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Anthropometric Measurements and Mortality in Frail Older Adults

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Abstract

Background—As the number of older adults increases, so does the number of frail older adults. Although anthropometry has been widely used as a way to stratify the overall mortality risk of a person, the significance of these measurements becomes blurred in the case of frail older adults who have changes in body composition. Therefore, the aim of this study is to determine the association of anthropometric measurements (body mass index, knee-adjusted height body mass index, waist-to-hip ratio and calf circumference) with mortality risk in a group of older Mexican adults.

Methods—This is a longitudinal analysis of the Mexican Health and Aging sub-sample (with biomarkers, n=2,573) from the first wave in 2001, followed-up to the last available wave in 2015. Only frail 50-year or older adults (Frailty Index with a cut-off value of 0.21 or higher, was used) were considered for this analysis (n=1,298). A survival analysis was performed with Kaplan-Meier curves and Cox regression models (unadjusted and adjusted for confounding). Socio-demographic, health risks, physical activity and comorbidities were variables used for adjusting the multivariate models.

Results—From the total sample of 1,298 older adults, 32.5% (n=422) died during follow-up. The highest hazard ratio in the adjusted model was for calf circumference 1.31 (95% confidence interval 1.02–1.69, p=0.034). Other measurements were not significant.

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Conflicts of interest

None declared.

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Conclusions—anthropometric measurements have different significance in frail older adults, and these differences could have implications on adverse outcomes. Calf circumference has a potential value in predicting negative health outcomes or likewise.

Keywords

Frailty; Mortality; Body Mass Index; Anthropometric Measures

1. Introduction

In addition to the growing demand of health care services by older adults, a specific subgroup of this age group particularly burdens the system, especially when not properly managed: the frail older adults (Cesari and others 2016b). Although there remains controversy (Bergman and others 2007; Hogan and others 2003) as to a precise definition or clinical characterization of frailty, it is generally accepted that when frailty remains undetected, the risk of an acceleration in the functional decline of an older adult increases exponentially, such that, even minimal stressors, may trigger catastrophic outcomes (Aalen and others 2014; Cesari 2011), including death. Thus, in spite of a lack of precision in its definition, it is important to seek indicators of enhanced mortality risk in frail elders in order to implement adapted care models which target the multidimensional and heterogeneous complexity of these individuals (Cesari and others 2016a).

Anthropometric measurements are commonly used in clinical practice; in particular, body mass index (BMI) is widely accepted and used in these settings (Dent and others 2015). In recent years, such assessments have strongly supported the risk stratification of an individual for adverse cardio-metabolic outcomes and any-cause mortality (Kim and others 2015). However, when it comes to frail older adults, results of these anthropometric measures are often misleading (Oreopoulos and others 2009; Zunzunegui and others 2012).

Indeed, there is an ongoing debate regarding the role of BMI and, for example, its alleged U-shape relationship with mortality in older adults (Hubbard and others 2010; Zunzunegui and others 2012). In particular, there is a lack of evidence as to how this measure may work in the prediction of mortality risk in frail older adults. Moreover, other anthropometric measures of similar interest, such as waist-to-hip ratio [WHR] or calf circumference [CC]), have little literature to their name (Landi and others 2014; Welborn and others 2003), even though they could also be potentially used for risk stratification.

Understanding the role that anthropometric measures may have in the risk stratification of frail elders is crucial (Abellan van Kan and others 2008), especially in low and medium income countries where a more sophisticated initial screening may not be feasible. As easy-to-administer screening and assessment tools are particularly needed (Elder 2013), such measurements could provide simple tests which can be quickly carried out by a healthcare professional in any consultation and which would be particularly useful in settings where human resources specialized in older adult healthcare are scarce (Gutierrez-Robledo 2002).

The aim of this study is to determine which anthropometric measurement (BMI, knee-adjusted height BMI, WHR and CC), better predicts mortality in a group of older Mexican

adults. We hypothesize that BMI will not be as good a mortality predictor as it is in non-frail older adults, and, further, that calf circumference and/or WHR will be better mortality predictors in frail older adults.

