Handgrip strength and its association with noncommunicable diseases and their risk factors among elderly individuals in Malaysia

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Abstract

Background: Handgrip strength (HGS) is indicative of overall physical health among older people. A reduction in HGS may be associated with an increased risk of disease. This study aims to assess the association between HGS and noncommunicable diseases (NCDs) and the related risk factors.

Methods: One thousand two hundred four (1204) participants from four areas in Selangor state, Malaysia, were recruited. A comprehensive face-to-face interview based on the Bahasa Malaysia version of the Japan Gerontological Evaluation Study (JAGES-BM) questionnaire was administered, followed by HGS assessments by a handgrip dynamometer.

Results: The mean age of the participants was 68.7 (SD 6.36) years. A total of 691 participants (57.4%) were male, and 513 (42.6%) were female. The mean HGS was 30.0 (SD 7.53) kg for men and 19.4 (SD 5.28) kg for women. Analysis of covariance (ANCOVA) showed that factors associated with HGS among elderly males were age group, employment status, smoking status, alcohol consumption, moderate physical activity, BMI class, diabetes mellitus and self-rated health status. For females, the significant factors were age group, moderate and light physical activity, and BMI class.

Conclusions: The study contributed to a better understanding of factors associated with HGS among elderly individuals in Malaysia. Consequently, HGS may be recommended as an assessment for identifying elderly individuals at risk of NCDs and poor health status.

Trial Registration

Not applicable

Background

Noncommunicable disease (NCDs) are responsible for 70% of all deaths worldwide and comprise diseases such as heart disease, stroke, cancer, diabetes and chronic lung disease [1]. Thus, this is one of the major public health challenges, as NCDs are becoming increasingly common among elderly individuals. It was stated in a report that 22 million of 36 million annual death among individuals older than 70 years are attributed to NCDs [2]. On the other hand, health expenditure among elderly individuals, including direct and indirect costs, is also increasing overall in Malaysia [3]. Therefore, it is necessary to determine elderly health status using recommended tools to commence control and prevention earlier among individuals in this population.

One of the essential determinants of healthy ageing is muscle strength [4]. A reduction in muscle strength has been shown to impair normal bodily function. The ageing process, physical inactivity and malnutrition lead to muscle deterioration among older people. In contrast, if elderly individuals were to be empowered with knowledge and education regarding a healthy diet and regular physical activity, reduced muscle strength could potentially be counteracted and improved despite the physiological ageing process [5]. It has been scientifically proven that improved physical activity and resistance exercise enhance the muscle strength and function of elderly people, even if they are burdened with severe disability [6].

To date, one of the easiest and most readily available measures of muscle strength is a handgrip strength test. Extensive scientific studies have proven that there is a significant association between handgrip strength and the strength of other muscles in the assessment of both healthy individuals and elderly people with some pathology. This practical measurement of handgrip strength is therefore widely used as a single indicator of overall muscle strength, especially in the elderly population [7, 8].

Handgrip dynamometers are widely used to measure maximum isometric handgrip strength with excellent intertester and test-retest reliability [9]. Low handgrip strength is commonly indicative of weak upper extremity strength and lower extremity function [10]. In the elderly population, this is usually observed as reduced mobility and increased dependency in their activities of daily living and is predictive of body function and mortality. Indeed, handgrip strength is considered one of the reliable measures of physical decline and future outcomes among the elderly population according to the World Health Organization [11].

No studies to date have been conducted on handgrip strength as a general health measurement among the elderly population in Malaysia. Indirectly, this may result from a lack of usage of handgrip measurements in clinical practice. Therefore, this study was carried out with the aim of assessing the association of handgrip strength measurement in the elderly population with noncommunicable diseases and the related risk factors. We hope that as a result of this study, HGS will be integrated into elderly assessments in the clinical setting.

Methods

Study Design

This was a cross-sectional study conducted among adults aged 60 years and above in four areas in Selangor State, Malaysia. Two rural and two urban areas were selected randomly from the list of housing areas or villages. The study was conducted from 1 December 2018 to 30 April 2020 and included 1204 respondents who were randomly selected. The interview was conducted in a quiet face-to-face environment by trained research assistants. The study used the Bahasa Malaysia version of the Japan Gerontological Evaluation Study (JAGES-BM) questionnaire, which adopted from the Japan version of JAGES [12]. It has multidimensional variables, namely, demographic, socioeconomic status, family environment, health status and medical history, and lifestyle factors, including physical activity indicators.

The inclusion criteria in this study were Malaysians aged 60 years old and above who were able to converse in the Malaysian language. All respondents were screened for the possibility of poor cognitive function using the Abbreviated Mental Test score (AMT). Those who received scores less than seven were excluded from the study.

