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Influence of Body Mass Index on Indirect Measurements of Appendicular Skeletal Muscle Mass in Overweight and Obese Older People

Influencia del Índice de Masa Corporal en las Mediciones Indirectas de la Masa del Músculo Esquelético Apendicular en Personas Mayores con Sobrepeso y Obesidad

Nicolás Vidal-Seguel[1,2]; Igor Cigarroa[3]; Rodrigo Lizama-Pérez[4]; Camilo Rubilar[5] & Gabriel Nasri Marzuca-Nassr[6]

VIDAL-SEGUEL, N.; CIGARROA, I.; LIZAMA-PÉREZ, R.; RUBILAR, C. & MARZUCA-NASSR, G. N. Influence of body mass index on indirect measurements of appendicular skeletal muscle mass in overweight and obese older people. *Int. J. Morphol., 42(5)*:1175-1180, 2024.

SUMMARY: Sarcopenia is a disease characterized by a decline in skeletal muscle mass, strength, and physical performance, leading to a loss of functional capacity. Appendicular skeletal muscle mass (ASMM) is one of the most used measurements to detect skeletal muscle mass loss; nevertheless, its assessment is expensive. Under this context, indirect anthropometric measurements include calf circumference (CC) and appendicular skeletal muscle mass index (SMI). However, these measurements may not be very sensitive in older people with different body mass index (BMI). The aim of this study was to determine the influence of BMI on indirect measurements of ASMM in overweight and obese older people. This study included 57 participants aged 60 years and over from the city of Los Angeles, Chile, divided into two groups according to nutritional status, overweight (OW; n=33; Men=8; Women=25; age, 72 ± 6 years; BMI, 27.54 ± 1.54 $kg·m^{-2}$) and obesity (OB; n=24; Men=5; Women=19; age, 72. ± 6 years; BMI, 33.70 ± 6.22 $kg·m^{-2}$). The results showed that 36 % of the variations observed in CC measurements are explained by BMI ($p<0.05$). Conversely, the variations in SMI are not explained by BMI. In conclusion, BMI in older people can affect CC results, but not SMI. These results contribute to the decision-making process regarding the use of SMI as a better method for the indirect measurement of ASMM in overweight and/or obese older individuals.

KEY WORDS: Appendicular skeletal muscle mass; Calf circumference; Aging; Elderly.

INTRODUCTION

According to World Health Organization (2024) reports, the percentage of inhabitants over 60 will double worldwide between 2020 and 2030, increasing from 12 % to 22 % of the total population (WHO). Aging is related to various diseases (Makovski *et al*., 2019), including sarcopenia (Matsuyama, 2020). This disease is characterized by a decrease in skeletal muscle mass, strength, and physical performance, a situation that causes progressive loss of functional capacity (Cruz-Jentoft *et al*., 2019). In addition, it increases the risk of falls, hospitalization, and mortality (Beaudart *et al*., 2017; Cruz-Jentoft & Sayer, 2019). On the other hand, obesity is a significant contributor to morbidity and mortality in the global population (WHO). The prevalence of obesity saw a significant rise from 1980 to 2019, soaring from 3.2 % to 12.2 % among men, and from 6 % to 15.7 % among women (Mathew *et al*., 2018). In people over 60 years of age, the average percentage of obesity according to the literature is 17,8 % (IC del 95 %: 13,3 %-22,2 %) (Hajek *et al*., 2022). In the population over 60, obesity is associated with negative alterations in functional capacity such as balance, walking speed, strength, and loss of skeletal muscle mass and quality (Artaud *et al*., 2016; Tanaka *et al*., 2020).

