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Research paper

Calf circumference predicts mobility disability: A secondary analysis of the Mexican health and ageing study

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ABSTRACT

Introduction: Calf circumference is a surrogate measurement of muscle mass. However, there is scarce evidence on its validity in predicting adverse outcomes such as mobility disability. The aim of this report is to determine if calf circumference could predict incident mobility disability in Mexican 60-year or older adults.

Methods: This is a secondary analysis of the Mexican Health and Aging Study and in particular of its two first waves. Sixty-year or older adults without mobility disability in the first assessment were included and followed-up for two years. Calf circumference quartile groups were compared to test the difference of incident mobility disability. Logistic regression models were fitted to test the independent association when including confounding variables.

Results: A total of 745 older adults were assessed, from which 24.4% of the older adults developed mobility disability at follow-up. A calf circumference > 38 cm was associated with a higher risk of developing mobility disability, even after adjustment in the multivariate model, with an odds ratio 0.55 (95% confidence interval 0.31–0.99, $P = 0.049$).

Conclusions: High calf circumference in Mexican older adults is independently associated with incident mobility disability. This could reflect the impact of adverse health conditions such as obesity (with high fat tissue) or edema. Further research should aim at testing these results in different populations.

1. Introduction

One of the main concerns of older adults health is nutrition. This concern is depicted in the latest years with an increasing interest in sarcopenia and associated conditions (e.g. sarcopenic obesity). Sarcopenia has shown to be closely related to aging and aging-related conditions [1]. There are a number of tools that measure body composition with different accuracy, from anthropometry to magnetic resonance imaging [2,3], in order to assess muscle mass or fat tissue. The measurement of calf circumference (CC) reflects low muscle mass and has been validated with the current reference standard (compared to Dual-energy X-ray absorptiometry [DEXA], $r = 0.63$), and has shown to be useful predicting adverse outcomes such as mortality and dependency [4,5]. In addition, a high CC in populations with elevated frequency of obesity it could be a marker of sarcopenic obesity [6]. Either way (low or high), it is a marker of malnourishment and potentially associated with sarcopenia. On the other hand, CC assessment is an easy to perform measurement that provides clinically useful information that can aid in the decision-making process in older adult health care [5–8]. This is especially true in contexts in which specialized resources for older adult care are scarce [9,10]. Moreover, along with new research in CC, there is an increasing interest in generating surrogates of the measurement of muscle mass with ready available information (epidemiologic, anthropometric, health-related, etc.) [11,12].

In 2010, Cruz-Jentoft et al. proposed an algorithm in order to detect sarcopenia in which along with muscle mass measurement, physical performance tests were also included (gait speed and handgrip strength) [13]. This algorithm has been increasingly used in clinical and research settings, as shown in a recent systematic review in which studies using the algorithm were several hundreds (in just four years) [14]. Physical performance tests are easy to evaluate in older adults and have shown good validity in predicting adverse outcomes in a number of settings [15–18]. The same is true for recommended muscle mass measurement tools DEXA and bioelectrical impedance analysis (BIA) [2]; however, in contrast to the other components of the algorithm, these tools are not available

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everywhere, need specialized personnel to be performed, are more expensive and not very popular even among geriatricians [19]. Notwithstanding, there are an increasing number of reports that use the algorithm using CC as the muscle mass measurement [20–25].

In contrast to gait speed and handgrip strength – the other two components of the algorithm – CC lacks of evidence of its potential predictive value of mobility disability. The aim of this study is to assess the predictive ability of CC in predicting mobility disability in a group of community-dwelling older adults (60 years and over) from the Mexican Health and Aging Study (MHAS).

2. Materials and methods

This is a secondary analysis of the MHAS and in particular from the baseline assessment (2001) and the second wave (2003). Complete methods and objectives are available elsewhere [26,27]. In brief, there are three waves of this study with a probabilistic sample of Mexican adults aged 60 years or older (2001, 2003 and 2012). A set of questionnaires (socio-demographic characteristics, health-related issues, access to health services, migration status, cognitive performance, functional status, and financial resources) was applied to all the participants. In addition, each wave included a sub-sample in which anthropometric measurements and blood samples were also obtained.

A total of 15,402 subjects were assessed in 2001 (which included adults with less than 60 years), and a 20% (n = 2573) randomly selected sub-sample was drawn to obtain anthropometric measurements, such as: height, weight, calf circumference, knee height, hip and abdominal circumferences. After exclusion of subjects with less than 60 years and those with mobility disability already in 2001; the final sample was of 754 older adults, with complete follow-up to 2003.