Handgrip Strength (HGS)

Handgrip strength was measured using a T.K.K. 5001 GRIP-A from Takei Scientific Instrument Co. Ltd. (Japan). Handgrip strength was measured twice in each of the respondents with the dominant hand, and the mean was taken for data analysis.

Covariates

Demographic variables included age, sex, marital status and household composition. Age was categorized into the following three categories: 60-74 years, 75–84 years and ≥ 85 years. Marital status was categorized into married, widowed, divorced, never married, and other. The 2019 income structure of the Department of Statistics of Malaysia was used for the household income classification. B40 is the base group or bottom 40% of individuals who earn less than RM4,850 in monthly household income, while M40 is a middle-class group or the middle 40% of individuals who earn between RM4,851 and RM10,959. T20 is an upper-class group or the top 20% of individuals who earn more than RM10,959 [13]. Lifestyle factors that were included in the study were smoking, alcohol consumption, betel chewing and physical activity. All the questions were based on JAGES-BM, which assesses dose response. Weight and height were measured twice to calculate body mass index (BMI). The Malaysian BMI classification was used as a reference [14]; underweight was defined as BMI <18.5 kg/m^2, normal was 18.5-22.9 kg/m^2, overweight was ≥23 kg/m^2, preobese was 23.0-27.4 kg/m^2, obese I was 27.5-34.9 kg/m^2, obese II was 35.0-39.9 kg/m^2 and obese III was ≥40 kg/m^2. Participants were also asked whether they had hypertension, heart disease, diabetes, stroke, cancer, dyslipidaemia, depression, or difficulties remembering or concentrating and were asked about their self-rated health status. The answer was yes or no, except for on the question 'difficulties in remembering or concentrating' and 'self-rated health status', which had four-option answers. In addition, the study used the Japanese version of the 15-item Geriatric Depression Scale (GDS) to assess depressive symptoms in older adults. The GDS score ranges from 0 to 15, with higher scores indicating more severe symptoms.

Data Analyses

To determine the associations among the study variables, one-way analysis of variance (ANOVA) and independent t-tests were carried out. Post hoc Bonferroni tests were used when homogeneity of variance assumptions were met. Moreover, post hoc Tamhane's test was used if the assumed homogeneity of variance was violated. Spearman's correlation was used to assess the relationship between HGS and GDS. For multivariate analysis, analysis of covariance (ANCOVA) was used to test the main effect associated with the dependent variable. A P-value of less than 0.05 was considered to indicate significance in all tests. Analyses were performed using IBM SPSS version 21.0 (IBM Corp., Armonk, NY, USA).

Permission and Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki, whereby the participation was on a voluntary basis, and the rights and wellbeing of the participant were protected. Participant information sheets and consent forms were given to the participants after they received a thorough explanation of the study. Participants not providing consent were not interviewed. The anonymity of all the participants was guaranteed by the creation of a code based on their location. The study was approved by the Research Ethics Committee of Universiti Kebangsaan Malaysia (UKM) (approval code: FF-2018-532).

Results

Sociodemographic Characteristics

Participants were aged between 60 and 91 years with a mean age of 68.7 (6.36) years. Age was further classified into three age groups, and the overall older age group was significantly associated with lower handgrip strength (HGS) [$F(2,1202)=78.05$. $p<0.001$]. There were slightly more males (57.4%) than females (42.6%). There was a significant difference in mean HGS between elderly males (30.0 (SD 7.5) kg) and elderly females (19.4 (SD 5.28)) [$F(1, 1202) = 746.12$, $p<0.001$]. Most of the participants were married and lived with their spouse (65.6%). Our study revealed that higher HGS among older people was significantly associated with marital status and cohabitating [$F(4,1199)=72.61$. $p<0.001$]. Post hoc Tamhane's test revealed that those who were married (living together) had significantly higher HGS than those who were widowed or divorced. The majority of participants lived with blood-related family members (94.2%), and high HGS was significantly associated with living with blood-related family members over living alone [$F(1,1201)=10.58$, $p<0.001$). However, the analysis within sex groups showed no significant association between HGS and household composition. In terms of educational level, 10% of participants had no education, 44.0% had a primary school education, and 17.5% had studied at the university, vocational or high school level. Those who studied at the university, vocational and high school level had a significantly higher HGS than those who had no school [$F(7,1196)=20.56$, $p<0.001$]. A significant proportion of participants (72.1%) had retired from their job, 14.0% were still working and 13.9% never had a job. Those who were employed had a significantly higher HGS than those who retired [$F(2,1201)=88.72$, $p<0.001$]. Post hoc Tamhane's test also revealed that those who retired from a job had a significantly higher HGS than those who never had a job. Last, regarding household income, the majority of older people (86.7%) were in the B40 group. Those in the B40 group had a significantly lower HGS than those in the M40 group, but they had significantly higher HGS than those in the 'no income' group [$F(3,1200)=5.75$, $p=0.003$]. However, there was no significant difference when comparing the HGS in the income group by sex. Table 1 shows the overall sociodemographic characteristics of the respondents, including the differences according to sex.

