Uniciencia Vol. 37(1), pp. 1-12, January-December, 2023
www.revistas.una.ac.cr/uniciencia
revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

The Use of the Arm Circumference as a Measure to Detect Underweight in Individuals Aged 60 Years or Older Living in Costa Rica

Circunferencia del brazo como medida para detectar bajo peso en personas de 60 años o más residentes en Costa Rica

Circunferência do braço como medida para detectar baixo peso em pessoas com 60 anos de idade ou mais que vivem na Costa Rica.

Eduardo Aguilar-Fernández[1]*, **Xinia Fernández-Rojas**[2]

Received: Jun/27/2022 • Accepted: Mar/9/2023 • Published: Sep/1/2023

Abstract

[Objective]: This investigation focuses on the association between arm circumference and body mass index, and the estimation of cutoff values of this arm measurement for identifying low weight in Costa Rican residents aged 60 years and over. **[Methods]**: The study included a total of 2514 persons 60 years old or older who participated in the project "Costa Rica: Study of Longevity and Healthy Aging." The analysis included calculation of Spearman's correlation coefficient between arm circumference and the body mass index, the area under the Receiver Operating Characteristic (ROC) curve, and sensitivity and specificity values for measurements of arm circumference corresponding to a body mass index lower than 22 kg/m^2. **[Results]**: The Spearman's correlation coefficient between the body mass index and the arm circumference was 0.794 (0.774 for men and 0.806 for women). The optimum cutoff point was estimated at 26.5 cm, with a Youden's Index of 0.7256, a sensitivity of 87.79 %, and a specificity of 84.77 %. Specific cutoff points for men and women were 26.5 cm and 25.9 cm, respectively. **[Conclusions]**: There is a strong relationship between arm circumference and body mass index in Costa Rican residents aged 60 years and over. A first approach was established to determine an adequate cutoff point in the measurement of arm circumference that will allow the detection of persons with low weight and greater nutritional risk in this population.

Keywords: Body mass index; elderly; nutritional status; sensitivity; specificity.

* Corresponding author
Eduardo Aguilar-Fernández, eduardo.aguilar.fernandez@una.ac.cr, https://orcid.org/0000-0002-7864-2391
Xinia Fernández-Rojas, xinia.fernandezrojas@ucr.ac.cr, https://orcid.org/0000-0001-5279-9393
1 Escuela de Matemática, Universidad Nacional, Heredia, Costa Rica.
2 Escuela de Nutrición, Universidad de Costa Rica, San José, Costa Rica.

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Resumen

[Objetivo]: Estudiar la asociación entre la circunferencia del brazo y el índice de masa corporal así como estimar valores de corte de esta medida del brazo para detectar bajo peso en personas residentes en Costa Rica. **[Métodos]**: El estudio consideró 2514 personas de 60 años o más participantes en el proyecto Costa Rica: Estudio de longevidad y envejecimiento saludable. Los análisis incluyeron el cálculo de coeficientes de correlación de Spearman entre la circunferencia del brazo y el índice de masa corporal, el área bajo la curva Característica Operativa del Receptor y valores de sensibilidad y especificidad para medidas de la circunferencia del brazo, correspondientes al índice de masa corporal menores a 22 kg/m^2. **[Resultados]**: el coeficiente de correlación de Spearman entre el índice de masa corporal y la circunferencia del brazo fue de 0.794 (0.774 para hombres y 0.806 para mujeres). Además, el punto de corte óptimo se estimó en 26.5 *cm*, dado un Índice de Youden de 0.7256, una sensibilidad de 87.79% y especificidad de 84.77%. Los puntos de cortes específicos para hombres y mujeres fueron 26.5 *cm* y 25.9 *cm*, respectivamente. **[Conclusiones]**: existe alta relación entre la circunferencia del brazo y el índice de masa corporal en la población de 60 años o más residente en Costa Rica y se estableció un primer acercamiento hacia la determinación de un punto de corte adecuado en la medida de la circunferencia del brazo, para detectar personas con bajo peso y mayor riesgo nutricional en esta población costarricense.

Palabras claves: especificidad; estado nutricional; índice de masa corporal; personas mayores; sensibilidad

Resumo

[Objetivo]: estudar a associação entre a circunferência do braço e o índice de massa corporal, bem como estimar os valores de corte desta medição do braço para detectar baixo peso em pessoas que vivem na Costa Rica. **[Métodos]**: O estudo considerou 2514 pessoas com 60 anos ou mais participando do projeto "Costa Rica: Estudo da Longevidade e do Envelhecimento Saudável". As análises incluíram o cálculo dos coeficientes de correlação Spearman entre a circunferência do braço e o índice de massa corporal, a área sob a curva de características de operação do receptor, e os valores de sensibilidade e especificidade para medições da circunferência do braço correspondentes ao índice de massa corporal inferior a 22 kg/m^2. **[Resultados]**: O coeficiente de correlação do Spearman entre o índice de massa corporal e a circunferência do braço foi de 0,794 (0,774 para homens e 0,806 para mulheres). Além disso, o ponto de corte ideal foi estimado em 26,5 *cm*, dado um índice de Youden de 0,7256, uma sensibilidade de 87,79% e uma especificidade de 84,77%. Os pontos de corte específicos para homens e mulheres eram 26,5 *cm* e 25,9 *cm*, respectivamente. **[Conclusões]**: existe uma alta relação entre a circunferência do braço e o índice de massa corporal na população com 60 anos ou mais que vive na Costa Rica, e foi estabelecida uma primeira abordagem para a determinação de um ponto de corte adequado na medição da circunferência do braço, para detectar pessoas com baixo peso e maior risco nutricional nesta população costarriquenha.

