Mongolia ranks third globally in stroke-related deaths, with the age-adjusted death rate at 166.06 per 100,000 (World Life Expectancy, 2020).

In this study, we aimed to explore the relationship between hand-grip strength and stroke in Mongolians. We assessed the risk of stroke in people with a combination of suspected sarcopenia and obesity and people with a combination of suspected sarcopenia and hypertension.

2.0 MATERIALS AND METHODS

2.1 Data source and study population

This cross-sectional study used data from the Mon-Timeline cohort study, a multidisciplinary, prospective, population-based cohort study in Mongolia. We included people older than 18 years of age (n=1479). Suppose the participants had any missing data related to the main determinant variables (n=231). Another exclusion was physical disabilities, including paralysis or weakness in the limbs (arms and legs) and musculoskeletal disorders to rule out possible coexisting diseases (n=64). Additionally, we excluded pregnant women (n=4). Finally, 1180 participants were included in the current analysis. The study was conducted according to the Helsinki Declaration, and it was approved by the medical ethical committee of the Mongolian National University of Medical Sciences (METc 2020/3-05). All participants provided their written informed consent.

2.2 Variables and measurements

Independent and dependent variables: A digital grip strength dynamometer (Takei Hand Grip Dynamometer 5401-C, Japan) was used to measure HGS in both hands of the survey participants. The instrument can measure from 5 to 100 kg, and the minimum unit of measurement is 0.1 kg. Suspected sarcopenia was defined when dominant HGS is less than the 25th percentile of HGS based on its histogram in men and women, respectively. During the interview, the stroke questionnaire was administered. The diagnosis was confirmed by their medical records from their family doctors.

Covariates and other variables: The interview included questions related to participants' demographic and lifestyle characteristics based on the Food Frequency Questionnaire and the Global Physical Activity

Questionnaire (Armstrong & Bull, 2006; World Health Organization, 2008). Education and family income variables were categorized as low, medium, or high levels, separately. Marital status was classified as a dichotomous variable, including married or cohabiting or single. Lifestyle characteristics including smoking, alcohol use, fruit and vegetable use, and physical activity were classified as dichotomous variables: smokers/non-smokers, never/use of alcohol, sufficient/insufficient use of fruits and vegetables and physically active/inactive. Furthermore, participants' body weight (kg), height (cm) and waist circumference were measured by well-trained assistants using a standardized protocol, and Body Mass Index (BMI; kg/m^2) was subsequently calculated.

2.3 Statistical analysis

In descriptive statistics, data were expressed as means with a standard deviation (SD) and as numbers with percentages. The differences between groups were compared using the Student's T-test and Pearson Chi-Square test. Estimated HGS was calculated according to the presence of stroke using an adjusted Analysis of Variance (ANOVA). The adjustments (age, education, body height, waist circumference and systolic blood pressure) were selected based on the correlation between HGS and demographic and anthropometric findings.

Binary logistic regression analysis was performed to explore the association between body composition (based on HGS) and stroke. The main category of body composition includes suspected sarcopenia and non-suspected sarcopenia as the reference group for the regression analysis. In addition, body composition was categorized into normal (non-obese and non-sarcopenic), sarcopenic (non-obese), obese (non-sarcopenic), and sarcopenic obese groups, respectively and the normal composition was used as the reference group for the regression analysis. In the regression analysis, the odds ratio (OR) was reported with a 95% confidence interval (CI). Analysis was adjusted for age, education (model 1), BMI and waist circumference (model 2, as adiposity), and hypertension status (model 3). Statistical analyses were performed using IBM SPSS V.27.0 and GraphPad Prism V.4.03. A two-sided statistical significance was set at $p<0.05$ for all tests.

3.0 RESULTS

3.1 General characteristics of the study population

A total of 1,180 people were included in this study, with an average age of 39.2 ± 15.2 and 33.2% (n = 392) were men. Some demographic, socioeconomic and lifestyle characteristics of the respondents are shown in **Table 1**. In this study, 3.3% (n=39) of all participants had a stroke. According to the stroke incidence, there were no gender differences. Those who had a stroke were relatively older and were more likely to have obesity, diabetes, and hypertension ($p<0.05$).