Association of HGS with Lifestyle Factors

One-way ANOVA revealed that HGS was significantly associated with smoking status and alcohol consumption among males but not among females. Table 2 below shows the association between HGS and lifestyle factors. There was a significant effect of smoking status on HGS among males at the $p<0.05$ level for the four levels of smoking [$F(4,686)=2.47$, $p=0.044$]. Men who smoked almost every day had higher HGS than those who never smoked; however, post hoc Bonferroni showed that the relationship was not significant. Moreover, regarding alcohol consumption status in the male group, the relationship was significant with HGS [F(3,686)=2.68, p=0.046]. Post hoc Bonferroni showed that the mean HGS of those who were currently consuming alcohol was significantly higher than that of those who never consumed alcohol.

Overall, betel chewing status was significantly associated with HGS [F(4,1199)=2.67, p=0.003). Post hoc Tamhane's test showed that those who chew betel nuts almost every day had a significantly lower HGS than those who never chewed. However, analysis within sex groups showed no association of HGS with chewing betel nuts. The frequency of physical activity was also associated with HGS. Three types of physical activity (strenuous exertion, moderate exertion and light exertion) significantly affected HGS. Overall, elderly individuals who performed strenuous physical activity regularly had a significantly higher HGS than those who never or rarely exercised [F(5,1198)=10.49, p<0.001]. Even older people who performed frequent moderate and light physical activity had a significantly higher HGS than those who never or rarely exercised [F(5,1198)=22.55, p<0.001 and F(5,1198)=6.20, p<0.001, respectively].

Association of HGS with Comorbidity

There was a significant effect of BMI status on HGS at the p<0.05 level in the six BMI classes [F(4,1199)=4.06, p=0.003]. The post hoc Bonferroni test showed that those who were underweight had significantly lower HGS than those who were normal weight, preobese, obese I, or obese II. However, those in the preobese and obese III groups were not significantly associated with HGS.

Diabetes mellitus, cancer, self-claimed difficulties in remembering or concentrating, and self-rated health status were significantly associated with reduced HGS in males. For females, hypertension and heart disease were significantly associated with HGS. Table 3 shows the results of the statistical analysis of the relationships between comorbidities and HGS.

Although there was no association between the presence of depression and HGS, Spearman's correlation showed a significant but weak correlation between the general depression scale (GDS) and HGS (Spearman's correlation -0.172, p-value < 0.001). The R square value indicated that HGS only contributed 2.7% of the variability in the GDS. The linear regression model showed that for every 400-gram reduction in HGS, GDS increased one point. A higher GDS score indicates the presence of depression.

Multivariate Analysis

Analysis of covariance (ANCOVA) was used to test the main effect of all significant independent categorical variables associated with HGS. ANCOVA was conducted separately for males and females, and the GDS score was used as a covariate. Factors associated with HGS among male elderly individuals were age group [F(2,639)=23.58, p<0.001], employment status [F(2,639)=5.017, p=0.007], smoking status [F(2,639)=2.92, p=0.021], alcohol consumption [F(2,639)=2.84, p=0.037], moderate physical activity [F(2,639)=6.08, p=0.001], BMI class [F(2,639)=3.58, p=0.001], diabetes mellitus [F(2,639)=11.94, p=0.001] and self-rated health status [F(2,639)=2.99, p=0.03]. Levene's test of equality of error variance was not significant [F(676,14)=0.693, p=0.873). Thus, the variances were not significantly different, and the assumption was met. The model explained 26.7% of the variation in HGS in the study sample (adjusted R square = 0.267). Moreover, for females, the significant factors were age group [F(2,469)=19.40, p<0.001], moderate and slight physical activity [F(2,469)=2.94, p=0.013 and F(2,469)=2.67, p=0.022, respectively] and BMI class [F(2,469)=3.61, p=0.003]. Heart disease was almost significant [F(1,469)=3.86, p=0.05]. Levene's test of equality of error variance was not significant [F(493,19)=0.802, p=0.786]. Thus, the variances were not significantly different, and the assumption was met. The model explained 26.7% of the variation in HGS in the study sample (adjusted R square = 0.267). Table 4 shows the adjusted mean HGS according to age group after controlling for potential cofounders. In both males and females, neither age group, BMI nor physical activity was associated with diabetes.