Palavras-chave: especificidade; estado nutricional; índice de massa corporal; pessoas idosas; sensibilidade

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Introduction

Anthropometric characteristics are related to nutrition, genetic composition, environmental characteristics, social and cultural conditions, lifestyle, functional status, and health (Sánchez-García *et al*., 2007). On the other hand, the deterioration in the nutritional status of older adults is a complex, multidimensional phenomenon. It involves physical and psychological aspects and is exacerbated by an a reduction in autonomy, loneliness, and chronic diseases, which impacts the quality of life of this population group (Chen *et al*., 2001).

Body mass index (BMI) has been recognized as an appropriate measure for evaluating the nutritional status of individuals (World Health Organization, 1985), as it is inexpensive, non-invasive, and does not require a high level of expertise to be collected (Nube *et al*., 1998). However, this tool as a measuring instrument has been associated with certain constraints. In cases where individuals have mobility impairments, it may not always be feasible to measure weight and height accurately (Goswami *et al*., 2018; Sultana *et al*., 2015). Moreover, in field settings, it is often difficult to handle the equipment needed to assess weight and height (Das *et al*., 2020).

Considering these limitations, the measurement of the upper arm circumference, at the midpoint, between the olecranon and the acromion (arm circumference) has been proposed as an alternative to assess nutritional and health status in older adults (Goswami *et al*., 2018; Selvaraj *et al*., 2017; Thorup *et al*., 2020; Wijnhoven *et al*., 2012). This is because changes in this circumference have been associated with variations in weight (Tsai & Chang, 2011), the measurement is considered easier to implement than the BMI, requires the use of fewer resources (Shi *et al*., 2020), and has acceptable sensitivity and specificity for detecting underweight (Chakraborty *et al*., 2011).

The purpose of the study was to study the association between arm circumference and BMI. The study also aimed to estimate the cut-off values of this arm measurement to detect underweight in people aged 60 years or older living in Costa Rica.

Methodology

Type of Study

This study is a non-experimental, cross-sectional, and correlational design.

Study Population

Costa Rica: A Study of Longevity and Healthy Aging (CRELES) is a longitudinal study that considers a representative sample of individuals living in Costa Rica, regardless of their nationality, who were born before 1946; that is, who were 60 years of age or older at the time of the first interview. CRELES was developed by the Centro Centroamericano de Población (CCP—Central America Population Center) and the Instituto de Investigaciones en Salud (INISA—Institute of Health Research) of the University of Costa Rica, in collaboration with other institutions such as the Caja Costarricense del Seguro Social (CCSS—Costa Rican Social Security Fund) and the Consejo Nacional de la Persona Adulta Mayor (CONAPAM—National Council for Older Adults), with funding from the Welcome Trust Foundation, and was approved by the Scientific Ethics Committee of the University of Costa Rica at its March 17, 2004 session (ref: VI-763-CEC-23-04), research project number 828-A2-825, which

UNICIENCIA Vol. 37, N°. 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

conducted about 3000 interviews, and the first round took place between November 2004 and September 2006 (Rosero-Bixby *et al*., 2013). This research project includes 2514 individuals aged 60 years or older who participated in the first round of interviews and provided complete information on all the variables considered in the study.

Anthropometric Measurements

Body weight was measured with shoes and any items in pockets removed, using a Life Source, M&D medical, model UC-321p scale, placed on a flat and carpetless surface. The height measurement was taken using a Seca brand stadiometer and was not conducted on individuals presenting significant spinal deformities. Finally, the upper arm circumference was measured at the midpoint between the acromion (posterior shoulder bone) and the olecranon or protuberant bone of the elbow while the individual was seated or standing (Rosero-Bixby *et al*., 2013). The body mass index (BMI) was measured by dividing weight (*kg*) by height squared (m^2) and was categorized according to the established criteria for older adults. These criteria consider values below 22 kg/m^2 as underweight, between 22.0 kg/m^2 and 26.9 kg/m^2 as normal weight, between 27.0 kg/m^2 and 31.9 kg/m^2 as overweight, and greater than or equal to 32 kg/m^2 as obesity (Lipschitz, 1994).

Data Analysis

Descriptive statistics, such as the average and standard deviation (SD) for continuous variables and the number and percentage for categorical variables, were calculated. For the statistical analysis of the variables age, weight, height, BMI and arm circumference, the t-test was used; while for the variable BMI categories, the chi-square test was used to compare by sex. In addition, sampling weights were considered in the estimations.

