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ASSOCIATION OF GRIP STRENGTH, UPPER ARM CIRCUMFERENCE, AND WAIST CIRCUMFERENCE WITH DEMENTIA IN OLDER ADULTS OF THE WISE STUDY: A CROSS-SECTIONAL ANALYSIS

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Abstract: *Objective:* We examined the associations of handgrip strength, upper arm circumference, and waist circumference with dementia among Singapore older adults. *Design:* Cross-sectional epidemiological study. *Setting:* Residential homes, day care centres, nursing homes and institutions. *Participants:* 2,565 men and women aged 60 years and above who participated in the Well-being of the Singapore Elderly (WiSE) study in 2013. *Measurements:* Socio-demographic correlates, dietary habits, health behaviours, grip strength, upper arm circumference, and waist circumference were collected. Grip strength was measured using a hand dynamometer with the dominant hand. Upper arm circumference was measured using a measuring tape around the thickest part of the upper arm while waist circumference measured in centimetres was measured at the narrowest part of the body between the chest and hips for women, and measured at the level of the umbilicus for men. Dementia was diagnosed using the 10/66 dementia diagnostic criteria. *Results:* Mean grip strength was 13.07 kg (SE=0.60) for people with dementia and 21.98 kg (SE=0.26) for people without dementia. After adjusting for all factors, grip strength remained significantly associated with dementia ($p < 0.0001$). Upper arm circumference was associated with dementia ($p < 0.0001$) but this association was only significant in the univariate analysis. Waist circumference was not significantly associated with dementia. *Conclusions:* Lower grip strength was independently associated with dementia in the older adult population in Singapore. Further research needs to be done to ascertain whether this association exists for specific types of dementia and look into the relationship of other anthropometric measurements with dementia in Singapore.

Key words: Grip strength, arm circumference, waist circumference, dementia, Singapore.

Introduction

Aging population is a concern and challenge for many countries in the world. Between 2000 and 2050, the world's population of those aged 60 years and above will increase from 11% to 22% (1). Singapore is a country located in Southeast Asia with a multi-ethnic population (74.3% are Chinese, 13.3% are Malays, 9.1% are Indians, and 3.3% belong to Other ethnic groups) (2). It has one of the world's fastest aging populations with an increasing median age of the resident population from 37.4 years in 2010 to 39.3 years in 2014. With the post-war baby boomers turning 65 years old from 2012 onwards, the old-age support ratio is expected to drop from 6.3 in 2011 to 2.1 by 2030 (3).

The advancement of medical technologies has led to an increase in life expectancy. Individuals are more likely to live longer and thus are vulnerable to neurodegenerative illnesses such as dementia (1). A recent meta-analysis suggested that in most regions of the world, the age-standardized prevalence of dementia falls within 5% to 7%. Latin America had the highest prevalence (8.5%) whereas sub-Saharan Africa regions had the lowest prevalence (2% to 4%). The prevalence of dementia in East Asia was 5% and South East Asia was 6.4% (4).

Cognitive decline and loss of memory are common symptoms of dementia. However, other studies have found that dementia is also associated with changes in body composition and muscular strength (5-7). Furthermore, Rogers (2008) suggested that cognitive status is related to strength and reduced strength in people with dementia is the key factor to functional disability.

To assess changes in body composition and muscular strength, anthropometric measurements are useful. Anthropometry concerns the measurement of physical traits of human body and it is an important tool in nutritional assessment and acts as a clinical indicator for elderly (9, 10). Handgrip strength as an anthropometric measurement has been used as a determinant of an individual's hand motor abilities. It plays an essential role in daily activities and some studies have looked at grip strength as a proxy for motor functions among older people (11, 12). Reduced grip strength was correlated with physical functioning and disability (13-15), poor cognitive performance (16-18), and morbidity and mortality (19, 20). Literature on arm circumference and waist circumference has found that both measurements decreased with age (21, 22). Arm circumference is also associated with nutritional status and dementia. A cross-sectional survey found that elderly Africans with dementia were more likely to have a smaller arm circumference and suffered from under-nutrition than healthy people (23). Similarly, a study by Taylor (2012) across seven low and middle income countries found support for an

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inverse relationship between arm and waist circumference with dementia and its severity.