Mobility disability was defined as having difficulty to walk one block or having difficulty to climb one flight of stairs, as previously used with physical performance tests in older adults [15,28]. As previously stated, older adults with this condition in the first assessment were excluded from the analysis.

CC was measured in the most prominent region of the leg with the older adult in a sitting position with both legs on the floor and relaxed, three measurements were performed and the highest one was registered in centimetres [29]. Further categorization of CC was done by quartiles (for each sex group); these groups were used in the following analyses (see below).

Confounding variables were included in order to test the independent association of CC with incident mobility disability such as socio-demographic characteristics: age in years, sex, marital status (married, single, divorced or widower), currently working (including domestic chores), and years in school. Smoking status (never smoked, smoked in the past and currently smoking), and physical activity (having done exercise regularly in the past two years) were included as habits that could impact overall health. Finally health-related variables included self-rated health (excellent, very good, good, fair, poor), self-rated vision (excellent, very good, good, fair, poor), self-rated hearing (excellent, very good, good, fair, poor), pain (chronic and constant), weight loss (unintentional loss of 5 or more kilograms in the last two years), cognitive decline, significant depressive symptoms, falls, body mass index (weight/squared height), and a sum of comorbidities (including hypertension, diabetes mellitus, cancer, lung disease, ischemic cardiac disease, stroke, and articular disease). Subjects were considered to have cognitive decline if they failed in two or more sub-tests of the brief version of the Cross Cultural Cognitive Examination [30]. Regarding depression a score of 5 or higher was considered as significant depressive symptoms as already validated in Mexican older adults [31].

Descriptive statistics included frequencies (absolute and relative) for categorical variables, means and standard deviation (SD) for continuous variables and medians with inter-quartile ranges (IQR) for ordinal ones. In order to assess significance of the difference for each variable when comparing the group with incident mobility disability with the group without incident mobility disability further tests were performed: t-tests (continuous) and Wilcoxon rank-sum tests (ordinal) were performed along with Fisher's exact test to categorical variables. Finally a logistic regression was fitted estimate the odds ratio (OR) for predicting mobility disability of quartiles of CC, comparing the groups (without reference group). Unadjusted and adjusted models (for significant variables only) are reported; OR along with 95% confidence intervals (CI) and P-values were obtained. All analyses were performed with STATA 14® statistical software.

The MHAS is supported by the National Institutes of Health/National Institute on Aging (R01AG018016) and by the *Instituto Nacional de Estadística y Geografía* (INEGI) in Mexico. The MHAS study protocol and instruments were reviewed and approved by the Institutional Review Board or Ethics Committee of the University of Texas Medical Branch, the INEGI in Mexico, and the *Instituto Nacional de Salud Pública* (INSP) in Mexico.

3. Results

From a total of 754 60-year or older adults, 50.8% were women and the mean age of the sample was of 67.39 years (±SD 6.43). The majority of older adults were married (64.32%) and currently worked (61.8%). The median of years in school was 3 (IQR 0–19). A total of 267 older adults (35.41%) did vigorous physical activity in the last year and up to 415 (55.04%) have never smoked. Perception of health was mainly fair (46.68%), vision and hearing perception were more frequently reported as good (42.04% and 54.91% respectively). Regarding geriatric conditions pain, falls, depression and cognitive decline were common with a frequency of 30% or above. The median number of comorbidities was one (IQR 0–5). The mean of the BMI was 26.72 kg/m^2 (±SD 4.32) and CC 35.6 cm (±SD 3.02) (see Table 1). The mean BMI for each of the CC quartiles was (from the lowest to the highest); Q1 = 23.7 kg/m^2, Q2 = 26.5 kg/m^2, Q3 = 27.9 kg/m^2, Q4 = 30.3 kg/m^2.

Overall incidence of mobility disability was of 24.4% (n = 184). Regarding the significance between the group with incident mobility disability and without mobility disability only smoking status and BMI were not significantly different, while the rest of the variables were significantly different or with a significant trend. Specifically for the CC quartile groups, incidence of mobility disability was lower for the third quartile (Q3) group (16.22%); for the rest of the quartiles the incidence was: 25.51% for the first (Q1), 26.84% for the second (Q2) and 27.22% for the fourth (Q4) (P-value = 0.065) (see Table 1).