Discussion

This study revealed that the HGS level decreased significantly with age and was distinctly increased among males. A similar finding was also seen in contemporary and modern eras across the continent [15-17]. Furthermore, this finding regarding sex can be explained by the fact that females have less muscle mass than males [18] as a result of a low level of testosterone and differences in the amount of insulin-like growth factor-1 (IGF-1) and growth hormone (GH) [19]. Testosterone increases fast fibres with high glycolytic enzyme activity called type II fibres [20], which are present in high proportions in males. Moreover, high bone mineral density in males also contributed to the higher HGS among males than among females [21].

In the multivariate analysis, elderly males were found to have more factors associated with HGS than females. The proportion of elderly males who were employed and retired from a job, smoked and consumed alcohol was greater than that of females. Elderly males who were employed and retired from a job had significantly higher HGS than those who never had a job. Elderly individuals who were working or employed may participate in more active physical movement. Physical activity directly stimulates skeletal muscle and subsequently leads to improved muscle mass and higher HGS [22]. Coincidently, this study found that a lower frequency of physical activity was associated with lower HGS.

In terms of household income, although household income was not significantly associated with HGS in sex subgroups, the overall elderly sample with no income had lower HGS. This can be related to a previous study, as those in this group were physically inactive [23], which reflects that education and resources are ultimately important in preserving HGS in elderly individuals as an outcome of a healthy lifestyle.

Interestingly, this study found that alcohol consumers had higher HGS than nonconsumers. Although excessive drinking has been shown to be associated with sarcopenia [24], light-to-moderate alcohol intake has also been shown to have a protective effect against muscle mass loss [25]. Similar findings as those observed in this study were observed in a European and Koran study [26]. Further research is needed to ascertain the positive effects of alcohol consumption on HGS, in view of many other factors that can manipulate the result, such as the amount of alcohol, which was not measured in the study. Likewise, smoking was also found to be associated with higher HGS in this study. Perhaps this can be linked to other factors, such as occupation and physical activity of the smokers since most smokers comprised those with low socioeconomic status [27]. Although some studies have shown that smoking has negative effects on

HGS [28, 29], several other studies have shown mixed results on the effect of smoking [26, 30]. Additionally, a study noted low HGS among smokers with COPD as a predictor of future acute respiratory events [31, 32]. Hence, further research is needed to understand the effect of smoking on HGS.

In terms of HGS and comorbidities, this study revealed that lower HGS was significantly associated with underweight, while obesity was associated with higher HGS. This finding was consistent with a previous study [33-36]. BMI is related to fat and muscle mass; hence, low BMI is associated with low fat and muscle mass [37]. The ageing process, as well as low muscle mass, contribute to low muscle strength [38]. Additionally, poor nutritional intake, as observed in undernourished individuals, could also affect muscle mass [36, 37], but this was not measured in this study. Moreover, few studies have found contradictory results regarding the relationship between central obesity and HGS [39, 40]. Careful interpretation of the result is needed since the total weight used in the calculation of BMI, as a surrogate indicator of adiposity, includes fat mass and fat-free mass [35]. On the other hand, the presence of diabetes was associated with low HGS. Similar findings were noted in a previous study [41, 42], which can be attributed to diabetic neuropathy [43, 44]. Moreover, the duration of diabetes has been shown to be associated with lower HGS [45, 46], which supports the theory of neuropathy since neuropathy is one of the complications of chronic poorly controlled blood sugar levels. In addition, the insulin resistance state within skeletal muscle occurs as a result of greater intramuscular adipose tissue and muscle atrophy [47], thus damaging skeletal muscle [48]. In view of the apparent association between HGS and diabetes, HGS has been proposed to be used as a diabetes screening tool among apparently healthy adults [49].

We found that better self-rated health status in elderly males was associated with higher HGS. This is in agreement with a study conducted in Indonesia [33] and could be explained by the fact that better self-rated health indicated no or less disease and that many diseases are associated with poorer self-rated health [50]. In this study, we excluded participants who had poor cognitive function. In this study, difficulty in remembering or concentrating may reflect early cognitive impairment, and we found that normal memory and concentration were associated with higher HGS. In a review performed by Fritz et al. [51], poorer cognitive function was associated with lower HGS. The reason for cognitive decline and lower HGS may be based on the understanding that motor skill learning and motor output are dependent on the activity of the frontal and parietal brain regions [52, 53]. We also found that the presence of depression was not significantly associated with HGS, and a significant but weak correlation was found between GDS and GHS. However, many studies have revealed a significant association between depression and HGS [33, 54, 55].