This study aimed to examine the association of grip strength, upper arm circumference, and waist circumference with dementia among Singapore older adults by comparing the differences of these anthropometric measurements between those with and without dementia. The study also investigated whether the association was affected by other factors such as body mass index and dietary habits. We hypothesized that lower grip strength, smaller upper arm circumference, and smaller waist circumference would be associated with dementia.

Methods

Study Population

A cross-sectional epidemiological survey was conducted with 2,565 participants who were randomly selected from a national database of Singapore residents aged 60 years and above. The database consisted of administrative data (i.e. name, ethnicity, gender, and address) of all citizens and permanent residents in Singapore, which was updated on a regular basis. Disproportionate stratified sampling design was used where residents in the older age group and those from Malay and Indian ethnic groups were over-sampled. Older adults who resided in day care centres, nursing homes, and institutions were included as well. Individuals who were not living in Singapore and who could not be contacted due to invalid addresses were excluded from the study. An informant of each participant- someone who knew the participant best, was also invited to take part in the survey. The study was approved by the relevant ethics committees -National Healthcare Group Domain Specific Review Board and the SingHealth Centralised Institutional Review Board, and written informed consent was obtained from the participants. In the case where participants were unable to provide consent, consent was taken from their legally acceptable representative or next-of-kin. A detailed description of the methodology can be found in an earlier paper (25).

Measurements and Assessments

Data collection was conducted through an extensive face-to-face interview which lasted for two to three hours. Dementia was coded as a binary variable and diagnosis was made following the 10/66 diagnostic criteria where participants scoring above a cut-point of predicted probability of DSM-IV diagnosis of dementia (26), were given the diagnosis. The predicted probability was derived from the logistic regression developed in the 10/66 international pilot study (25, 27).

The NEUROEX (28), a brief fully structured physical and neurological assessment with objectified measures of anthropometric measurements, was administered. Anthropometric measures were obtained by trained interviewers and among these measurements were grip strength, upper arm circumference, and waist circumference. Participant's grip strength was measured in kilograms using a JAMAR® Plus+ Hydraulic hand dynamometer with the dominant hand and by taking the average of the two attempts measured. Upper arm circumference was measured in centimetres using a measuring tape around the thickest part of the upper arm while waist circumference measured in centimetres was measured at the narrowest part of the body between the chest and hips for women, and measured at the level of the umbilicus for men.

Information on socio-demographic characteristics, medical history, dietary habits, and health behaviours were collected. Socio-demographic information on age, gender, ethnicity, marital status, education, and employment status was collected from participants and verified with informants. Height and weight were measured, and body mass index (BMI) was calculated using the weight in kilograms divided by the height in metres squared (kg/m^2). Medical history of hypertension, heart problems, stroke, diabetes, and transient ischemic attack (TIA) were recorded. Dietary habits were assessed based on frequency of meat and fish intake and the number of servings of fruit and vegetables consumed over the last three days from the date of interview. Health behaviours such as smoking, alcohol consumption, and physical activity were assessed. Smoking behaviour was coded as yes or no. For alcohol consumption, participants were asked regarding their maximum regular consumption in units per week. Finally, self-reported physical activity was coded as physically active for those who reported that they were "very physically active" and "fairly physically active", and not physically active for those reporting "not very physically active" and "not at all physically active" (24). Previous studies have found that age, gender, ethnicity, body mass index, nutritional status, and physical activities were associated with the three anthropometric measurements and thus these variables were controlled for to account for any potential confounders (29-35).