Scatter plots were constructed with the estimated regression line to identify the relation between the arm circumference and the BMI. Likewise, Pearson's correlation coefficient was estimated to assess the level of the relation. Receiver operating characteristic (ROC) curves were obtained for all participants and for women and men separately, considering a BMI < 22 kg/m^2, which has been suggested as a cut-off point to indicate underweight in the older adult population (Lipschitz, 1994; Lipschitz, 1994; Spanish Society of Parental and Enteral Nutrition [SENPE], 2007; 2011). Sensitivity and specificity were estimated for the different groups of participants. The Youden index (YI) was also calculated as sensitivity + specificity - 1 to obtain an optimal cut-off point in arm circumference to identify underweight, which was established for the value of this circumference that presents the highest YI (Youden, 1950).

Statistical analyses were performed using STATA version 13.1 (StataCorp, 2013), and *p-values* < 0.05 were considered statistically significant.

Results

The information analyzed included 2,514 individuals, of which 1,164 were men and 1,350 were women. The average age of the population was 70.1 (69.8 for men and 70.5 for women). Weight and height were higher in men ($p < 0.001$, respectively), while arm circumference and BMI ($p = 0.012$ and $p < 0.001$, respectively) were higher in women. Besides, 11.1% of the population is underweight if BMI values < 22 kg/m^2 are taken as a reference (Table 1).

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Table 1. *General Characteristics of the Study Population*

Characteristics	Total (n = 2514)	Men (n = 1164)	Women (n = 1350)	*p*
Age (SD)	70.1 (7.85)	69.8 (7.71)	70.5 (7.97)	0.048
Weight (SD)	66.4 (13.8)	70.5 (13.1)	62.7 (13.4)	< 0.001
Height (SD)	156.4 (9.76)	163.7 (6.63)	149.7 (7.02)	< 0.001
Arm Circumference (SD)	30.1 (4.25)	29.9 (3.66)	30.4 (4.72)	0.012
BMI (SD)	27.0 (5.18)	26.1 (4.21)	27.8 (5.82)	< 0.001
Class BMI				< 0.001
< 22.0	11.1	12.1	10.2	
22.0-26.9	38.6	45.0	32.7	
27.0-31.9	34.6	33.0	36.2	
≥ 32.0	15.7	9.9	20.9	

Note: Own source of research

The scatter plot with regression adjustments between arm circumference and BMI showed a positive correlation between these indicators. The estimated regression equation shows that BMI = 0.056 + 0.893 * arm circumference (BMI = – 0.188 + 0.880 * arm circumference in men and BMI = 0.821 + 0.887 * arm circumference in women) with $p < 0.001$ in all cases. In addition, Spearman's correlation coefficient of 0.794 (0.774 for men and 0.806 for women) indicates a high correlation between arm circumference and BMI (Figure 1).

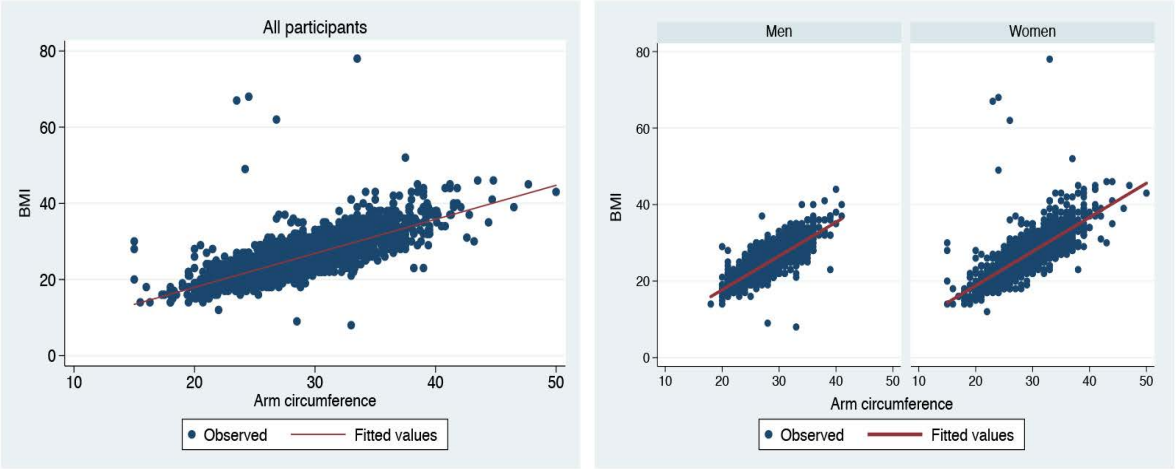

Figure 1. *Correlation Between the Arm Circumference and BMI*
Note: Own source of research

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Analysis of ROC curves generated for all individuals and for men and women separately. The area under the ROC curve showed values greater than 0.90 (0.9317 for all individuals, 0.9042 for men, and 0.9536 for women), and differences ($p < 0.001$) were found in the results between men and women (Figure 2).

The estimated YI for different arm circumference measurements revealed an optimal cut-off point of 26.5 *cm*, considering a YI = 0.7256, a sensitivity of 87.79%, and a specificity of 84.77%. On the other hand, the YI by sex, estimated for arm circumference measurements, revealed an optimal cut-off point of 26.5 *cm* in men with YI = 0.6664, sensitivity = 82.80%, and specificity = 83.84%, and 25.9 *cm* in women with YI = 0.7861, sensitivity = 89.37% and specificity = 89.24% (Table 2).