Given that most of the variables were self-reported and no confirmation of the data was available, the results must be interpreted carefully. However, we measured depression symptoms through the validated GDS. Nevertheless, the study is a population-based study with a large sample size. Although the respondents were chosen at random, the study sample managed to cover a good proportion of the elderly population and was similar to the demographics of the elderly population in Malaysia.

In conclusion, there are slight differences between male and female elderly individuals in the factors that influence HGS. Overall, factors such as sociodemographic factors (age, sex and household income), lifestyle factors (smoking, alcohol intake and moderate exertion of physical activity) and comorbidities (BMI and diabetes) were associated with HGS. By identifying these factors, good HGS can be preserved, which can subsequently prevent disability in elderly individuals, hence ensuring a good quality of life. Therefore, the routine use of hand grip measurement is strongly recommended in clinical practice for identifying elderly individuals at risk of poor health status.

Abbreviations

HGS: Handgrip strength; NCDs: Noncommunicable diseases; JAGES-BM: Bahasa Malaysia version of the Japan gerontological evaluation study; ANCOVA: Analysis of covariance; BMI: Body mass index; AMT: Abbreviated mental test; B40: Bottom 40%; M40: Middle 40%; T20: Top 20%; GDS: Geriatric depression scale

Declarations

Ethics Approval and Consent to Participate

The Research Ethics Committee of Universiti Kebangsaan Malaysia (UKM) approved this study (FF-2018-532). Before the interview, all participants were provided with all information on the research and provided their written informed consent. Participants not providing consent were not interviewed. The anonymity of all the participants was guaranteed by the creation of a code based on their location.

Consent for Publication

Not applicable

Availability of Data and Materials

The research datasets analysed during the current study are available in the Mendeley dataset repository, [http://dx.doi.org/10.17632/hsc4k7vtfp.1].

Competing Interests

The authors declare that they have no compering interest.

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Authors' Contributions

SAS conceived of the study and supervised all aspects of its implementation. ZM and SRN completed the statistical analyses and led the writing of the manuscript. NS, SA, WAHWI and JM assisted with the study and data analyses. MRH and YS assisted in critical revision. All authors contributed to conceptualizing ideas, interpreting findings, and reviewing the drafts of the manuscript, and they approved the final manuscript.

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Authors' Information

Not applicable

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Tables

Table 1. Sociodemographic characteristics of respondents

Variables	Total					Male					Female				
	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-value
			Mean	SD				Mean	SD				Mean	SD	
Age group[1]															
Young old (60-74 years)	996	82.7	26.7	8.19	**<0.001**#	588	85.1	31.1	7.16	**<0.001***	408	79.5	20.5	4.82	**<0.001***
Middle old (75-84 years)	186	15.4	19.9	6.97		96	13.9	23.8	6.49		90	17.5	15.7	4.66	
Old old (≥85 years)	22	1.8	14.6	6.37		7	1.0	20.9	4.57		15	2.9	11.6	4.74	
Sex															
Male	691	57.4	30.0	7.53	**<0.001**#										
Female	513	42.6	19.4	5.28											
Marital status[2]															
Married (living together)	790	65.6	28.1	8.13	**<0.001**#	608	88.0	30.3	7.55	**0.003***	182	35.5	20.8	5.14	**<0.001**#
Married (living separately)	12	1.0	27.3	8.65		6	.9	33.5	8.34		6	1.2	21.1	1.56	
Widowed	22	1.8	21.2	6.49		4	.6	32.3	4.27		18	3.5	18.8	3.71	
Divorced	362	30.1	20.0	6.31		66	9.6	26.7	6.44		296	57.7	18.5	5.23	
Never married	18	1.5	24.0	9.22		7	1.0	29.5	9.37		11	2.1	20.5	7.56	
Household composition[3]															
Live alone	64	5.3	20.8	6.31	**<0.001**#	13	1.9	27.9	7.12	0.566*	51	9.9	19.0	4.64	0.777#
Live with blood-related family	1134	94.2	25.7	8.51		676	97.8	30.0	7.55		458	89.3	19.4	5.30	
Live with other family (non-blood-related)	6	0.5	24.3	10.33		2	0.3	31.8	1.77		4	0.8	20.5	10.98	
Location															
Rural	602	50.0	25.3	8.63	>0.05*	339	49.1	29.9	7.82	0.775*	263	51.3	19.3	5.29	0.668*
Urban	602	50.0	25.7	8.34		352	50.9	30.1	7.25		250	48.7	19.5	5.28	
Education Level[4]															
No school	121	10.0	19.9	6.98	**<0.001***	26	3.8	26.9	8.30	**<0.001***	95	18.5	18.0	5.18	**<0.001***
Some primary	202	16.8	23.4	8.33		109	15.8	28.2	7.32		93	18.1	17.8	5.41	
Finished primary	327	27.2	24.6	8.04		172	24.9	28.8	7.92		155	30.2	20.0	5.02	
Middle school	328	27.2	27.1	8.32		214	31.0	30.6	7.55		114	22.2	20.6	5.14	
High school	88	7.3	29.1	7.99		65	9.4	32.4	6.05		23	4.5	19.8	5.01	
Vocational	10	0.8	28.9	6.33		7	1.0	31.2	5.71		3	0.6	23.3	4.16	
College/university	113	9.4	29.9	8.02		92	13.3	32.0	7.00		21	4.1	21.0	5.85	
Others	15	1.2	22.6	6.83		6	.9	28.5	4.46		9	1.8	18.7	5.12	
Current employment status[5]															
Employed	169	14.0	29.3	7.86	**<0.001**#	127	18.4	31.9	6.88	**<0.001***	42	8.2	21.5	4.92	**0.001***
Retired from job	868	72.1	26.1	8.31		558	80.8	29.6	7.53		310	60.4	19.7	5.23	
Never had a job	167	13.9	18.4	5.56		6	.9	21.8	11.14		161	31.4	18.3	5.26	
Household income[6]															
No income	50	4.2	24.4	8.03	**0.003***	28	4.1	28.4	7.79	0.101*	22	4.3	19.4	4.99	0.759*