Statistical Analysis

Data analysis was carried out using Statistical Analysis Software (SAS) system version (9.3). Mean and standard error were calculated for continuous variables, and frequencies and percentages were calculated for categorical variables. A univariate test using simple linear regression was conducted to compare the means of the three anthropometric measurements of older adults with dementia to those without dementia. To test for any independent associations between dementia and grip strength, upper arm circumference, and waist circumference, five series of multiple linear regression models were used to estimate modifying effects of socio-demographic variables, body mass index, medical history, dietary habits, and health behaviours. Multivariate analyses were run using linear regression models where dementia was treated as a main predictor and each anthropometric measurement as an outcome variable (24). First regression model was run separately for each of the anthropometric measurements adjusted for socio-demographic variables. The subsequent models were analysed by adding additional factors into each model. The final model was adjusted for socio-demographic variables; body mass index; medical history: hypertension, heart problems, stroke, diabetes, and TIAs; dietary habits: frequency of eating fish, meat, fruit, and vegetables; and health behaviours: smoking, alcohol, and exercise (Table 3, model 5). All statistical significant differences were set at $p < 0.05$.

Results

Characteristics of Study Participants

Of the 2,565 participants, 2,421 cases with completed informants' interview which were required for the 10/66 dementia diagnosis algorithm were included in our sample. The response rate was 65.6%. Table 1 shows the majority were of aged 60-74 (58.0%), women (57.1%) and Chinese (38.5%). Most participants were married/ cohabiting (58.7%), had completed primary education (24.8%), and were retired (39.6%). The distributions of socio-demographic correlates (i.e. age, and ethnicity) were adjusted to match Singapore residents' population for those aged 60 years and above (Table 1; weighted %).

Comparing Group Means

Table 2 shows the mean grip strength, mean upper arm circumference, and mean waist circumference by dementia diagnosis. 2,170 cases with all three measurements were included for the analysis. Missing data from each measurement were due to reasons such as the older adult being bedridden, suffering from stroke or paralysis. Some subjects also opted out as they were uncomfortable with the measurements. The estimated average grip strength for elderly with dementia was 13.07 kg and 21.98 kg for elderly without dementia. An association was found between grip strength and dementia. Participants with dementia had significantly lower grip strength (M= 13.07, SE= 0.60) compared to participants without dementia (M= 21.98, SE= 0.26; $p < 0.0001$). The average upper arm circumference for elderly with dementia was 25.74 cm and 27.51 cm for elderly without dementia. A significant difference was also found for upper arm circumference where participants with dementia had smaller upper arm circumference (M= 25.74, SE= 0.34) than participants without dementia (M= 27.51, SE= 0.11; $p < 0.0001$). The average waist circumference for elderly with dementia was 87.41 cm and 88.55 cm for elderly without dementia. For waist circumference, no significant differences were found between participants with dementia (M= 87.41, SE= 1.07) and those without dementia (M= 88.55, SE= 0.33, $p > 0.05$).

Multivariate Analysis to Test the Independent Association of Anthropometric Measurements with Dementia

Table 3 shows the unadjusted and adjusted estimates representing difference in grip strength, upper arm circumference, and waist circumference. The multiple linear regression models showed that after sequentially adjusting for socio-demographic variables, BMI, medical history, dietary habits, and health behaviours, the effect of grip strength remained significantly associated with dementia (β =-3.00, 95% CI, -4.67, -1.33, $p < 0.001$). Unadjusted model showed a significant association between upper arm circumference and dementia ($p < 0.0001$) however this association did not reach statistical significance after accounting for other variables (Table 3, model 1 to model 5).

Table 1
Demographic profile of sample

	Sample (n= 2,421)		
	Unweighted N	**Unweighted %**	**Weighted %**
Age group			
60-74	1403	58.0	74.8
75-84	633	26.2	19.4
85+	385	15.9	5.7
Gender			
Men	1039	42.9	43.0
Women	1382	57.1	57.0
Ethnicity			
Chinese	931	38.5	82.6
Malay	728	30.1	9.8
Indian	728	30.1	6.1
Others	34	1.4	1.5
Marital status			
Never married	108	4.5	6.8
Married/cohabiting	1419	58.7	65.4
Widowed	798	33.0	22.8
Divorced/separated	94	3.9	5.0
Education			
None	502	20.9	17.1
Some, but did not complete primary	579	24.1	23.8
Completed primary	597	24.8	24.1
Completed secondary	488	20.3	22.5
Completed tertiary	241	10.0	12.5
Employment status			
Paid work (part-time and full-time)	632	26.4	32.9
Unemployed	30	1.3	1.4
Homemaker	782	32.7	27.2
Retired	947	39.6	38.5