Conclusions

The study found a high and positive correlation between arm circumference and BMI. This result coincides with previous studies that have reported high correlations between arm circumference and BMI in different populations. Examples of reported values have been 0.872 (Thorup *et al.*, 2020) and 0.780 (Benítez Brito *et al.*, 2016) in hospitalized individuals and 0.860 in non-pregnant adult women (Kumar *et al.*, 2019). In contrast, values of 0.760 (Goswami *et al.*, 2018) and 0.740 (Selvaraj *et al.*,

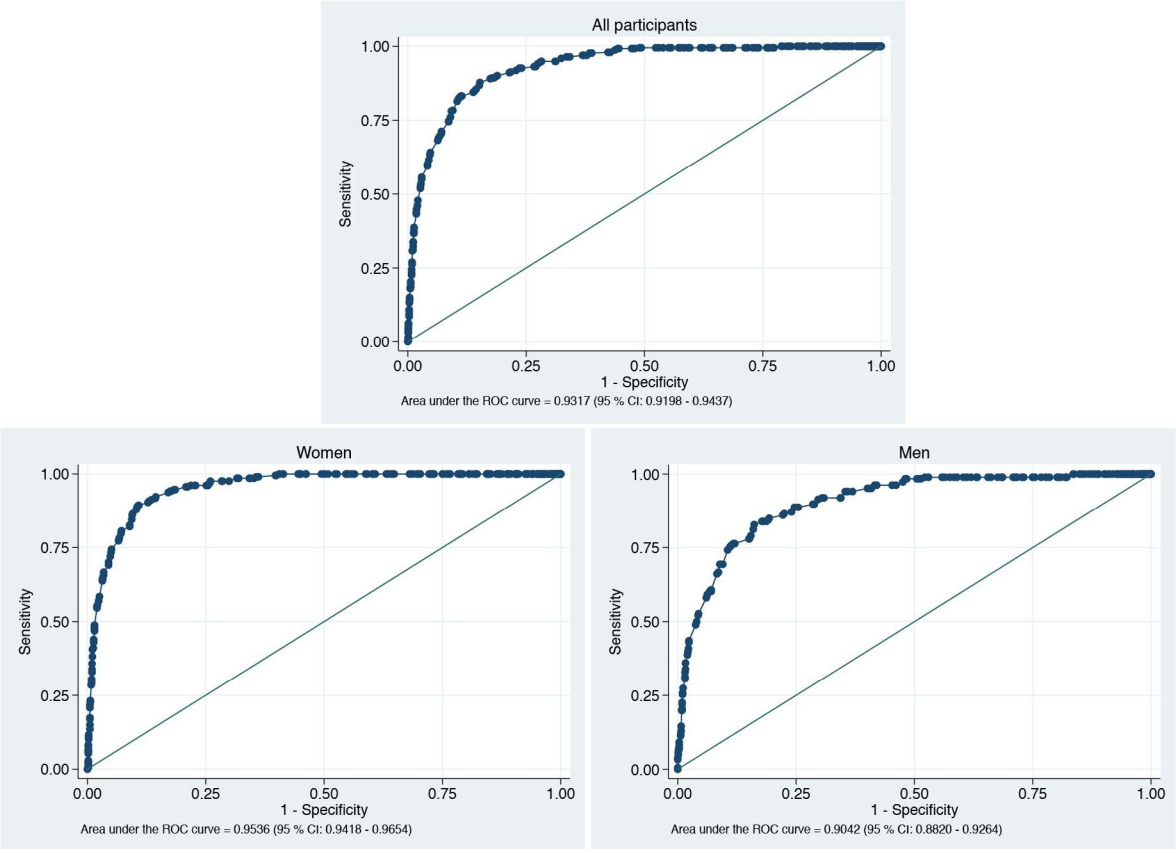

Figure 2. *ROC Curves of Arm Circumference From BMI < 22 kg/m²*
Note: Own source of research

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Table 2. *Sensitivity, Specificity, and YI for Different Values of the Arm Circumference for All Individuals and by Sex*

Arm circumference	Sensitivity	Specificity	YI
All participants			
24.0	0.5573	0.9708	0.5280
24.5	0.6412	0.9524	0.5936
25.0	0.7125	0.9288	0.6413
25.5	0.7837	0.9048	0.6885
26.0	0.8321	0.8859	0.7180
26.5	**0.8779**	**0.8477**	**0.7256**
27.0	0.9008	0.8109	0.7117
27.5	0.9262	0.7595	0.6858
28.0	0.9491	0.7176	0.6667
28.5	0.9644	0.6577	0.6221
29.0	0.9771	0.6115	0.5886
		Men	
24.0	0.4355	0.9765	0.4120
24.5	0.5269	0.9560	0.4829
25.0	0.6075	0.9294	0.5370
25.5	0.6935	0.9049	0.5985
26.0	0.7634	0.8793	0.6428
26.5	**0.8280**	**0.8384**	**0.6664**
27.0	0.8495	0.8067	0.6562
27.5	0.8871	0.7454	0.6325
28.0	0.9194	0.6912	0.6106
28.5	0.9409	0.6309	0.5717
29.0	0.9624	0.5798	0.5421
		Women	
24.0	0.6667	0.9658	0.6325
24.5	0.7440	0.9493	0.6932
25.0	0.8068	0.9283	0.7350
25.5	0.8647	0.9046	0.7694
25.9	**0.8937**	**0.8924**	**0.7861**
26.0	0.8937	0.8915	0.7852
26.5	0.9227	0.8556	0.7783
27.0	0.9469	0.8145	0.7614
27.5	0.9614	0.7717	0.7330
28.0	0.9758	0.7402	0.7160
28.5	0.9855	0.6807	0.6662
29.0	0.9903	0.6387	0.6290