Table 1: General characteristics of the study population.

Findings	**Total (n=1180)**	**Stroke**		***P* value**
		With (n=39)	**Without (n=1141)**	
Age *(year)*	39.2 ± 15.3	50.1 ± 10.2	38.8 ± 15.3	**0.001**
Male gender, n (%)	392 (33.2%)	15 (38.5%)	377 (33.0%)	0.455
Education: low level, n (%)	361 (30.5%)	18 (46.1%)	343 (30.1%)	0.164
Married or cohabitant, n (%)	681 (57.7%)	26 (81.3%)	655 (66.8%)	0.117
Living area: Urban n (%)	417 (35.3%)	18 (56.3%)	399 (40.7%)	0.122
Family income level: Low, n (%)	330 (28.0%)	17 (48.6%)	313 (38.6%)	0.482
Current smokers, n (%)	256 (21.7%)	11 (28.2%)	245 (21.7%)	0.476
Alcohol use, n (%)	898 (76.1%)	31 (79.4%)	871 (76.0%)	0.709
Fruit use: Insufficient, n (%)	368 (31.2%)	12 (30.8%)	356 (34.6%)	0.622
Vegetable use: Insufficient, n (%)	156 (13.2%)	3 (7.7%)	153 (13.5%)	0.324
Physically inactive, n (%)	652 (55.3%)	24 (61.5%)	628 (55.9%)	0.519
Body mass index (kg/m^2)	26.5 ± 5.6	28.5 ± 4.1	26.4 ± 5.6	**0.004**
Obesity, n (%)	304 (25.8%)	16 (41.0%)	288 (25.2%)	**0.039**
Type 2 diabetes, n (%)	51 (4.3%)	6 (15.4%)	45 (3.9%)	**0.005**
Systolic blood pressure (mm Hg)	126.1 ± 20.4	131.5 ± 26.1	124.3 ± 17.9	**0.016**
Hypertension, n (%)	445 (37.7%)	25 (64.1%)	420 (36.0%)	**0.001**

Data are presented as mean ± SD and number (percentages, %).

3.2 Hand-grip strength and body composition

The mean HGS of the participants aged 18-65 years was 40.05 ± 10.4 for men and 24.5 ± 5.6 for women. By age group, the highest value was 44.2 ± 11.3 for men in the 30-39 age group and 26.3 ± 5.7 for women in the 20-29 age group. To determine the minimum HGS (suspected sarcopenia) for the study population, the 25th percentile of HGS was calculated as 31.8 for men and 20.5 for women (**Figure 1**). We divided the participants into four groups according to their body composition: non-obese and non-sarcopenic, sarcopenic, obese and sarcopenic obese groups. In terms of gender, 51.8% of men and 48.5% of women were normal or without obesity and had no sarcopenia, 17.8% of men and 15.5% of women had sarcopenia, 23.2% of men and 15.5% of women had obesity and 7.2% of men and 9.2% of women had a combination of sarcopenia and obesity respectively. There were no statistically significant differences between the gender in terms of body composition. Therefore, we did not consider gender stratification in further analysis.