B40	1044	86.7	25.2	8.42	581	84.1	29.8	7.56	463	90.3	19.4	5.25
M40	98	8.1	28.5	8.70	71	10.3	31.9	6.91	27	5.3	19.6	6.25
T20	12	1.0	29.3	7.41	11	1.6	29.7	7.64	1	0.2	25.0	.

* One-way ANOVA

Welch's ANOVA test as homogeneity of variance was violated

1 Post hoc Tamhane's test, all significant

2 Post hoc Tamhane's test, only significance was married and living together with widowed and divorced

3 Post hoc Tamhane's test, the only significance was staying alone and staying with a blood-related family

4 Post hoc Bonferroni, all were significant except 'some primary' with 'finished primary', and middle school, high school and vocational

5 Post hoc Tamhane's test, all were significant

6 Post hoc Bonferroni, the only significance was 'M40' with 'No income' and 'B40'.

Table 2. Bivariate analysis to determine the association between lifestyle factors and handgrip strength (HGS)

Variables	Total					Male					Female				
	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-value
			Mean	SD				Mean	SD				Mean	SD	
Smoking status[1]															
Smoke almost everyday	169	14.0	31.1	7.83	**<0.001***	165	23.9	31.5	7.63	**0.44***	4	0.8	17.9	3.47	0.887*
Smoke sometimes	46	3.8	29.5	7.63		41	5.9	30.7	6.91		5	1.0	19.9	6.93	
Quit less than 5 years ago	30	2.5	28.5	6.02		29	4.2	28.6	6.06		1	0.2	24.0	.	
Quit more than 5 years ago	179	14.9	29.0	7.59		171	24.7	29.5	7.44		8	1.6	19.6	3.39	
Never smoked	780	64.8	23.1	7.94		285	41.2	29.5	7.66		495	96.5	19.4	5.31	
Alcohol consumption[2]															
Currently drink	42	3.5	30.6	8.39	**<0.001***	32	4.6	33.5	6.33	**0.46***	10	1.9	21.1	7.10	0.691*
Quit less than 5 years ago	9	0.7	27.3	6.63		8	1.2	28.0	6.70		1	0.2	21.5	.	
Quit more than 5 years ago	69	5.7	29.1	8.24		64	9.3	30.0	7.89		5	1.0	18.1	3.42	
Never drank	1084	90.0	25.0	8.40		587	84.9	29.8	7.52		497	96.9	19.4	5.26	
Betel chewing[3]															
Chew almost every day	18	1.5	20.2	4.26	**0.003#**	4	.6	21.3	4.35	0.139*	14	2.7	19.9	4.35	0.178*
Chew sometimes	32	2.7	24.3	8.32		18	2.6	28.6	5.85		14	2.7	18.9	7.93	
Quit chewing less than 5 years ago	3	0.2	23.8	3.69		2	0.3	25.3	3.89		1	.2	21.0	.	
Quit chewing more than 5 years ago	90	7.5	24.2	9.34		48	6.9	30.1	7.96		42	8.2	17.5	5.53	
Never chewed	1061	88.1	25.7	8.44		619	89.6	30.1	7.53		442	86.2	19.6	5.17	
Strenuous physical activity[4]															
4 or more times a week	61	5.1	28.4	7.93	**<0.001***	45	6.5	31.4	6.42	**0.001#**	16	3.1	20.2	5.77	**0.030***
2 or 3 times a week	56	4.7	29.4	7.49		44	6.4	32.1	5.74		12	2.3	19.6	4.23	
Once a week	55	4.6	27.1	8.37		32	4.6	32.1	6.08		23	4.5	20.1	5.69	
1 to 3 times a month	35	2.9	31.1	8.20		27	3.9	33.7	6.28		8	1.6	22.4	8.14	
A few times a year	42	3.5	28.0	9.07		25	3.6	31.5	9.91		17	3.3	22.9	4.14	
Rarely/None	955	79.3	24.6	8.36		518	75.0	29.3	7.65		437	85.2	19.1	5.20	
Moderate physical activity[5]															
4 or more times a week	346	28.7	27.7	8.00	**<0.001***	213	30.8	32.0	6.48	**<0.001#**	133	25.9	21.0	4.95	**<0.001***
2 or 3 times a week	197	16.4	27.0	8.48		120	17.4	31.6	6.71		77	15.0	19.7	5.17	
Once a week	89	7.4	26.2	7.87		50	7.2	31.0	6.30		39	7.6	20.0	4.68	
1 to 3 times a month	70	5.8	28.1	8.50		46	6.7	31.8	7.52		24	4.7	21.0	5.14	
A few times a year	77	6.4	26.2	8.78		47	6.8	29.6	9.33		30	5.8	21.6	4.86	
Rarely/None	425	35.3	22.2	7.93		215	31.1	26.6	7.64		210	40.9	17.7	5.23	
Light physical activity[6]															
4 or more times a week	679	56.4	26.1	7.95	**<0.001#**	381	55.1	30.6	6.79	**0.006#**	298	58.1	20.2	4.96	**<0.001***