Note: Own source of research

2017) have been reported in individuals aged 60 years and older. In addition, an area under the curve of 0.9317 in the ROC curve analysis showed that arm circumference has a high ability to detect underweight among older adults, as a value in the range of 0.9 to 1.0 considers the diagnostic test as excellent (Okeh & Okoro, 2012).

On the other hand, the YI has been proposed as a method to obtain the optimal cut-off point in arm circumference to detect underweight. However, this value may vary

UNICIENCIA Vol. 37, N°. 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

depending on the definition adopted and the type of population studied. Different studies have reported arm circumference values including 22.5 *cm* in non-pregnant adult women (Kumar *et al*., 2019), 22.7 *cm* in men and 21.9 *cm* in women aged 18 years and older (Das *et al*., 2018), 24.3 *cm* in men older than 18 years (Chakraborty *et al*., 2011) or 24.5 *cm* in hospitalized individuals (Thorup *et al*., 2020). Furthermore, Tang *et al*. (2020) mentioned that values ranging from 23.5 *cm* to 25.0 *cm* could be useful as an appropriate indicator for detecting underweight in adults. In older adults, suggested values are 24 *cm* (Selvaraj *et al*., 2017) or 25.2 *cm* (Goswami *et al*., 2018). However, these studies considered underweight based on BMI values < 18.5 kg/m^2 following the categorization proposed by the World Health Organization (World Health Organization, 2000).

In this study, BMI values < 22 kg/m^2 were used as criteria to determine underweight in the older adult population. This helped to establish that arm circumference measurements of less than 26.5 *cm* can be indicators of underweight in this population. A study conducted on gastrostomy-fed older adults, for whom a BMI value of 22.5 kg/m^2 was used as a cut-off point, found an arm circumference measurement of 26 *cm* (Barosa *et al*., 2018). Likewise, based on the principle of considering the highest possible sensitivity for a specificity above 80% (Thorup *et al*., 2020), an appropriate cut-off point of arm circumference is suggested, considering an adjustment of 26.5 *cm*.

In the analysis for men and women, the arm circumference cut-off points of 26.5 *cm* and 25.9 *cm* , respectively, had the highest possible sensitivity when considering a specificity greater than 80%. Other studies (Ferro-Luzzi & James, 1996; Goswami *et al*., 2018; Sultana *et al*., 2015) have also reported cut-point values different for men and women for assessing nutritional status in different populations. In this regard, Ferro-Luzzi & James (1996) suggest the importance of considering the variable of sex separately when lower body weights are present since men with normal weight have substantially more muscle but less fat in the arms than women. Females lose less muscle per kilogram of weight loss than men because their fat reserves are constitutionally larger.

Concerning the nutritional status of people, it is important to mention that poor condition triggers a series of health problems that affect well-being and quality of life (Abizanda *et al*., 2016; Balcombe & Saweirs, 2001). Besides, underweight in the older adult population may aggravate the deterioration of health and functional status, loss of autonomy and increase the risk of disability (Zhen *et al*., 2018), and elevate mortality rates (Payette *et al*., 1999).

On the other hand, decreasing arm circumference measurement at lower values increases mortality risk for all causes of death (Chen *et al*., 2014; Hollander *et al*., 2013; Mason *et al*., 2008; Schaap *et al*., 2018; Weng *et al*., 2018; Wijnhoven *et al*., 2010; Wu *et al*., 2017), as well as for specific causes, such as cardiovascular disease (Chen *et al*., 2014), chronic obstructive pulmonary disease (Ho *et al*., 2016), or Alzheimer's disease (Sousa *et al*., 2020). Moreover, it has been recommended that arm circumference be implemented in the design of nutritional or health assessment scales (Tsai & Chang, 2011) and be considered as a more feasible and valid anthropometric measure of poor nutritional status than body mass index given the ease of its assessment in older adults (Schaap *et al*., 2018; Wijnhoven *et al*., 2010).

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Thus, the specification of appropriate cut-off points can bring significant benefits to public health programs aimed at addressing nutritional problems in the older adult population. In addition, taking into account that a BMI value < 22 kg/m^2 has been recommended to indicate underweight in older adults, the results of the study can contribute to establishing an adequate cut-off point in arm circumference for the evaluation of the nutritional status of this population. This becomes relevant because of the feasibility with which it is possible to obtain this measurement in individuals, even including those with different mobility problems, who may be highly represented in this age group. It is also possible that this aids the identification of people at risk of being underweight, which can contribute to the effectiveness of action plans aimed at treating possible deficiencies in the nutritional status of these people. Thus, an early intervention can conduce to the improvement of their quality of life.