As shown in Table 2, the only significant association was when comparing Q3 group to the rest of the groups, those in Q3 of CC had a lower risk of incident mobility disability, with the highest effect when comparing Q3 with Q4: OR 0.51 (95% CI 0.29–0.89, P = 0.02). The rest of the group comparisons in the unadjusted model were non-significant. In the adjusted model only the Q3 to Q4 comparison was significant: OR 0.55 (95% CI 0.31–0.99, P = 0.049) (see Table 2).

4. Discussion

CC predicts incident mobility disability in a group of Mexican community-dwelling older adults. However, older adults with a relatively high CC were those that showed the highest risk (Q4 group). To our knowledge, this is the first study reporting that a high CC could be associated with incident mobility disability. Our

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Table 1
General characteristics of the sample and comparison between incident mobility disability status.

Variables	Total (*n* = 754)	Incident mobility disability (*n* = 184 [24.4%])	No mobility disability (*n* = 570 [75.6%])	*P*-value
Age in years, mean (SD)	67.39 (6.4)	69.3 (7.3)	66.77 (5.9)	< 0.001
Sex, *n* (%)				
Men	371 (49.2)	108 (58.6)	275 (48.2)	0.009
Women	383 (50.8)	76 (41.3)	295 (51.7)	
Marital status, *n* (%)				
Married	485 (64.3)	101 (54.8)	384 (67.3)	< 0.001
Single	30 (3.9)	5 (2.7)	25 (4.4)	
Divorced	59 (7.8)	12 (6.5)	47 (8.2)	
Widower	180 (23.8)	66 (35.8)	114 (20)	
Currently working, *n* (%)	466 (61.8)	94 (51)	372 (65.2)	< 0.001
Years in school, median (IQR)	3 (0–19)	2.5 (0–18)	3 (0–19)	0.002
Done physical activity in the last year, *n* (%)	267 (35.4)	52 (28.2)	215 (37.7)	0.012
Smoking status, *n* (%)				
Never smoked	415 (55.04)	109 (59.2)	306 (53.6)	0.274
Smoked in the past	224 (29.7)	46 (25)	178 (31.2)	
Currently smokes	115 (15.3)	29 (15.7)	86 (15.08)	
Self-rated health, *n* (%)				
Excellent	11 (1.4)	3 (1.6)	8 (1.4)	0.001
Very good	37 (4.9)	9 (4.8)	28 (4.9)	
Good	248 (32.8)	45 (24.4)	203 (35.6)	
Fair	352 (46.6)	85 (46.1)	267 (46.8)	
Poor	106 (14.06)	42 (22.8)	64 (11.2)	
Self-rated vision, *n* (%)				
Excellent	27 (3.5)	3 (1.6)	24 (4.2)	0.052
Very good	94 (12.4)	25 (13.5)	69 (12.1)	
Good	317 (42.04)	71 (38.5)	246 (43.1)	
Fair	246 (32.6)	59 (32.06)	187 (32.8)	
Poor	70 (9.2)	26 (14.1)	44 (7.7)	
Self-rated hearing, *n* (%)				
Excellent	33 (4.3)	2 (1.08)	31 (5.4)	0.005
Very good	130 (17.2)	35 (19.02)	95 (16.6)	
Good	414 (54.9)	90 (48.9)	324 (56.8)	
Fair	144 (19.1)	47 (25.5)	97 (1.5)	
Poor	33 (4.3)	10 (5.4)	23 (4)	
Pain, *n* (%)	301 (39.9)	92 (50)	209 (36.6)	0.001
Falls, *n* (%)	289 (38.3)	89 (48)	200 (35)	0.001
Weight loss, *n* (%)	198 (26.2)	63 (34.2)	135 (23.6)	0.004
Depression, *n* (%)	240 (31.8)	79 (42.9)	161 (28.2)	< 0.001
Cognitive decline, *n* (%)	285 (37.8)	81 (44.02)	204 (35.7)	0.028
Sum of comorbidities, median (IQR)	1 (0-5)	1 (0-4)	1 (0-5)	0.001
Body mass index, mean (SD)	26.7 (4.3)	26.7 (4.5)	26.7 (4.2)	0.919
Calf circumference, mean (SD)	35.6 (3.9)	35.2 (3.9)	35.7 (3.9)	0.18
Quartiles of calf circumference, *n* (%)				
Q1	247 (32.7)	63 (34.2)	184 (32.2)	0.065
Q2	190 (25.2)	51 (27.7)	139 (24.3)	
Q3	148 (19.6)	24 (13.04)	124 (21.7)	
Q4	169 (22.4)	46 (25)	123 (21.5)	

Q1: first quartile of calf circumference (< 34 for women and < 35 for men); Q2: second quartile of calf circumference (34–35 for women and 35–36 for men); Q3: third quartile of calf circumference (36–38 for women and 37–39 for men); Q4: fourth quartile of calf circumference (> 38 for women and > 39 for men).