Table 2
Means of grip strength, upper arm circumference, and waist circumference between participants with and without dementia

	With Dementia			Without Dementia			
Measurements	**N**	**Mean**	**Standard Error**	**N**	**Mean**	**Standard Error**	**p**
Grip strength (kilograms)	228	13.07	0.60	1942	21.98	0.26	<.0001
Upper arm circumference (centimetres)	228	25.74	0.34	1942	27.51	0.11	<.0001
Waist circumference (centimetres)	228	87.41	1.07	1942	88.55	0.33	>.05

Table 3
Unadjusted and adjusted Beta coefficient (β) estimates (95% Confidence Interval) representing the difference in grip strength, upper arm circumference and waist circumference for participants with and without dementia

	Grip Strength			Upper Arm Circumference			Waist Circumference		
	β	**95% CI**	**p**	**β**	**95% CI**	**p**	**β**	**95% CI**	**p**
Unadjusted model	-8.92	-10.20 -7.63	<.0001	-1.77	-2.47 -1.07	<.0001	-1.14	-3.33 1.06	0.310
Model 1	-4.27	-5.98 -2.55	<.0001	-0.26	-0.74 0.23	0.303	0.97	-0.44 2.38	0.177
Model 2	-3.67	-5.28 -2.06	<.0001	-0.17	-0.67 0.33	0.508	0.78	-0.61 2.17	0.269
Model 3	-3.42	-5.05 -1.78	<.0001	-0.20	-0.72 0.33	0.462	0.80	-0.59 2.18	0.261
Model 4	-3.42	-5.06 -1.79	<.0001	-0.21	-0.74 0.31	0.429	0.83	-0.56 2.22	0.242
Model 5	-3.00	-4.67 -1.33	0.0004	-0.08	-0.59 0.43	0.765	0.66	-0.72 2.05	0.347

Notes: CI = confidence interval; Model 1: Adjusted for age, gender, ethnicity, education, marital status, employment, and BMI; Model 2: Adjusted for age, gender, ethnicity, education, marital status, employment, BMI, hypertension, heart problems, stroke, diabetes, TIAs, and smoking; Model 3: Adjusted for age; gender; ethnicity; education; marital status; employment; BMI; hypertension; heart problems; stroke; diabetes; TIAs; smoking; and frequency of eating fish, meat, fruit, and vegetables; Model 4: Adjusted for age; gender; ethnicity; education; marital status; employment; BMI; hypertension; heart problems; stroke; diabetes; TIAs; smoking; frequency of eating fish, meat, fruit, and vegetables; and alcohol consumption; Model 5: Adjusted for age; gender; ethnicity; education; marital status; employment; BMI; hypertension; heart problems; stroke; diabetes; TIAs; smoking; frequency of eating fish, meat, fruit, and vegetables; alcohol consumption; and physical activity.

Discussion

From our cross-sectional epidemiological study of older adults in Singapore, we found an association between lower grip strength and dementia. The association between grip strength and dementia remained significant after controlling for other factors such as age, gender, BMI, and dietary habits, which influence grip strength. However, our results are not consistent with other studies that found independent associations between upper arm circumference, and waist circumference with dementia (24, 36), although there were studies that did not find significant associations between waist circumference and risk of dementia (37, 38). An association was found between smaller upper arm circumference and dementia in our univariate analysis. However this association was better accounted for by socio-demographic variables, BMI, medical history, dietary habits, and health behaviours.