Notwithstanding the positive implications of the results, the study has limitations. First, the cross-sectional nature of the sample does not help establish causal relations between arm circumference and BMI. In addition, variables related to the actual nutrient intake and morbidity of the participants were not included.

Finally, this study concludes that there is a significant relation between arm circumference and BMI in the population aged 60 years and older living in Costa Rica. The results establish that values of 26.5 *cm* in men and 25.9 cm in women constitute the first approach to determine an adequate cut-off point for measuring arm circumference to detect individuals with nutritional problems in the study population from BMI values below 22 kg/m^2. In such a way, a low-cost measure of this nature can be implemented in regions where resources are scarce and among individuals for whom prompt and timely treatment can bring substantial improvements in the quality of life.

Funding

Universidad Nacional, Costa Rica [National University, Costa Rica].

Acknowledgments

We are grateful to the CRELES project, a longitudinal study of the University of Costa Rica conducted by the Centro Centroamericano de Población [Central America Population Center] in collaboration with the Instituto de Investigaciones en Salud [Institute of Health Research], with the support of the Wellcome Trust Foundation. Principal investigator: Luis Rosero-Bixby. Co-investigators: Xinia Fernandez and William H. Dow. Collaborating researchers: Ericka Méndez, Guido Pinto, Hannia Campos, Kenia Barrantes, Floribeth Fallas, Gilbert Brenes, and Fernando Morales. IT and support staff: Daniel Antich, Aaron Ramirez, Jeisson Hidalgo, Juanita Araya, and Yamileth Hernandez. Field personnel: José Solano, Julio Palma, Jenny Méndez, Maritza Aráuz, Mabelyn Gómez, Marcela Rodríguez, Geovanni Salas, Jorge Vindas, and Roberto Patiño.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

Author Contributions Statement

All authors acknowledge that the final version of this article has been read and approved.

The total percentage of contributions to the conceptualization, preparation, and correction of this article was as follows: E.A.F. 80% and X.F.R. 20%

Data Availability Statement

Data supporting the results of this study will be made available by the corresponding author E.A.F. upon reasonable request.

References

Abizanda, P., Sinclair, A., Barcons, N., Lizán, L., & Rodríguez-Mañas, L. (2016). Costs of malnutrition in institutionalized and community-dwelling older adults: A systematic review. *Journal of the American Medical Directors Association*, *17*(1), 17-23. https://doi.org/10.1016/j.jamda.2015.07.005

Balcombe, N., & Saweirs, W. (2001). Nutritional status and well-being. Is there a relationship between body mass index and the well-being of older people? *Current Medical Research and Opinion*, *17*(1), 1-7. https://www.proquest.com/docview/207969893?pq-origsite=gscholar&fromopenview=true

Barosa, R., Ramos, L. R., Santos, C. A., Pereira, M., & Fonseca, J. (2018). Mid upper arm circumference and Powell-tuck and Hennessey's equation correlate with body mass index and can be used sequentially in gastrostomy fed patients. *Clinical Nutrition*, *37*(5), 1584-1588. https://doi.org/10.1016/j.clnu.2017.08.011

Benítez Brito, N., Suárez Llanos, J. P., Fuentes Ferrer, M., Oliva García, J. G., Delgado Brito, I., Pereyra-García Castro, F., Caracena Castellanos, N., Acevedo Rodríguez, C. X., & Palacio Abizanda, E. (2016). Relationship between mid-upper arm circumference and body mass index inpatients. *PloS One*, *11*(8), e0160480. https://doi.org/10.1371/journal.pone.0160480

Chakraborty, R., Bose, K., & Koziel, S. (2011). Use of mid-upper arm circumference in determining undernutrition and illness in rural adult Oraon men of Gumla district, Jharkhand, India. *Rural and Remote Health*, *11*(3), 118-129. https://doi.org/10.22605/RRH1754

Chen, C., Schilling, L. S., & Lyder, C. H. (2001). A concept analysis of malnutrition in the elderly. *Journal of Advanced Nursing*, *36*(1), 131-142. https://doi.org/10.1046/j.1365-2648.2001.01950.x

Chen, Y., Ge, W., Parvez, F., Bangalore, S., Eunus, M., Ahmed, A., Islam, T., Rakibuz-Zaman, M., Hasan, R., Argos, M., Levy, D., Sarwar, G., & Ahsan, H. (2014). A prospective study of arm circumference and risk of death in Bangladesh. *International Journal of Epidemiology*, *43*(4), 1187-1196. https://doi.org/10.1093/ije/dyu082

Das, A., Saimala, G., Reddy, N., Mishra, P., Giri, R., Kumar, A., Raj, A., Kumar, G., Chaturvedi, S., Babu, S., Srikantiah, S., & Mahapatra, T. (2020). Mid-upper arm circumference as a substitute of the body mass index for assessment of nutritional status among adult and adolescent females: Learning from an impoverished Indian state. *Public Health*, *179*, 68-75. https://doi.org/10.1016/j.puhe.2019.09.010