2 or 3 times a week	151	12.5	26.5	8.57	96	13.9	30.5	7.45	55	10.7	19.5	5.27
Once a week	67	5.6	25.9	8.95	39	5.6	29.9	8.93	28	5.5	20.3	5.27
1 to 3 times a month	28	2.3	26.6	7.61	18	2.6	29.7	7.31	10	1.9	21.0	4.28
A few times a year	25	2.1	27.0	11.82	15	2.2	32.0	12.60	10	1.9	19.5	4.54
Rarely/None	254	21.1	22.9	8.94	142	20.5	27.8	8.08	112	21.8	16.7	5.47

* One-way ANOVA # Welch's ANOVA test as homogeneity of variance was violated

1 = Post hoc Bonferroni, the only significance was 'never smoking' with others

2 = Post hoc Bonferroni, the significance was 'currently drink' with 'never drank', and 'quit more than 5 years ago with 'never drank.'

3 = Post hoc Tamhane's test, the only significance was 'chew almost every day' with 'never chewed.'

4 = Post hoc Bonferroni, the only significance was 'rarely/none' with '4 or more times a week', '2 or 3 times a week' and '1 to 3 times a month'.

5 = Post hoc Bonferroni test, the only significance was 'rarely/none' with all other exercise frequencies

6 = Post hoc Tamhane's test, the only significance was 'rarely/none' with '4 or more times a week' and '2 or 3 times a week'.

Table 3. Bivariate analysis to determine the association between comorbidity and handgrip strength (HGS)