[1] Universidad de La Frontera, Facultad de Medicina, Departamento de Ciencias Básicas, Temuco, Chile.
[2] Universidad de La Frontera, Facultad de Medicina, Doctorado en Ciencias Morfológicas, Temuco, Chile.
[3] Escuela de Kinesiología, Facultad de Ciencias de la Salud, Universidad Católica Silva Henríquez, Santiago, Chile
[4] Departamento de Ciencias Morfológicas, Facultad de Medicina y Ciencia, Universidad San Sebastián, Lientur 1457, Concepción 4080871, Chile.
[5] Escuela de Kinesiología, Facultad de Salud, Universidad Santo Tomás, Los Ángeles, Chile.
[6] Universidad de La Frontera, Facultad de Medicina, Departamento de Ciencias de la Rehabilitación, Temuco, Chile.
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According to the European Working Group in Older People (EWGOP) (Cruz-Jentoft *et al*., 2019), the diagnosis of sarcopenia involves three dimensions: skeletal muscle strength, skeletal muscle mass or quality, and physical performance. Within these parameters, skeletal muscle mass stands out as a factor of great relevance in the diagnosis and progression of the disease (Rosenberg, 1997; Cruz-Jentoft *et al*., 2019). The skeletal muscle system undergoes significant age-related changes (McCormick & Vasilaki, 2018), highlighting alterations in neuromotor units, decreased muscle regeneration, and increased non-contractile fibrous tissue (Andersen, 2003; Larsson *et al*., 2019; Mahdy, 2019). In turn, overweight and/or obesity promote intramuscular infiltration of immune and adipose cells, triggering morphological and functional changes in skeletal muscle (Kalinkovich & Livshits, 2017).

Skeletal muscle mass in older people can be assessed through the quantification of appendicular skeletal muscle mass (ASMM), a marker of sarcopenia measured directly through dual-energy X-ray absorptiometry (Chen *et al*., 2007), computed tomography (Amini *et al*., 2019) and magnetic resonance imaging (Fuchs *et al*., 2023). These techniques accurately describe skeletal muscle qualitatively and quantitatively (Sizoo *et al*., 2021). However, these techniques may be inaccessible to some people due to their high cost (Fuchs *et al*., 2023). Consequently, indirect ASMM estimation measurements have been established (Al-Gindan *et al*., 2014). Mid-arm circumference, thigh circumference, and calf circumference (CC) have been widely used as indirect measurements (Nakanishi *et al*., 2021). The last one has been used in a wide variety of geriatric studies as a simple and practical marker for diagnosing low skeletal muscle mass and/or sarcopenia (Borges *et al*., 2022; Landi *et al*., 2022). In addition, anthropometric measurements have enabled the creation of predictive formulas for ASMM that have shown great utility in detecting sarcopenia in older people (Santos *et al*., 2004; Visvanathan *et al*., 2012; Rathnayake *et al*., 2021). In this context, the work by Lera *et al*. (2014), establishes an ASMM estimation equation for the timely diagnosis of sarcopenia in older individuals, validated in the Chilean population (Lera *et al*., 2015).

A relevant clinical and scientific concern understands the limitations that indirect measurements of ASMM can raise in older people with different BMI. Although they have been shown to be a great tool for the indirect estimation of ASMM, measurements such as CC could be insensitive in older people with varying BMI ranges, as they are unable to discriminate between skeletal muscle mass and fat mass correctly (Nakanishi *et al*., 2021; Wei *et al*., 2022). In this context, the present study aimed to determine the influence of BMI on the estimation of ASMM in overweight and obese older people. It is hypothesized that the BMI influences indirect measurements of ASMM in the older population.

MATERIAL AND METHOD

Design: This study has been designed as a cross-sectional correlational study and is part of a large research project aimed to determine the effects of a multicomponent telehealth-based exercise program on physical health, cognitive functions, and quality of life in older (FONDEPORTE n°2200120032). Participants voluntarily signed an informed consent, and the scientific ethics committee at the Universidad Santo Tomás in the south-central macrozone approved the protocol (n° 22-62, approval date 27 April 2022). All study procedures were conducted by the Singapore and Helsinki Declarations for research involving human subjects.