2. Materials and Methods

2.1. Design

The Mexican Health and Aging Study (MHAS) is based on a cohort of older adults aged 50-years with a follow-up of 14 years. The sample was designed to be representative of the whole country. Households were qualified to be in the sample if they contained at least one 50-year or older person; they were then invited face to face, and if they accepted, an appointment was made to perform the interview at home. The full description, objectives and database of the MHAS are available to the public (Wong and others 2015), and it is from this database that the present longitudinal analyses were performed. In addition to socio-demographic and health-related measurements, the database contains a sub-sample of other objective measurements (i.e. serum biomarkers, physical performance tests and anthropometry).

2.2. Sample

The study sample was obtained from a subgroup of participants that underwent anthropometric evaluation in the first wave in 2001 (n=2,573). This subsample of interest was drawn from the overall cohort (n=16,540) through a probabilistic and representative method from all the country's participating sites (Wong and others 2007).

A 40-item Frailty Index (FI) was constructed, with deficits covering multiple health domains (see Supplementary Table 1), per the methods proposed by Searle (Searle and others 2008). A FI cut-off point value of 0.21 is conventionally used for Mexican older adults, having been previously validated using this same dataset (Garcia-Gonzalez and others 2009). This FI has been used as an operational definition of frailty, and has been shown to be useful for distinguishing individuals at higher risk of adverse outcomes (in particular, mortality and disability) (Jones and others 2004; Mitnitski and others 2002). This value of the FI (0.21) was used throughout to define frail participants, with the effect of reducing the study sample to 1,298 older adults, who were then followed for a maximum of 168 months. A total of 124 older adults were lost to follow-up, with no survival data. The follow-up of these participants was censored at the last contact date. For the remaining 1,174 frail older adults, complete data about follow-up was available.

2.3. Variables

We obtained the analyses' dependent variable, mortality of the subjects, through a next-of-kin informant. The date of death was recorded and used to calculate the length of survival (in months) from the baseline assessment.

Anthropometric measurements (independent variables of interest) were BMI, knee-adjusted height BMI, WHR, and CC. Given the possible non-linear relationship with mortality risk, the anthropometric variables were categorized using standard recommended cut-off points.

BMI was categorized according to the World Health Organization standards into four groups (underweight, normal, overweight and obese) (Organization 2017). Additionally, a second, non-standard BMI categorization was made in order to take into account potential height loss in older adults, by using knee-adjusted height and applying the available formulas for Mexican older adults (Carrillo-Vega and others 2017; Mendoza-Nunez and others 2002) (see supplementary table 2 for formulas). For WHR, calculated by waist measurement divided by hip measurement and used to define central obesity, a cut-off point of 0.8 was used for women and 1.0 for men (Salud 1998). Finally, CC was applied for identifying individuals with possible malnutrition, using a cut-off point of 31 cm or less. This has been incorporated into nutritional assessment tools in a wide range of populations (Guigoz and Vellas 1997).

Other variables included in the analysis were from different domains, such as socio-demographic (age, sex, living environment [urban vs rural]), education in years), health risks (smoking [never smoked, used to smoke and currently smokes], physical activity [performed hard work or exercise at least three days a week last year]) and comorbidities (self-report of the following diseases: hypertension, type 2 diabetes mellitus, cancer, lung disease, heart attack, stroke, articular disease and tuberculosis). These variables were used to adjust the multivariate models.

2.4. Statistical Analysis

For descriptive purposes, all the variables were contrasted according to survival status; with relative and absolute frequencies, as dichotomous variables. Ordinal variables were described with median and inter-quartile range (IQR), while continuous variables were described with means and standard deviations (SD). t-tests, Wilcoxon and Chi square tests for significance were used in the bivariate analysis. Survival curves were constructed for the different categories of the anthropometric measurements, using the log-rank test to contrast the differences between the curves. In order to adjust for confounding variables, Cox regression models were fitted for each of the anthropometric measurements, with the potential confounding variables: age, sex, marital status, education, living environment, smoking status, physical activity, and number of comorbidities. As a measure of association, hazard ratios (HR) with 95% confidence intervals (CI) were estimated. Lastly, the assumption of proportionality was checked with log-log curves (Hess 1995). All statistical procedures were carried out utilizing the STATA® 14 (StataCorp 4905, Lakeway Drive, College Station, Texas 77845 USA) software.