Our findings lend support to previous studies that found an association of lower grip strength with dementia. A study on twins in Sweden reported that poorer grip strength was one of the predictors for dementia (39). Furthermore, in a study on a Korean elderly population, older people in Korea with both low grip strength and BMI were more likely to be at risk for dementia (40). Although the findings in this Korean study showed that there was an interaction effect between BMI and grip strength, our study did not show such an effect. A separate analysis using BMI as an outcome variable and dementia as a main predictor showed no significant association between BMI and dementia after controlling for other factors.

Several underlying mechanisms have been proposed for this association between grip strength and dementia. Firstly, three neural pathways- integrated sensory, motor, and sensory systems are interconnected and thus any impairment in one neural pathway may alter the other neural systems (41). Progressive brain cells death in people with dementia would cause impairment to the cognitive system and eventually affect the motor system. Meta-analysis has shown that the primary motor cortex activity exhibits differently in AD patients than in healthy older adults (42). Motor impairments would affect a portion of AD patients at the initial stage of the disease and deteriorate along with cognitive impairment. This could therefore influence the grip strength of the older adults with dementia. Furthermore, a cross-sectional study suggested that the combination of age, gender, and cognitive status was related to grip strength in adults with AD or a related dementia (8). Yet in our results, after controlling for age and gender, the association between grip strength and dementia remained significant. Hence we hypothesize that cognitive status could be more related to the association instead.

Secondly, genetic variants could play a role in affecting the physical functions of people with dementia. Previous research has suggested that the AD risk genes such as presenilin 1 (PS1) and apolipoprotein E (APOE E4) are associated with motor syndromes (43). However, genetic factors were not assessed in the current study and thus future studies could look into this area of research.

Lastly, engaging in physical activity could affect grip strength. Horowitz et al (1997) found significant association between greater grip strength with weekly physical activity in older adults in United States. In model 5 of our multivariate analyses when physical activity variable was included (Table 3), the significance of the finding dropped slightly suggesting that engaging in physical activities might affect the association between grip strength and dementia.

The cross-sectional design of our study does not enable us to make conclusions on the temporal relationship between grip strength and dementia. In addition, this study only looked at dementia as the main predictor. Previous studies have indicated that the association between dementia subtypes with other anthropometric measurements (i.e. skull circumference and leg length) differs (44). Thus it is possible that upper arm circumference and waist circumference are associated with specific types of dementia instead of dementia in general. Lastly, there is also the possibility that the participants, particularly those with dementia, may not have understood the instructions for measuring grip strength and that could affect the validity of the measurements taken (40). To reduce the likelihood of such occurrence, all interviewers received standardized instructions and training from senior researchers to ensure proper use of the equipment and demonstrations of using the dynamometer were also conducted for all subjects.

Notwithstanding the limitations stated above, results from this study have important implications on the healthcare of the elderly. Our findings add to the growing literature that highlights the potential use of physical measurements such as grip strength as markers for cognitive functioning in elderly (45, 46). Home-based self-monitoring of grip strength using reliable instrument such as a grip-ball (47) could be promoted as a non-invasive efficient method to detect elderly who are at risk of having dementia. Furthermore, a number of studies showed that improving grip strength has various other benefits including reduction of risk of mortality and chronic diseases (48, 49). Lastly, given the strength of the association coupled with other studies that found the reliability of grip strength tests in non-severe dementia patients (50, 51), this anthropometric measurement has potential value as a measure in interventions for those with dementia.

In conclusion, lower grip strength was found to be independently associated with dementia in the older adult population in Singapore. This finding adds on to the existing literature that looks at anthropometric measurements and their associations with dementia and showed that dementia was associated with lower grip strength after controlling for other confounding variables. Important implications of our findings have been discussed in this paper and future studies could look into assessing these suggestions.

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Conflict of Interest: All authors report grants from Ministry of Health, Singapore, and Singapore Millennium Foundation, during the conduct of the study.

Ethical Standards: The authors declare that the study procedures comply with the current ethical standards for investigation involving human participants in Singapore.

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