Participants: The present study included fifty-seven people aged 60 and over from the commune of Los Angeles, Chile, divided into two groups according to their nutritional status: an overweight group (OW; n=33; Men=8; Women=25; age, 72 ± 6 years; BMI, 27.54 ± 1.54 kg-m^{-2}) and an obese group (OB; n=24; Men=5; Women=19; age, 72 ± 6, BMI, 33.70 ± 6.22 kg-m^{-2}). Inclusion criteria were people aged 60 years and older with cognitive ability that allowed them to understand verbal instructions. The exclusion criteria were fractures and acute myocardial infarction in the last 6 months, severe acute respiratory failure, uncontrolled arterial hypertension, uncontrolled diabetes mellitus, and the practice of any physical exercise in the previous 6 months.

Body composition: Weight was recorded on a SECA® platform scale (Madison, WI, USA) with a graduation of 0.1 kg, while height was measured to the nearest 0.5 cm using a stadiometer connected to the scale, with barefoot participants. With these data, the BMI was calculated using the formula: weight in kilograms divided by height in meters squared (WHO). Waist circumference was measured in exhalation at the midpoint between the lower rib and the iliac crest on the right hemibody. Hip circumference was measured as the largest circumference around the gluteal region. These measurements were made with a metal tape to an accuracy of 0.1 cm.

Appendicular skeletal muscle mass: The measurement of ASMM was performed indirectly through 1) CC and 2) appendicular skeletal muscle mass index (SMI). CC was measured with the subject seated on a chair. Measurements were made by positioning the knee and ankle at a 90-degree angle at the most voluminous half of the muscle belly with a metal tape to an accuracy of 0.1 cm (Santos *et al*., 2004). The SMI was performed following the formula proposed by Lera *et al*. (2014) for the Chilean population detailed below:

SMI (kg) = 0.107 (weight in kg) + 0.251 (knee height in cm) + 0.197 (calf circumference in cm) + 0.047 (dynamometry in kg) - 0.034 (hip circumference in cm) + 3.417 (male sex) - 0.020 (age in years) - 7.646

Statistical analysis. The results were analyzed using the statistical software SPSS (IBM SPSS Statistics, v. 21), and the figures were created using the GraphPad Prism 8.2 software (San Diego, CA). The Data are expressed as mean ± standard deviation (SD). The characteristics and data between the OW and OB groups were compared by means of an independent samples t-test. The influence of BMI on CC and SMI was determined using a simple linear regression test. The baseline effect size between group results was estimated using Cohen's d and represented as d. An effect size <0.2 indicates no effect, 0.2-0.49 indicates a small effect, 0.5-0.79 indicates a medium effect, and ≥0.8 indicates a large effect (Cohen, 2013). The statistical significance was set at ($p<0.05$).

RESULTS

Baseline characteristics of participants. The baseline characteristics of the participants show homogeneity between overweight vs. obese older participants in sex, and age ($p>0.05$). However, heterogeneity is observed in body composition parameters, included waist circumference and Hip circumference ($p<0.05$) (Table I).

Indirect measurement of ASMM. The data show that the CC is higher in the obese group than the overweight group ($p<0.0001$; mean effect size, 0.782; Table II). On the other hand, SMI values did not present any significant differences between the two groups ($p=0.277$; small effect size, 0.294; Table II).

Influence of BMI on CC and SMI. The data show that 36 % of the observed variations in CC measurements are explained by BMI ($p<0.001$; $r=0.3649$; Fig. 1a). When analyzed by groups, the data show that BMI only influences CC in the OB group ($p=0.010$; $r=0.264$; Fig. 1e) and not in the OW group ($p=0.092$; $r=0.089$; Fig. 1c). Similarly, BMI does not influence SMI values ($p<0.05$; Figs. 1b, d, f).