2.5. Ethical Issues

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 the Instituto Nacional de Geriatria in Mexico approved the study. All study subjects signed an informed consent form.

3. Results

3.1. Cohort demographic assessment

Of the 1,298 adults in the sample, the average age was 62.08, with survivors having a lower average age than those who died. The sample contained 819 women (63.1%) and 479 men (36.9%), which is consistent with the proportions found in other Mexican based health questionnaire studies (Easton and others 2017a; Easton and others 2017b). Other demographic variables considered were: Marital status, living environment, education, smoking status, physical activity and number of comorbidities. A summary of these variables can be seen in Table 1. For binary variables, data is presented for only one response, as the alternative can be simply calculated from the totals.

3.2. Survival curves for anthropometric measurements

In line with the principal aim of this study, the four chosen anthropometric measurements BMI, knee-adjusted height BMI, WHR and CC were compared, with Kaplan-Meier survival curves being created for each of the four methods individually. For both BMI measurements, the standard categorization was made for underweight, normal, overweight and obese. The Kaplan-Meier survival curves plotted against time in months can be seen in Figures 1a) and 1b) for BMI and knee-adjusted height BMI respectively.

Moving away from the weight categorization methods of BMI, the survival curves for WHR can be seen in Figure 2. Here, the grouping is made based on WHR ≤ 0.8 for women and WHR ≤ 1 for men, where the cohort is analyzed as a whole.

The final measure considered is CC, where the universal cut-off for both men and women is 31cm. The corresponding Kaplan-Meier survival curves for CC can be seen in Figure 3.

3.3. Statistical analysis of anthropometric measurements

To accompany the Kaplan-Meier survival curves seen in Figures 1a), 1b), 2 and 3, the results of a log-rank test have been introduced and can be seen in Table 2, where it is clear that, while all measurement models produce significant results ($p < 0.05$), the most significant is that for CC ($p < 0.001$).

In order to further test the significance of the results seen in the Kaplan-Meier survival curves, Cox proportional hazards models were used. These models take one category of the variable as a reference point with value=1, BMI normal for example, and compare the other categories to this reference. The HRs and their 95% confidence intervals were created for the unadjusted model and also for an adjusted model, taking into account all variables seen in Table 1. The HRs were calculated for all four anthropometric measurements and the results can be seen in Table 3.

4. Discussion

According to our results, the widely-used BMI measurement (in both its knee-adjusted and normal versions) is not useful in categorizing those frail older adults with a higher risk of dying. In addition, WHR was not useful either, once the considered covariates were taken

into account. However, a low CC was shown to be associated with higher risk of mortality. To our knowledge, this is the first work to address the use of anthropometric measurements to categorize mortality risk in frail older adults. There is a previous report on this regard, in the Women's Health Initiative Study, where lower BMI and WHR were both associated with higher rates of death in that completely female population (Zaslavsky and others 2016). That work did not include CC, however.

In interpreting our result that CC is more relevant than the other anthropometric measures in characterizing mortality risk in frail older adults, we believe that CC is a better measure, as it is much more directly associated with a lack of muscle mass when compared to the other measures that are more focused on capturing excess adiposity, obesity and overweight. Interestingly, the low adapted BMI (defining underweight) has estimates of risk (and 95% CIs) very similar to those reported by low CC. Thus, we could say that anthropometric measures might work in frail elders if they were used to target undernutrition rather than excessive weight (which is instead neutral in terms of mortality risk).

