Original article

The fat mass index, not the fat-free mass index, is associated with impaired physical performance in older adult subjects: Evidence from a cross-sectional study

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SUMMARY

Background: Impaired physical performance (IPP) and physical disability (PD) are two serious public health problems in older adult populations worldwide. While studies show that changes in body composition are important risk factors for developing these conditions, there is little evidence that the fat-free mass (FFM) and fat mass (FM) indices (FFMI and FMI, respectively) are associated with IPP in older men and women. This study assessed the association among FFMI, FMI, and IPP using Short Physical Performance Battery (SPPB) in Mexican men and women aged over 60 years.
Methods: This cross-sectional study included 217 older people (men 34.6%, women 65.4%; 60—92 years). FFM and FM were assessed by dual X-ray absorptiometry, assuming a two-compartment model. FFM and FM were adjusted by height squared and the indices were obtained. After assessment of physical performance by SPPB, subjects with scores ≤6 were classified as having IPP. Associations were tested by multiple logistic regression analysis in separated models.
Results: IPP prevalence was 14.3%. Women were affected more than men. Regression analysis showed no significant association between FFMI and IPP, but FMI was strongly-associated, as for each unit increase in FMI, the risk of IPP rose significantly (OR: 1.14), and this result remained significant after adjusting for age, comorbidity, polypharmacy, and the appendicular skeletal muscle mass index (OR: 1.23; $p \leq 0.001$). These results emphasize the importance of preventing increases in FM and avoiding overweight and obesity in older men and women.

1. Introduction

Body composition compartments such as fat-free mass and components such as skeletal muscle, all decrease as fat mass increases during normal aging [1—3]. The clinical impact of low fat-free mass (FFM), low skeletal muscle, and increases in fat mass (FM) is their independent association with impaired physical performance (IPP) and functional disability in older people [4—10]. Physical disability (PD), understood as the difficulty that a person experiences in carrying out daily living activities and instrumental activities of daily life, is associated with rates of hospitalization, loss of quality of life, and major risk of mortality [11]. Regard to its causes, polypharmacy, anorexia, undernutrition and the risk of undernutrition, obesity [11—15], and age-related body composition changes [4—10], have all been associated with PD in older people. Also, these same causes have been associated with IPP or the difficulty in performing different movements by different body regions in order to displace the body, either partially or totally [16]. Cross-sectional [4,10,17] and follow-up analyses [6,7] have shown that low FFM [6] and high FM levels are independently-associated

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with both IPP and PD in older adults. Importantly, all studies cited used FFM and FM compartments, measured in kilograms and as percentages, respectively, as unadjusted variables.

Some body composition compartments and components have been adjusted for height squared or other anthropometric variables. FFM and FM indices (FFMI and FMI, respectively) eliminated height-associated differences from FFM and FM, thus increasing the comparability of body composition data [18]. One of the most widely-used indices, and one directly-associated with IPP and PD, is appendicular skeletal muscle mass (ASM) index (ASMI) [19,20]. With respect to other body composition indices, Ramsay et al. (2006) examined the association of FFMI and adiposity with health status (in ill men) and functional disability. They found no association between FFMI and PD, but only a significant association between high FFMI and fewer respiratory problems and cancer [5]. Recently, Campbell and Vallis (2014), published a predictive model in which muscle strength, gait speed and the body mass index (BMI) were included as predictor variables of FFMI [21]. These findings suggest a possible association between FFMI and IPP. Since it is widely-recognized that gait speed is associated with leg strength and PD [22,23], it would be interesting to test whether low FFMI values are significantly associated with a greater risk of IPP in older people.

With respect to the association between FMI and mobility limitations and PD problems few studies were found [5]. However, previous work has shown an association among BMI — as a surrogate of total fat mass [24], FM with IPP and PD in older adult populations [6–10,15,17]. Based on our search, only one study showed a significant relationship using FM as the index with mobility limitations and PD. Ramsay et al. (2006) showed that older men located in the last quintile showed a greater risk of mobility limitations and PD than the older men aged 60–79 who placed in the lowest quintile of FMI distribution [5]. However, that study did not include women. Since it is widely-accepted that obesity/higher fat mass/adiposity and functional disability are all public health problems reported more frequently in women [8,9,25,26], and that the short physical performance battery (SPPB) is one of the most reliable tools for assessing lower extremity physical performance, and for predicting mortality, nursing home admission, and disability [27]. The aim of the present study was to assess the association among FFMI, FMI, and IPP using the SPPB in Mexican men and women subjects aged over 60.

2. Methods

2.1. Study design and subjects

This study used a cross-sectional design, including a non-randomized sample of 217 community-dwelling older subjects over 60 years of age. Invitations to participate were made through face-to-face interviews, phone calls and during visits to homes and clubs for older people. According to the Barthel activities of daily living (ADL) index [28], no subjects had PD. This index assesses an individual's ability to feed, bathe, groom and dress her/himself, control bowels and bladder, use the toilet, transfer, move about and climb stairs; all of which are considered basic activities of daily living. It thus provides a high quantitative estimate of independence. In relation to health status, the average BMI value was 28 kg/m², hence the total sample classified as overweight [29]. In addition, some of our volunteers had a controlled chronic disease, and 23.9% of the total sample had high comorbidity according to the Charlson comorbidity scale [30]. Most participants were free of cognitive decline, according to the Mini-Mental State Examination (>13 score) [31], but 7.3% did show this condition (<13 score). The study was performed at the Body Composition and Functionality

Laboratory of the Coordination of Nutrition at the Research Center for Food and Development in Hermosillo, Sonora, Mexico.