DISCUSSION

The present study aimed to determine the influence of BMI on the estimation of ASMM in overweight and obese older people. The results show that CC is higher in the obese group than in the overweight group, in addition, BMI directly influences these results. In contrast, our data show that SMI does not differ between groups, nor is it influenced by the BMI of older participants being studied. The indirect ASMM measurements should consider the previous nutritional status of the older.

Table I. Participants' characteristics.

	OW (n=33)	OB (n=24)	p value
Age (years)	72± 6	72 ± 6	0.878
Height (m)	1.56 ± 0.09	1.54 ± 0.09	0.896
Weight (kg)	67.72 ± 8.10	80.02 ± 10.67	**0.000**
BMI (kg·m^{-2})	27.54 ± 1.54	33.70 ± 3.59	**0.000**
Waist circumference (cm)	93.42 ± 6.41	104.41 ± 8.31	**0.000**
Hip circumference (cm)	102.70 ± 4.60	112.77 ± 8.79	**0.000**
Men	8 (24.24 %)	5 (20.83 %)	
Women	25 (75.76 %)	19 (79.17 %)	

OW: overweight older adults; OB: obese older adults; Values represent means ± SD; Bold values indicate differences between OW and OB at the p<0.05 level.

Table II. Indirect measurement of ASMM between groups.

	OW n=33	OB n=24	f value	p value	Effect size	95 % CI for Mean Difference		
						Mean difference	Lower	Upper
Calf Circumference (cm)	35.94 ± 2.35	38.83 ± 2.97	2.089	**0.000**	0.782	-2.894	-4.307	-1.481
SMI (kg)	15.47 ± 3.33	16.43 ± 3.18	0.109	0.277	0.294	-0.962	-2.717	0.792

n: number of patients; Values represent means ± SD. Bold values indicate difference between OW and OB at the p<0.05 level. d. An effect size <0.2 indicates no effect, 0.2–0.49 indicates small effect, 0.5–0.79 indicates medium effect, and ≥ 0.8 indicates large effect.