Table 2
Multiple logistic regression models for prediction of incident mobility disability and quartiles of calf circumference.

Calf circumference quartile	Unadjusted	Adjusted[a]
Q1 to Q2	1.07 (0.69–1.64, 0.753)	0.82 (0.51–1.31, 0.42)
Q1 to Q3	1.76 (1.04–2.98, 0.032)	1.35 (0.77–2.37, 0.283)
Q1 to Q4	1.09 (0.7–1.7, 0.696)	0.75 (0.46–1.22, 0.259)
Q2 to Q3	1.89 (1.1–3.26, 0.021)	1.64 (0.92–2.92, 0.088)
Q2 to Q4	0.98 (0.61–1.56, 0.936)	0.91 (0.55–1.5, 0.731)
Q3 to Q4	0.51 (0.29–0.89, 0.02)	0.55 (0.31–0.99, 0.049)

Q1: first quartile of calf circumference (< 34 for women and < 35 for men); Q2: second quartile of calf circumference (34–35 for women and 35–36 for men); Q3: third quartile of calf circumference (35.1–38 for women and 36.1–39 for men); Q4: fourth quartile of calf circumference (> 38 for women and > 39 for men)

[a] Adjusted only for significant variables in the model: age, marital status, currently working, self-rated vision, self-rated hearing, pain, falls, sum of comorbidities.

results show that in addition to previous findings in cross-sectional studies in which low calf circumference is associated with lower functional performance, high calf circumference can also be related with adverse outcomes [4]. To this regard, Hsu et al. already pointed to the fact that high CC values could be associated with disability, but difficult to observe in populations where obesity has a low prevalence [5]. In contrast, in Mexico obesity is considered to have epidemic dimensions in all age groups [32].

As our results show that a very high CC (> 38 cm) is independently associated with the development of mobility disability. This shows the potential impact that fat tissue could have in function; older adults with sarcopenic obesity have higher rates of disability [33]. Moreover, the BMI mean in the highest quartile of CC was in the range of obesity (>30 kg/m^2), supporting the association of a potential fatty infiltration of the muscles of the leg. High CC could reflect also a greater amount of subcutaneous fat in addition to fatty muscle infiltration, both favoring an

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inflammatory state that could explain those higher rates of disability [34]. On the other hand, edema could also be a marker of worsening health, and be reflected in a higher CC, however available evidence in younger adults points to the fact that calf swelling is not detected by measuring CC [35].

When evaluating an older adult in order to discriminate which would benefit from further evaluation due to a suspected condition, measuring CC could aid the primary care physician with a busy office to have a readily available biomarker with a good clinical utility [5,8]. In addition, our findings support the already described phenomenon of a U-shaped relationship between BMI and frailty; a similar association between CC and disability (or other adverse health scenarios) may be also possible [36]. Other measurements or complementary ones such as mid-arm circumference adjusted for skin folds, or even adjustment of calf circumference to skin fold of the leg are other options to be explored, however this could add accuracy in detriment of simplicity [6].

One of the main flaws of this study was the short time of follow-up. In addition, only having 754 older adults could also have lowered power in having false negative estimates. Finally this methodology should be replied in populations different to the one described in our manuscript. Future research should aim to further explore how cut-off values of calf circumference based on middle values instead of lower ones could re-shape the value of this measurement and increase its specificity, one of the main pitfalls argued by other research groups in order to not recommend its routine use in the clinical setting. In addition, validation studies with reference standards such as DEXA or BIA in order to address if those with a high calf circumference in fact have a muscle infiltration of this region is needed. There was a lack of power due to attrition when categorizing by BMI quartiles, giving rise to lack or marginal significance in the adjusted models.

5. Conclusion

Calf circumference is a useful tool for screening older adults and focus further evaluation in those with a higher risk of developing adverse outcomes such as mobility disability. Advancing the field not only in high-tech procedures but in ready available ones may aid in a better care for a continuously growing aging population.

Ethical statement

The Institutional Review Boards or Ethics Committees of the University of Texas Medical Branch in the United States, the *Instituto Nacional de Estadística y Geografía*, the *Instituto Nacional de Salud Pública* and *Instituto Nacional de Geriatría* in Mexico approved the study. The study was performed according to the Helsinki declaration and all subjects signed informed consent.

Disclosure of interest

The authors declare that they have no competing interest.

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