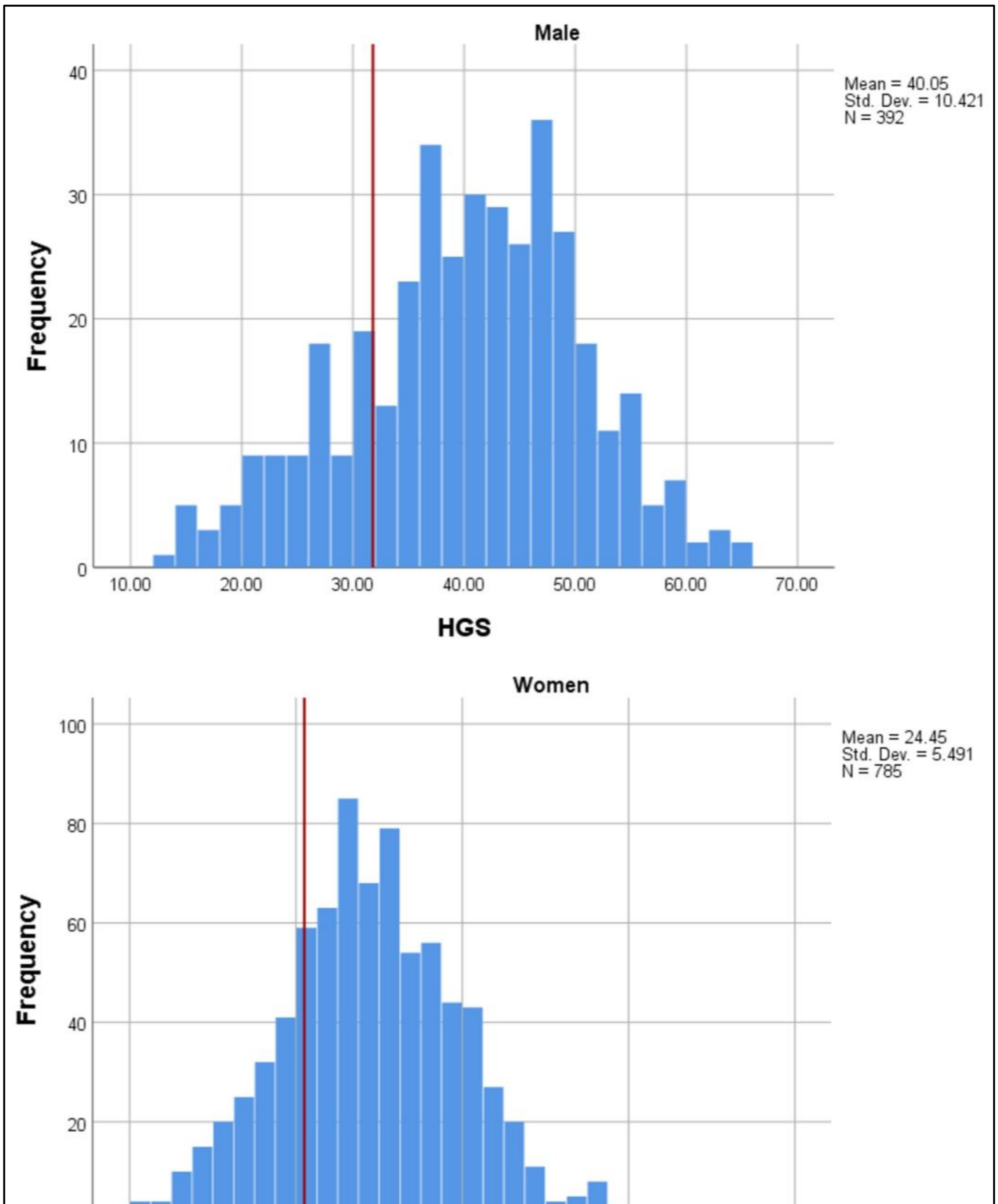

Figure 1: Histogram of HGS, according to gender (male=upper panel, female=lower panel).

3.3 Suspected sarcopenia and the risk of stroke

The incidence of stroke was significantly higher (5.2% and 1.9%) in people with sarcopenia, which is less than the 25th percentile of HGS. According to body composition, the incidence of stroke was more frequently in sarcopenic obese people: 1.3%, 2.4%, 2.8% and 6.2% in normal, sarcopenic, obese and sarcopenic obese groups, respectively. Furthermore, this is more likely to occur with age and the presence of hypertension. **Figure 2** shows the relationship between sarcopenia and stroke with age and hypertension. This suggests that people > 45 years with sarcopenia and those with a combination of hypertension and sarcopenia have a higher incidence of stroke.