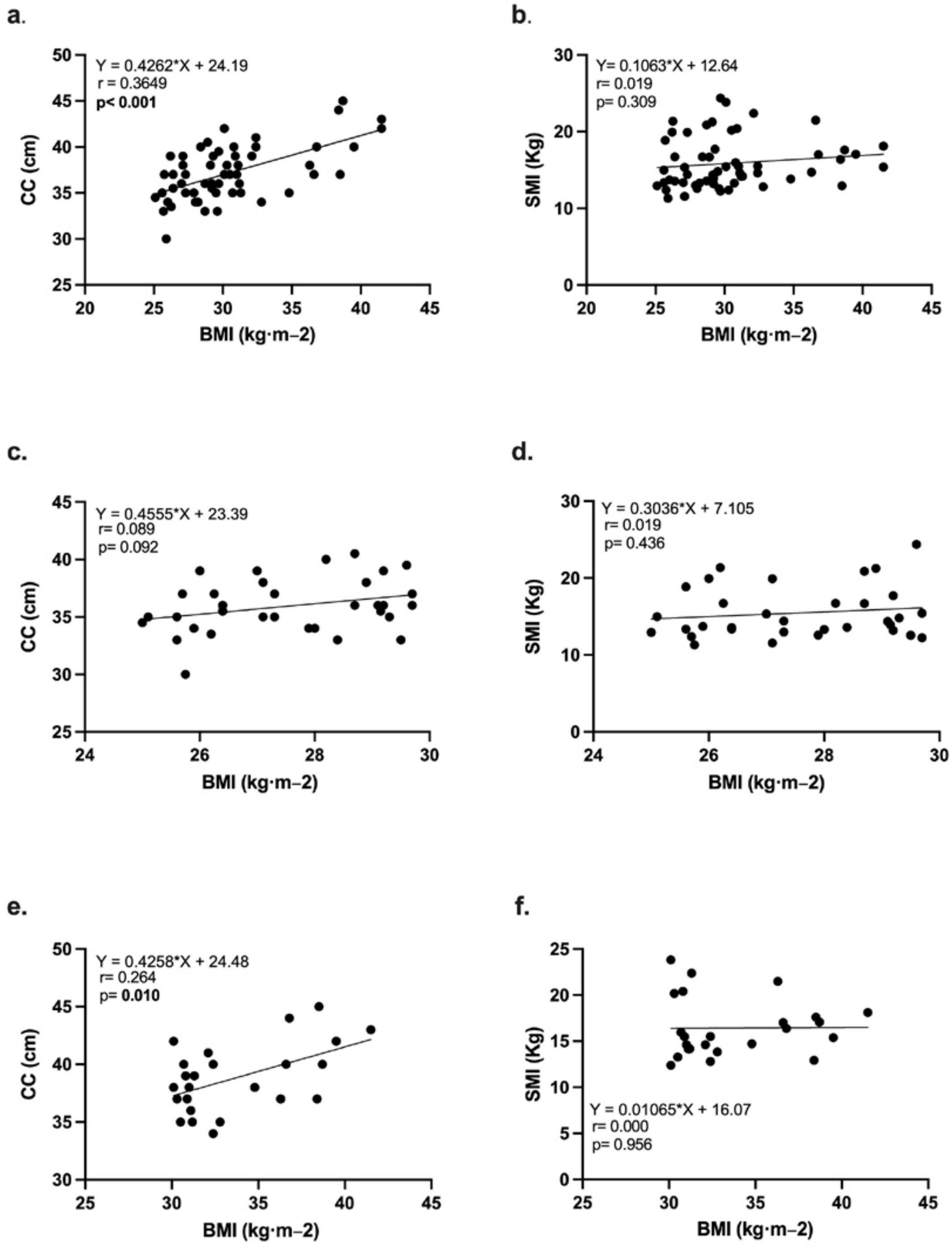

Fig. 1. Influence of BMI on CC and SMI. **a.** Influence of BMI on CC in all participants. **b.** Influence of BMI on SMI in all participants; **c.** Influence of BMI on CC in OW; **d.** Influence of BMI on SMI in OW; **e.** Influence of BMI on CC in OB; **f.** Influence of BMI on SMI in OB, (simple linear regression; sig: $p<0.05$).

Our results show a significant difference in ASMM estimation between groups according to the type of measurement used (Table II). That is, for the same group of older individuals, two indirect measurements of ASMM show significant differences. Aging and obesity impact skeletal muscle morphology (Barazzoni *et al*., 2018), which is characterized by an increase in intramuscular and subcutaneous adipose tissue and a decrease in the number and size of muscle fibers (Choi *et al*., 2016; Carbone, 2022). Muscle analysis through ultrasonography in overweight and obese older individuals shows a larger cross-section area of the quadriceps muscle than older people with a normal weight (Arieta *et al*., 2022). However, this is accompanied by a higher level of echo intensity. In other words, although muscle size appears to be larger, this is due to the infiltration of adipose, fibrous, and non-contractile tissues.

Under this scenario, the indirect assessment of ASMM through anthropometric measurements may vary in older people with different BMI, as they cannot discriminate between muscle mass and fat mass (Nakanishi *et al*., 2021). A recent systematic review assessment the correlation between conventional anthropometric and imaging derived measures, such a magnetic resonance imaging (MRI) and dual x-ray absorptiometry (DEXA). Shown that BMI and Waist circumference are strongly correlated with total abdominal fat (MRI-derived: r=0.88; DXA-derived: 0.50–0.86) and subcutaneous abdominal fat (MRI: 0.83–0.85); and were less strongly correlated with visceral abdominal fat (MRI: 0.76-0.79; DXA: 0.80) (Mouchti *et al*., 2023). That is, people with a higher BMI may have a greater amount of adipose tissue, which could affect the indirect assessment of ASMM. Our results support this, demonstrating that the estimation of ASMM was statistically different between groups based on CC measurement, especially in older participants with obesity (Fig. 1). Multiple studies demonstrate the usefulness of CC to estimate low skeletal muscle mass and diagnosing sarcopenia in older people (Nakanishi *et al*., 2021; Borges *et al*., 2022). However, considering the present results, we believe this measurement may not be the most indicated for older people with obesity (Fig. 1). The possible excess of intramuscular and subcutaneous adipose tissue could be involved in an incorrect ASMM estimation value. On the other hand, the results of this study confirm the sensitivity of ASMM predictive equations, demonstrating that SMI is not influenced by the BMI of the older participants studied this study. Our results show that the SMI is a better strategy for predicting ASMM in older obese individuals than a single anthropometric measurement, like the CC. A growing literature demonstrates the frequent use of equations for predicting ASMM. These studies consistently show that these equations have good sensitivity in indirectly and inexpensively measuring ASMM in older (Kawakami *et al*., 2021; Arieta *et al*., 2022).