Approximately one third of Mexican older adults have been reported to be frail (Garcia-Pena and others 2016). This hardly qualifies then as a rare condition, and its systematic detection should be incorporated into the daily activities of clinicians in order to avoid a one-size-fits-all strategy. This is particularly relevant given the convergence of the so-called obesity epidemic and overall population aging. Ongoing campaigns to halt obesity, which are mainly based on weight reduction, could pose a risk for this specific group of older adults (Salud 2017) where sarcopenic obesity is a possibility. Moreover, the WHO has also issued similar strategies without taking into account the significant fraction of frail older adults. Therefore, risk stratification with anthropometric measurements in older adults should involve a two-step process: 1. detect or discard frailty (Cesari and others 2016b); and 2. use appropriate measures accordingly (as shown by our results, CC would be the best measurement for these purposes).

Even though the measurements we have used may reflect different aspects of body composition, the findings may be applied in the clinical and research settings, shifting the focus of classifying older adults using BMI and promoting the use of CC, and, in general, alerting the clinician to the fact that an undernourished (i.e., low CC and low WHR) frail older adult might be at higher risk of dying (Lustgarten and Fielding 2011). Moreover, there is evidence that frail older adults have an accelerated loss of muscle mass, eventually leading to sarcopenia and disability (Jung and others 2014), a phenomenon that could be accelerated by restrictive diets in frail older adults.

Our study has several limitations: For example, using standard cut-off points could bias the categorization of the subjects and therefore under or overestimate HR. As previously stated, though, keeping these already known and widely used—in the clinical geriatrics field—values may help clinicians to interpret the results. However, further research should test population-tailored values. Another important issue was the number of older adults categorized as underweight, which raises issues of low power when estimating HR for the BMI measures when categorized. As per our results, it could be said that there is a potentially higher HR in those classified as underweight, both with conventional BMI and knee-adjusted height BMI.

Finally, it is of great importance to acknowledge the lack of an absolute operational definition of frailty (Cesari 2016b). Using the frailty index for our work was based only on the fact that previous work has been done with this definition in this same cohort (Garcia-Gonzalez and others 2009).

One area of potential future work is to investigate the potential time dependence of the risk factors. For all four measurements, the Kaplan-Meier curves show a noticeable shift in behaviour for low versus high values of the measure between about 50 and 70 months. With a larger data base, the potential time evolution of risk factors over distinct time ranges could be determined. Similar methods have been successfully applied to post-stroke mortality (Easton and others 2014). Expanding the age range to include younger frail adults is another possibility, in order to see if they are dying earlier under different stressors. It would be interesting to consider the relation between mortality and our anthropometric measurements in the case of non-frail elders as well. Finally, it would be useful to include muscle status metrics other than CC, such as grip strength, in order to determine the degree to which the observed enhanced mortality risk is associated with sarcopenic frail elders; however, it would have different implications beyond that of body composition, which was the object of study.

5. Conclusions

As per previous studies contrasted with our results, frail older adults, a complex and at-risk segment of the population, require care that differs from their non-frail counterparts. Anthropometric measurements have different significance in frail older adults, and these differences could have implications on adverse outcomes. As the interpretation of anthropometric measurements may have different connotations in frail older adults, they should be interpreted cautiously before taking action, given that such action may render them prone to subsequent adverse events.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

BMI	Body Mass Index
WHR	Waist-to-hip ratio
CC	Calf Circumference
MHAS	Mexican Health and Aging Study

FI	Frailty Index
HR	Hazard Ratios
CI	Confidence Intervals
IQR	Inter-Quartile Range
SD	Standard Deviation

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Highlights

- Frailty is a common condition in older adults, and merits differentiated assessment for older adults who have it
- Body composition has different implications in frail older adults
- Body mass index is a less precise measurement in older adults when compared to calf circumference
- Muscle mass seems to be more relevant in older adults in terms of predicting mortality

Figure 1.

a) Kaplan-Meier Survival Curves for Body Mass Index Categories with Measured Height; b) Kaplan-Meier Survival Curves for Body Mass Index Categories with Knee-adjusted Height

Figure 2. Kaplan-Meier Survival Curves for Categorized Waist-to-Hip Ratio (< 0.8 for women, < 1 for men)

Figure 3.
Kaplan-Meier Survival Curves for Categorized CC (>31cm)