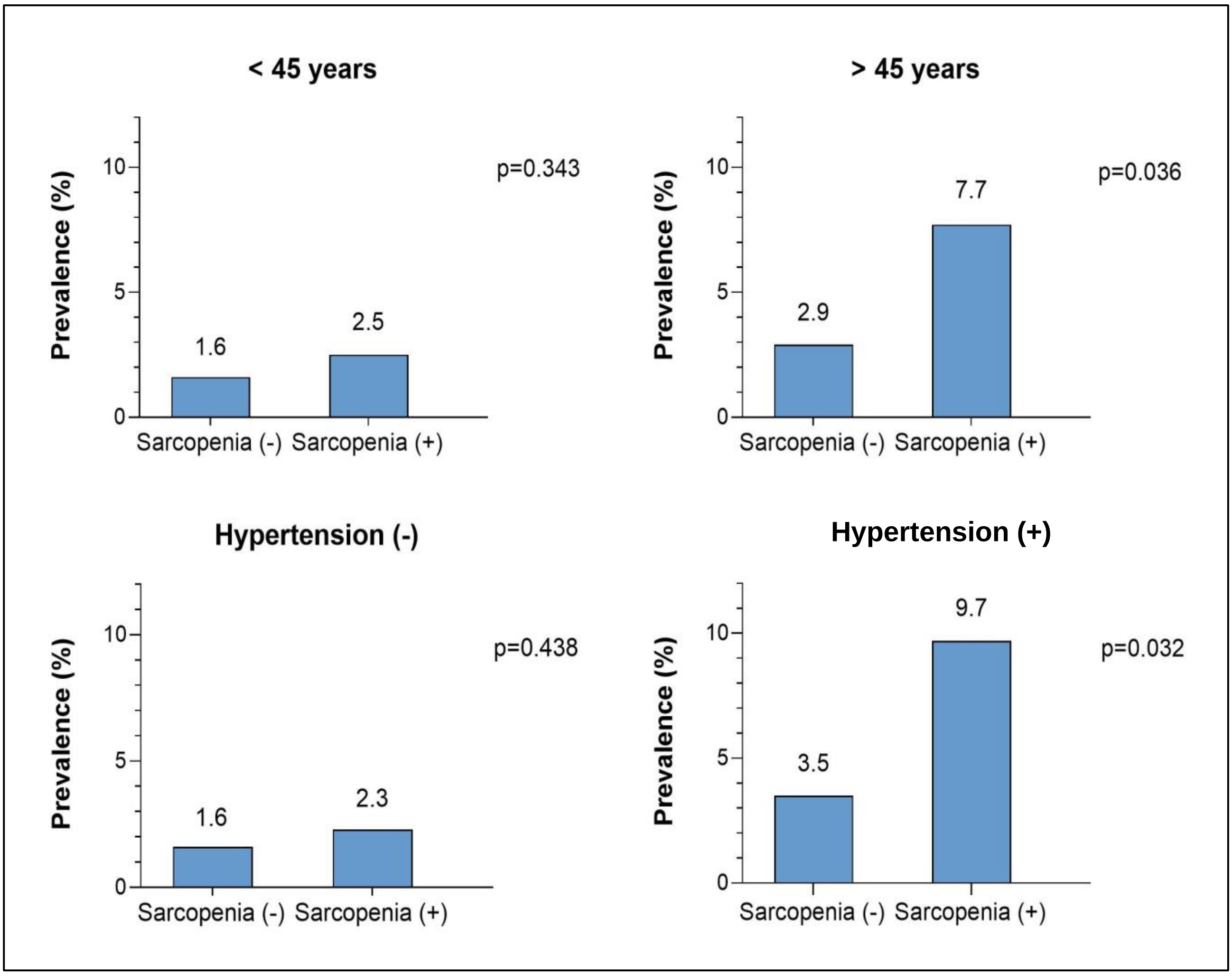

Figure 2: Association between sarcopenia and stroke with age and hypertension status.

In regression analysis, people with suspected sarcopenia were associated with a high risk of stroke (**Table 2**). The OR (95% CI) was 2.84 (1.44; 5.59) for sarcopenia (< 25th percentile of HGS), when comparing the without sarcopenia (higher than the 25th percentile of HGS). The adjustments for body mass index and hypertensive status attenuated the associations, but lower HGS remained significantly associated with a higher risk of stroke. Then, we used a logistic regression analysis to study the relationship between sarcopenia and stroke in relation to obesity. When compared to people with normal body composition (non-obese and non-sarcopenic), both other forms of the body composition (sarcopenic but non-obese, non-sarcopenic obese and sarcopenic obese) are at risk for stroke (**Table 2**). Interestingly, sarcopenic obesity was significantly associated with a high risk of stroke. After adjusted for hypertensive status, the association attenuated but remained significant.