Das, P., Khatun, A., Bose, K., & Chakraborty, R. (2018). The validity of mid-upper arm circumference as an indicator of low BMI in population screening for undernutrition: A study among adult slum dwellers in eastern India. *Public Health Nutrition*, *21*(14), 2575-2583. https://doi.org/10.1017/S1368980018001301

Ferro-Luzzi, A., & James, W. (1996). Adult malnutrition: Simple assessment techniques for use in emergencies. *British Journal of Nutrition*, *75*(1), 3-10. https://doi.org/10.1079/bjn19960105

Goswami, A. K., Kalaivani, M., Gupta, S. K., Nongkynrih, B., & Pandav, C. S. (2018). Usefulness of mid-upper arm circumference in assessment of nutritional status of elderly persons in urban India. *International Journal of Medicine and Public Health*, *8*(1). https://doi.org/10.5530/ijmedph.2018.1.7

Ho, S. C., Wang, J. Y., Kuo, H. P., Huang, C. D., Lee, K. Y., Chuang, H. C., Feng, P. H., Chen, T. T., & Hsu, M. F. (2016). Mid-arm and calf circumferences are stronger mortality

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470

predictors than body mass index for patients with chronic obstructive pulmonary disease. *International Journal of Chronic Obstructive Pulmonary Disease*, *11*, 2075. https://doi.org/10.2147/COPD.S107326

Hollander, E. L. de, Bemelmans, W. J., & Groot, L. C. de. (2013). Associations between changes in anthropometric measures and mortality in old age: A role for mid-upper arm circumference? *Journal of the American Medical Directors Association*, *14*(3), 187-193. https://doi.org/10.1016/j.jamda.2012.09.023

Kumar, P., Sinha, R., Patil, N., & Kumar, V. (2019). Relationship between mid-upper arm circumference and BMI for identifying maternal wasting and severe wasting: A cross-sectional assessment. *Public Health Nutrition*, *22*(14), 2548-2552. https://doi.org/10.1017/S1368980019000727

Lipschitz, D. A. (1994). Screening for nutritional status in the elderly. *Primary Care: Clinics in Office Practice*, *21*(1), 55-67. https://doi.org/10.1016/S0095-4543(21)00452-8

Mason, C., Craig, C. L., & Katzmarzyk, P. T. (2008). Influence of central and extremity circumferences on all-cause mortality in men and women. *Obesity*, *16*(12), 2690-2695. https://doi.org/10.1038/oby.2008.438

Nube, M., Asenso-Okyere, W., & Van den Boom, G. (1998). Body mass index as indicator of standard of living in developing countries. *European Journal of Clinical Nutrition*, *52*(2), 136-144. https://doi.org/10.1038/sj.ejcn.1600528

Okeh, U., & Okoro, C. (2012). Evaluating measures of indicators of diagnostic test performance: Fundamental meanings and formulations. *Journal of Biometrics & Biostatistics*, *3*(1), 2. https://doi.org/10.4172/2155-6180.1000132

Payette, H., Coulombe, C., Boutier, V., & Gray-Donald, K. (1999). Weight loss and mortality among free-living frail elders: A prospective study. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *54*(9), M440-M445. https://doi.org/10.1093/gerona/54.9.M440

Rosero-Bixby, L., Dow, W., & Fernández, X. (2013). *CRELES: Costa Rican longevity and healthy aging study. Methods, wave 1*. Berkeley, CA: Department of Demography, University of California. http://www.creles.berkeley.edu/pdf/Methods_w1.pdf

Sánchez-García, S., García-Peña, C., Duque-López, M. X., Juárez-Cedillo, T., Cortés-Núñez, A. R., & Reyes-Beaman, S. (2007). Anthropometric measures and nutritional status in a healthy elderly population. *BMC Public Health*, *7*(1), 1-9. https://doi.org/10.1186/1471-2458-7-2

Schaap, L. A., Quirke, T., Wijnhoven, H. A., & Visser, M. (2018). Changes in body mass index and mid-upper arm circumference in relation to all-cause mortality in older adults. *Clinical Nutrition*, *37*(6), 2252-2259. https://doi.org/10.1016/j.clnu.2017.11.004

Selvaraj, K., Jayalakshmy, R., Yousuf, A., Singh, A. K., Ramaswamy, G., & Palanivel, C. (2017). Can mid-upper arm circumference and calf circumference be the proxy measures to detect undernutrition among elderly? Findings of a community-based survey in rural Puducherry, India. *Journal of Family Medicine and Primary Care*, *6*(2), 356-359. https://doi.org/10.4103/jfmpc.jfmpc_357_16

Shi, J., Yang, Z., Niu, Y., Zhang, W., Li, X., Zhang, H., Lin, N., Gu, H., Wen, J., Ning, G., Qin, L., & Su, Q. (2020). Large mid-upper arm circumference is associated with metabolic syndrome in middle-aged and elderly individuals: A community-based study. *BMC Endocrine Disorders*, *20*(1), 1-8. https://doi.org/10.1186/s12902-020-00559-8

Spanish Society of Parental and Enteral Nutrition. (2007). *Nutritional assessment in the elderly*. Galenitas-Nigra Trea. https://senpe.com/documentacion/consenso/senpe_valoracion_nutricional_anciano.pdf

Spanish Society of Parental and Enteral Nutrition. (2011). *Multidisciplinary consensus on the approach to hospital malnutrition in Spain*. Editorial Glosa SL. https://senpe.com/documentacion/consenso/SENPE_Consenso_Multidisciplinar_Abordaje_Desnutricion_ESP.pdf

Sousa, O. V. de, Mendes, J., & Amaral, T. (2020). Nutritional and functional indicators and their association with mortality among older adults with Alzheimer's disease. *American Journal of Alzheimer's Disease & Other Dementias*, *35*, 1533317520907168. https://doi.org/10.1177/1533317520907168

StataCorp. (2013). *Stata statistical software: Release 13*. College Station.