Variables	Total					Male					Female				
	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-value	N	(%)	HGS (kg)		P-valu
			Mean	SD				Mean	SD				Mean	SD	
BMI class[1]															
Underweight	39	3.2	20.7	7.76	**0.003**	22	3.2	24.5	7.69	**<0.001**	17	3.3	15.7	4.40	**<0.0**
Normal	223	18.5	25.1	8.26		148	21.4	28.7	7.04		75	14.6	18.1	5.52	
Pre-Obese	454	37.7	26.2	8.39		271	39.2	31.0	6.69		183	35.7	19.0	4.58	
Obese I	410	34.1	25.4	8.75		216	31.3	30.1	8.37		194	37.8	20.3	5.73	
Obese II	61	5.1	24.7	8.41		27	3.9	29.9	9.13		34	6.6	20.5	4.81	
Obese III	17	1.4	26.1	5.71		7	1.0	31.6	2.71		10	1.9	22.4	3.77	
Hypertension															
Yes	775	64.4	24.8	8.49	**<0.001**#	420	60.8	29.7	7.55	0.164*	355	69.2	19.0	5.26	**0.00**
No	429	35.6	26.7	8.33		271	39.2	30.5	7.47		158	30.8	20.3	5.24	
Stroke															
Yes	48	4.0	24.3	8.45	0.323#	29	4.2	28.9	8.12	0.425*	19	3.7	17.2	5.82	0.07
No	1156	96.0	25.5	9.25		662	95.8	30.0	7.50		494	96.3	19.5	5.25	
Heart Disease															
Yes	139	11.5	25.4	8.31	0.936#	99	14.3	28.8	6.90	0.099*	40	7.8	17.0	4.65	**0.00**
No	1065	88.5	25.5	8.51		592	85.7	30.2	7.62		473	92.2	19.6	5.29	
Diabetes Mellitus															
Yes	434	36.0	24.3	8.15	**<0.001**#	242	35.0	28.5	7.79	**<0.001***	192	37.4	19.0	4.93	0.23
No	770	64.0	26.1	8.59		449	65.0	30.8	7.26		321	62.6	19.6	5.48	
Dyslipidaemia															
Yes	570	47.3	25.1	8.08	0.139#	316	45.7	29.5	7.24	0.128*	254	49.5	19.6	5.17	0.39
No	634	52.7	25.8	8.82		375	54.3	30.4	7.75		259	50.5	19.2	5.40	
Cancer															
Yes	25	2.1	21.1	6.89	**<0.009***	11	1.6	24.7	8.07	**0.019***	14	2.7	18.2	4.17	0.40
No	1179	97.9	25.6	8.49		680	98.4	30.1	7.50		499	97.3	19.4	5.31	
Depression															
Yes	4	0.3	22.4	8.60	0.956#	2	0.3	27.3	8.13	0.607*	2	0.4	17.5	7.78	0.61
No	1200	99.7	25.5	8.49		689	99.7	30.0	7.53		511	99.6	19.4	5.28	
Difficulty of remembering/concentrating[2]															
No difficulty	744	61.8	26.3	8.44	**<0.001***	437	63.2	30.7	7.42	**0.001***	307	59.8	20.0	5.18	**0.00**
Yes, some difficulty	440	36.5	24.2	8.37		243	35.2	29.0	7.41		197	38.4	18.4	5.24	
Yes, a lot of difficulty	18	1.2	20.7	8.57		9	1.3	23.1	9.72		9	1.8	18.4	7.01	
Cannot do at all	2	0.2	24.8	8.13		2	0.3	24.8	8.13		-	-	-	-	
Self-rated health status[3]															
Excellent	44	3.7	28.2	8.70	**<0.001***	27	3.9	32.7	7.62	**<0.001***	17	3.3	21.0	4.41	0.16
Good	668	55.5	25.9	8.39		376	54.4	30.9	6.95		292	56.9	19.5	5.16	
Fair	441	36.6	25.1	8.54		264	38.2	29.0	8.05		177	34.5	19.2	5.25	
Poor	51	4.2	20.5	7.08		24	3.5	23.7	5.85		27	5.3	17.6	6.93	

* One-way ANOVA # Independent T-Test

1 = Post hoc Bonferroni, the only significance was underweight with normal, preobese, obese I, and obese II

2 = Post hoc Bonferroni, the only significance was ‘normal’ with ‘mild’ and ‘normal’ with ‘moderate’.

3 = Post hoc Bonferroni, the only significance was poor with excellent, good and fair

Table 4. Comparison of HGS between sexes while controlling for potential cofounders

	N	Adj mean (95% CI)[a]	Adj mean diff (95% CI)[b]		P value
Male					
Young old	588	24.7 (19.60, 29.82)	Middle old	5.4 (3.51, 7.28)	**<0.001**
			Old old	3.4 (-3.06, 9.89)	0.618
Middle old	96	19.3 (14.16, 24.46)	Young old	-5.4 (-7.28, -3.51)	**<0.001**
			Old old	-2.0 (-8.47, 4.51)	1.000
Old old	7	21.3 (14.50, 28.09)	Young old	-3.4(-9.89, 3.06)	0.618
			Middle old	2.0 (-4.51, 8.47)	1.000
Female					
Young old	408	20.4 (17.98, 22.75)	Middle old	2.9 (1.42, 4.33)	**<0.001**
			Old old	6.3 (3.25, 9.42)	**<0.001**
Middle old	90	17.5 (14.86, 20.13)	Young old	-2.9 (-4.33, -1.42)	**<0.001**
			Old old	3.5 (0.33, 6.58)	**0.025**
Old old	15	14.0 (10.67, 17.40)	Young old	-6.3 (-9.42, -3.25)	**<0.001**
			Middle old	-3.5 (-6.58, -0.33)	**0.025**

[a] Adjusted mean using ANCOVA

[b] Bonferroni adjustment for 95% confidence interval for difference