3.4 Estimated HGS according to the presence of stroke

A descriptive analysis did not show a statistically significant difference in the mean HGS in people with and without stroke (**Table 3**). We performed a correlation analysis of HGS with demographic and anthropometric measures. Among all correlation analyses, HGS was inversely correlated to age in males and females (r = -0.352, r = -0.284), with a positive correlation between male and female height (r = 0.598, r = 0.409). Then we estimated the average HGS of people who had a stroke and those who did not have a stroke based on the above parameters. We found that people who had a stroke had lower HGS.

Table 2: Association between body composition and stroke risk.

Body composition	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Sarcopenia (-)	1.00	-	1.00	-	1.00	-
Sarcopenia (+)	2.84 (1.44-5.59)	0.002	2.57 (1.17-5.61)	0.018	2.42 (1.10-5.31)	0.027
Sarcopenia (-), Ob (-)	1.00	-	-	-	1.00	-
Sarcopenia (+), Ob (-)	1.93 (0.45-8.21)	0.371	-	-	1.84 (0.43-7.87)	0.406
Sarcopenia (-), Ob (+)	2.22 (0.72-6.88)	0.164	-	-	1.83 (0.58-1.29)	0.298
Sarcopenia (+), Ob (+)	5.12 (1.92-13.6)	0.001	-	-	3.64 (1.30-10.2)	0.014

Binary logistic regression analysis. The reference group refers to the "without sarcopenia" and "non-obese and non-sarcopenic", respectively. Data are expressed as ORs and 95% confidence intervals (95% CIs). OR, odds ratio; CI, confidence interval; Ob, obesity.
Model 1= adjusted for age and education.
Model 2= Model 1 + BMI and waist circumference.
Model 3= Model 2 + Hypertensive status.

Table 3: Target and estimated mean of HGS, according to gender.

Gender	Target means of HGS $\pm$ SD	Estimated HGS $\pm$ SE	
		Without stroke	With stroke
Males	40.1 ± 10.4	39.2 ± 0.51	38.6 ± 2.15
Females	24.5 ± 5.7	24.0 ± 0.22	22.7 ± 1.03

Estimated HGS (kg) adjusted with ANOVA for age, education, body height, waist circumference, systolic blood pressure.

4.0 DISCUSSION

In this cross-sectional study, we aimed to investigate the association of HGS, a predictor of muscle deficiency, with the risk of stroke. We found that suspected sarcopenia is associated with a higher risk of stroke, independent of adiposity and hypertensive status.

Although most previous studies have focused on the risk of post-stroke sarcopenia, several studies have shown that obesity-induced sarcopenia increases the risk of stroke. The incidence of cardiovascular disease and diabetes is exceptionally high in obese people with sarcopenia, which is supposed to increase the risk of stroke. Researchers have found that high levels of inflammatory mediators in adipose tissue slow down muscle tissue metabolism during obesity, leading to a decrease in muscle mass (Gregor & Hotamisligil, 2011; Roh & Choi, 2020; Zamboni et al., 2008). In addition, people with age-related muscle weakness (sarcopenia) experience decreased motor activity (Baumgartner, 2000). As a result, energy expenditure decreases, and body weight increases or increases the risk of obesity (Zamboni et al., 2008). In other words, researchers have found a link between obesity and muscle wasting (Baumgartner, 2000; Gregor & Hotamisligil, 2011; Roh & Choi, 2020; Wannamethee & Atkins, 2015; Zamboni et al., 2008), and people with sarcopenia and obesity have a higher risk of cardiovascular disease than obese people with relatively normal muscle mass. For instance, insulin deficiency, dyslipidaemia, and high blood pressure are eight times more common in people with sarcopenic obesity (Chung et al., 2013; Kim et al., 2013). An eight-year follow-up study found that people with obesity and sarcopenia were 23% more likely to develop cardiovascular disease (Stephen & Janssen, 2009).