DOI: http://dx.doi.org/10.15359/ru.37-1.24
E-ISSN: 2215-3470
CC: BY-NC-ND

Sultana, T., Karim, M. N., Ahmed, T., & Hossain, M. I. (2015). Assessment of under nutrition of Bangladeshi adults using anthropometry: Can body mass index be replaced by mid-upper-arm-circumference? *PloS One*, *10*(4), e0121456. https://doi.org/10.1371/journal.pone.0121456

Tang, A. M., Chung, M., Dong, K. R., Bahwere, P., Bose, K., Chakraborty, R., Charlton, K., Das, P., Ghosh, M., Hossain, M., Nguyen, P., Patsche, C. B., Sultana, T., Deitchler, M., & Maalouf-Manasseh, Z. (2020). Determining a global mid-upper arm circumference cut-off to assess underweight in adults (men and non-pregnant women). *Public Health Nutrition*, *23*(17), 3104-3113. https://doi.org/10.1017/S1368980020000397

Thorup, L., Hamann, S. A., Kallestrup, P., Hjortdal, V. E., Tripathee, A., Neupane, D., & Patsche, C. B. (2020). Mid-upper arm circumference as an indicator of underweight in adults: A cross-sectional study from Nepal. *BMC Public Health*, *20*(1), 1-7. https://doi.org/10.1186/s12889-020-09294-0

Tsai, A. C., & Chang, T. L. (2011). The effectiveness of BMI, calf circumference and mid-arm circumference in predicting subsequent mortality risk in elderly Taiwanese. *British Journal of Nutrition*, *105*(2), 275-281. https://doi.org/10.1017/S0007114510003429

Weng, C. H., Tien, C. P., Li, C. I., L'Heureux, A., Liu, C. S., Lin, C. H., Lin, C. C., C. C., Lai, S. W., Lai, M. M., & Lin, W. Y. (2018). Mid-upper arm circumference, calf circumference and mortality in Chinese long-term care facility residents: A prospective cohort study. *BMJ Open*, *8*(5), e020485. https://doi.org/10.1136/bmjopen-2017-020485

Wijnhoven, H., Bokhorst-de van der Schueren, M. van, Heymans, M., Vet, H. de, Kruizenga, H. M., Twisk, J. W., & Visser, M. (2010). Low Mid-Upper Arm Circumference, Calf Circumference, and Body Mass Index and Mortality in Older Persons. *The Journals of Gerontology: Series A*, *65A*(10), 1107-1114. https://doi.org/10.1093/gerona/glq100

Wijnhoven, H., Schilp, J., Vet, H. C. de, Kruizenga, H. M., Deeg, D. J., Ferrucci, L., & Visser, M. (2012). Development and validation of criteria for determining undernutrition in community-dwelling older men and women: The short nutritional assessment questionnaire 65+. *Clinical Nutrition*, *31*(3), 351-358. https://doi.org/10.1016/j.clnu.2011.10.013

World Health Organization. (1985). *Physical status: The use of and interpretation of anthropometry, report of a WHO expert committee*. World Health Organization. https://apps.who.int/iris/handle/10665/37003

World Health Organization. (2000). *Obesity: Preventing and managing the global epidemic. Report of a WHO consultation*. World Health Organization. https://apps.who.int/iris/handle/10665/42330

Wu, L. W., Lin, Y. Y., Kao, T. W., Lin, C. M., Wang, C. C., Wang, G. C., Peng, T. C., & Chen, W. L. (2017). Mid-arm circumference and all-cause, cardiovascular, and cancer mortality among obese and non-obese US adults: The national health and nutrition examination survey III. *Scientific Reports*, *7*(1), 1-8. https://doi.org/10.1038/s41598-017-02663-7

Youden, W. J. (1950). Index for rating diagnostic tests. *Cancer*, *3*(1), 32-35. https://doi.org/10.1002/1097-0142(1950)3:1<32::AID-CNCR2820030106>3.0.CO;2-3

Zhen, L., Pang, S. J., Man, Q. Q., Wang, J. Z., Zhao, W. H., & Zhang, J. (2018). Prevalence of undernutrition and related dietary factors among people aged 75 years or older in China during 2010-2012. *Biomedical and Environmental Sciences*, *31*(6), 425-437. https://doi.org/10.3967/bes2018.056

UNICIENCIA Vol. 37, N° 1, pp. 1-12. January-December, 2023 • www.revistas.una.ac.cr/uniciencia • revistauniciencia@una.cr