Table 1

General Description of the Sample at Baseline Assessment Comparing Survival Status *

	Total (N=1,298)	Survived (n=876)	Not-survived (n=422)	p-value
Age, mean (SD)	62.08 (9.46)	60.13 (7.78)	68.34 (10.21)	<0.001
Women, n (%)	819 (63.1)	577 (65.87)	242 (57.35)	0.003
Marital status (married), n (%)	863 (66.4)	618 (70.5)	245 (58.1)	<0.001
Living environment (urban), n (%)	855 (65.8)	577 (65.8)	278 (65.8)	0.997
Education (years), median (IQR)	3 (0–19)	3 (0–18)	2 (0–19)	<0.001
Smoking status, n (%)				
Never	760 (58.5)	539 (61.5)	221 (52.3)	0.003
Smoked	347 (26.7)	211 (24.09)	136 (32.2)	
Smokes	191 (14.7)	126 (14.3)	65 (15.4)	
Physical activity, n (%)	431 (33.2)	334 (38.1)	97 (22.9)	<0.001
Number of comorbidities, median (IQR) [†]	1 (0–4)	1 (0–4)	1 (0–4)	<0.001

* For categorical/dichotomous variables, percentages for totals are for the column while for survival status for the row; p-values correspond to log-rank tests of the survival curves

[†] The sum of hypertension, diabetes mellitus, cancer, lung disease, heart attack, stroke, articular disease and tuberculosis

Table 2

Comparison of Anthropometric Measurement Categorization by Survival Status *

	Total (n=1,298)	Survived (n=876)	Not Survived (n=422)	p-value †
Standard BMI				
Underweight	24 (1.85)	14 (1.59)	10 (2.36)	0.001
Normal	363 (27.9)	217 (24.7)	146 (34.5)	
Overweight	519 (39.9)	360 (41.1)	159 (37.6)	
Obese	392 (30.2)	285 (32.5)	107 (25.3)	
Modified BMI				
Underweight	33 (2.54)	17 (5.87)	16 (3.79)	0.026
Normal	375 (28.8)	238 (27.16)	137 (32.46)	
Overweight	489 (37.6)	336 (38.35)	153 (36.25)	
Obese	401 (30.8)	285 (32.53)	116 (27.48)	
High WHR	899 (69.2)	627 (71.57)	272 (64.45)	0.009
Low CC	171 (13.1)	85 (9.7)	86 (20.37)	<0.001

BMI=Body Mass Index, WHR=Waist-to-Hip Ratio, CC=Calf Circumference

* For categorical/dichotomous variables, percentages for totals are for the column while for survival status for the row

† p-values are from log-rank test results

Table 3
Cox Regression Models (Adjusted and Unadjusted) for Each Categorized Anthropometric Measurement

Anthropometric measurements	Number of events (n/N)	Unadjusted			Adjusted *		
		HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value
Standard BMI							
Underweight	10/24	0.97 (0.51–1.84)	0.928	0.94 (0.49–1.79)	0.851		
Normal	146/363	Reference		Reference			
Overweight	159/519	0.70 (0.56–0.87)	0.002	0.84 (0.6–1.06)	0.145		
Obese	107/392	0.60 (0.47–0.78)	<0.001	0.85 (0.65–1.11)	0.239		
Modified BMI							
Underweight	16/33	1.40 (0.83–2.36)	0.195	1.25 (0.74–2.1)	0.397		
Normal	137/375	Reference		Reference			
Overweight	153/489	0.83 (0.6–1.05)	0.128	1.05 (0.83–1.34)	0.645		
Obese	116/401	0.75 (0.58–0.96)	0.025	0.98 (0.76–1.27)	0.904		
High WHR	272/899	0.74 (0.60–0.90)	0.003	0.83 (0.62–1.10)	0.2		
Low CC	86/171	1.90 (1.50–2.41)	<0.001	1.31 (1.02–1.69)	0.034		

* Adjusted for age, sex, marital status, living environment, education, smoking, physical activity, number of comorbidities