In our study, it has been observed that a combination of suspected sarcopenia and obesity are associated with a higher risk of stroke than those of normal weight showing the people who may have sarcopenia where the risk of stroke was twice as high regardless of the amount of body fat or waist circumference and hypertensive status. However, the association was attenuated when adjusted for adiposity markers. Indeed, we expected the association to become stronger. Then we made a category of body composition including normal (non-obese and non-sarcopenic), sarcopenic (non-obese), obese (non-sarcopenic) and sarcopenic obese groups to distinguish a real addition of sarcopenia into obesity. The regression analysis showed that the risk of stroke was five times higher in people with sarcopenic obesity than people with normal body composition. All of this suggests that people with sarcopenia have a higher risk of stroke. Furthermore, because people with hypertension have a higher incidence and risk of stroke, we consider the risk of stroke in people with suspected sarcopenia depending on whether they have high blood pressure or not. The presence of sarcopenia in people without hypertension also increased the risk of stroke, and the combination of muscle weakness in people with high blood pressure increased the risk even more. Therefore, it is important to prevent and detect sarcopenia in obese people and people with hypertension.

The most widely used clinical methods for calculating body mass index (BMI) and measuring waist circumference are indistinguishable from muscle mass (Frankenfield et al., 2001; Oterdoom et al., 2009; Wang et al., 2003). Several studies have shown that estimating the amount of hand-grip strength can be used to predict sarcopenia in the short term (Celis-Morales et al., 2018; Lera et al., 2018; Metter et al., 2002). Studies show that a decrease in hand-grip strength is a predictor of stroke and many diseases. For instance, Lera et al. found that HGS decreased below the 25th percentile value of the hand-grip strength, and the risk of all types of death was 1.39 times higher than in people above (Lera et al., 2018). Metter et al. (2002) found that HGS as a predictor of all-cause mortality in healthy men over 60 and under initial muscle strength was a significant predictor of all-cause mortality after stratification for age ≥60 years, with a relative risk (RR) = 0.985, and a 95% confidence interval (CI) of 0.980–0.991, per kilogram increase in grip strength. The finding implies that a man at the 25^{th} percentile of grip strength (83 kg for both hands) would have a RR of 1.22 (a 22% increased risk of death) compared with a man at the median for grip strength (96 kg for both hands) (Metter et al., 2002). Celis-Morales et al. (2018) also followed participants through medical records for an average of seven years, and during that time, more than 13,000, or nearly 3%, had died, while close to 6% developed heart disease, about 2% developed respiratory disease and close to 6% were diagnosed with cancer. Interestingly, after accounting for age and a wide range of other factors, such as diet, sedentary time and socioeconomic status, the researchers found that muscle weakness, defined as a hand-grip strength measurement of fewer than 26 kg (57 pounds) for men and less than 16 kg (35 lb) for women, was associated with higher overall risk of death and higher risk for specific illnesses (Celis-Morales et al., 2018).

The strength of this study was that it involved a relatively large number of people, representing the population of each region of Mongolia. However, the cross-sectional study design is a limitation, which does not directly indicate an increase in the risk of stroke due to a decrease in hand-grip strength, or the hand-grip strength may be reduced due to the stroke. Therefore, further follow-up studies should be conducted to confirm the results. Also, there was a limitation to determine reference values of HGS because of the limited male participants in this study. Thus, we used the value of HGS less than the 25^{th} percentile to identify the suspected sarcopenia in this study. In the future, it is crucial to study the reference values of the HGS in Mongolians. Another limitation is that the number of stroke incidences in the population was small and was not suitable for analysis involving many other confounding factors.

5.0 CONCLUSIONS

This study found that the lower HGS was significantly associated with a higher risk of stroke. It is mainly observed in sarcopenic obese people with a five times higher stroke risk than people with normal body composition. Furthermore, the association between HGS and stroke is independent of hypertensive status.

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Conflicts of Interest: The authors declare no conflict of interest.

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