Among the limitations of our study, we believe it would be interesting to have a larger sample of older, in addition to having underweight and normal weight groups, to establish the relationship between CC and SMI according to each nutritional status. On the other hand, have a direct evaluation of muscle mass and total fat. However, waist and hip circumference were measured to confirm the increase in adipose tissue associated with BMI. In addition, it is necessary to have a direct measurement of ASMM to contrast the reliability of the indirect measurements of ASMM analyzed in this study.

In conclusion, our data demonstrate that an older person's BMI can affect CC outcomes but not SMI. These results contribute to the decision-making process regarding the use of SMI as a better method for the indirect measurement of ASMM in overweight and/or obese older individuals. These results could provide relevant information to health professionals who work with older people about factors that could influence the presence of sarcopenia. However, further studies are needed to demonstrate the reliability of indirect measurements in the obese older individuals.

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RESUMEN: La sarcopenia es una enfermedad caracterizada por una disminución de la masa del músculo esquelético, la fuerza y el rendimiento físico, lo que conduce a una pérdida de la capacidad funcional. La masa de músculo esquelético apendicular (ASMM) es una de las mediciones más utilizadas para detectar la pérdida de masa de músculo esquelético; sin embargo, su evaluación es costosa. En este contexto, las mediciones antropométricas indirectas incluyen la circunferencia de la pantorrilla (CC) y el índice de masa del músculo esquelético apendicular (SMI). Sin embargo, estas mediciones pueden no ser muy sensibles en personas mayores con diferentes índices de masa corporal (IMC). El objetivo de este estudio fue determinar la influencia del IMC en las mediciones indirectas de ASMM en personas mayores con sobrepeso y obesidad. Este estudio incluyó a 57 participantes de 60 años y más de la ciudad de Los Ángeles, Chile, divididos en dos grupos según estado nutricional, sobrepeso (SP; n=33; Hombres=8; Mujeres=25; edad, 72 ± 6 años ; IMC, 27,54 ± 1,54 kg·m^{-2}) y obesidad (OB; n=24; Hombres=5; Mujeres=19; edad, 72 ± 6 años; IMC, 33,70 ± 6,22 kg·m^{-2}). Los resultados mostraron que el 36 % de las variaciones observadas en las mediciones de CC son explicadas por el IMC (p<0,05). Por el contrario, las variaciones del SMI no se explican por el IMC. En conclusión, el IMC en personas mayores puede afectar los resultados del CC, pero no el SMI. Estos resultados contribuyen al proceso de toma de decisiones sobre el uso del SMI como un mejor método para la medición indirecta de ASMM en personas mayores con sobrepeso y/u obesidad.

PALABRAS CLAVE: Masa de músculo esquelético apendicular; Área de la pantorrilla; Envejecimiento; Personas mayores.

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Corresponding author:
Gabriel Nasri Marzuca-Nassr
Universidad de La Frontera
Facultad de Medicina.
Claro solar 115
Temuco
CHILE

E-mail address: gabriel.marzuca@ufrontera.cl