Body composition and physical performance were assessed by dual energy X-ray absorptiometry (DXA) and the SPPB, respectively. Also, questionnaires to gather information on health, socioeconomic status and demographic variables were applied. Subjects were residents of Hermosillo, Sonora, a city in a region of northwest Mexico characterized by high levels of obesity in the general population [25]. All volunteers received a full explanation of the procedures required by the protocol, and were asked to sign the appropriate consent format before beginning the study, which was approved by the Ethics Committee of CIAD, A.C (CE/011/2015). Work was conducted from May 2015 to July 2016.

2.2. Anthropometry and body composition measurements

Body weight was measured using an electronic scale (HV-200KGL, A & D Weighing, CA, US) with subjects dressed only in a disposable gown. Height was measured with a digital stadiometer (SECA stadiometer 274, SECA, Hamburg, Germany) following the Frankfurt horizontal plane. Both were measured without shoes. Body mass index (kg/m²) was calculated using these two measures. Waist and hip circumferences were also measured using a MABIS Fiberglass Retractable Compact Tape Measure.

Body composition, particularly the FM (kg) and FFM (kg) compartments, and ASM (kg), were measured by DXA (Hologic DQR 4500, Hologic, Waltham, USA), as published previously [32]. Briefly, evaluations of anthropometry and body composition were made after at least 8 h of fasting. ASM was determined from the DXA scans by a trained researcher following recommended anatomical landmarks. The sum of lean mass in both arms and legs was considered ASM (kg), while FFM (kg) was determined as the sum of total lean tissue (kg) plus total bone mineral content (kg), according to the assumptions of the two-compartment model [33]. FM, FFM and ASM were adjusted by height squared (m²) to obtain three indices: FFMI (kg/m²), FMI (kg/m²) and ASMI (kg/m²).

2.3. Physical performance testing

Difficulty in performing different movements was assessed by the SPPB using the standing balance task, chair stands, and gait speed [27]. The results of these three tests produced a total combined score of 0–12 points. Higher scores indicate greater ability in performing each test, while lower scores indicate poorer performance on the tasks. Low physical performance is associated with a greater risk of falling [34–36]. Subjects with scores ≤6 on the SPPB were classified as having low physical performance, or IPP [16].

2.4. Covariates

Potential confounder variables, such as age, gender, BMI, physical activity level (estimated by specific predictive equations for older people), years of schooling, and socioeconomic status (by questionnaires), handgrip strength (by dinamometry), comorbidities (by the Charlson comorbidity scale), polypharmacy, cognitive decline (by the Mini-Mental State Examination), ASM and the ASMI, smoking, and occupation, Barthel's ADL index [28] and the Lawton instrumental activities of daily living (IADL) scale [37], were chosen based on risk factors for IPP reported by other authors [19,38,39].

2.5. Statistical analysis

Age differences and the general characteristics of the groups were analyzed by a t-test (mean ± SD) and Chi square test (%). The

main hypotheses were analyzed by multiple logistic regression analyses in separate models, obtaining the odds ratio (OR), each generated using a mixed univariate analysis and stepwise model approach. Simple logistic regression analysis was performed to explore the preliminary association of possible predictor variables with IPP ($p < 0.2$). Subsequently, the selected variables, including those considered physiologically important – such as appendicular skeletal muscle mass and ASMI (kg/m^2) – were entered into the stepwise model ($p \leq 0.05$). The different interactions ($p \leq 0.1$) with the variable of interest (FMI, kg/m^2) and the variables that remained in the preliminary model (age, cognitive decline, comorbidity, ASMI) were tested. Collinearity was evaluated for the predictor variables (FMI, age, cognitive decline, comorbidity, ASMI) using a correlation matrix ($p \geq 0.7$). The model was further evaluated by the linearity assumption for the continuous predictor variables (FMI, age, ASMI). Statistical significance of the association was tested at a probability ≤ 0.05 using STATA software (StataCorp, College Station).

3. Results

3.1. General characteristics of the subjects according to physical performance status

Of the total sample of 217 community-dwelling older people, 65.4% were women. Mean age was 71.6 ± 6.7 years, with a BMI of 28.1 ± 4.6 kg/m^2 and a percentage of body fat of 39.7 ± 7.7. All volunteers were free of PD according to the Barthel ADL index (97.8 ± 5.2 score), but 14.3% – mostly women – had IPP (74.19%). Also, the volunteers had some controlled chronic diseases: 41.2% had hypertension, 19.3% had type 2 diabetes, 35.9% had more than 2 diseases, and 33.6% presented polypharmacy. Based on the results of the SPPB, the sample was divided into two groups: those with IPP, and those with normal physical performance status. Table 1 shows the behavior of age and several anthropometric, body composition, sociodemographic, health, and cognitive status variables, according to physical performance status. The group of men and women with IPP was older, had higher BMI, total fat mass and FMI, and a larger waist circumference ($p \leq 0.05$) than the subjects in the normal physical performance group. Also, 19.35% showed cognitive decline according to the Mini-Mental State Examination scale, and 51.61% had polypharmacy ($p \leq 0.05$). No significant between-group differences were found with respect to FFM and FFMI, ASM and ASMI, but the mean value of handgrip strength was significantly lower in the IPP group than in the normal physical performance group.

3.2. Association between FMI and IPP

A univariate analysis of the association between different exposition variables, on the one hand, and IPP as the response variable, on the other, was performed using logistic regression analysis. All selected and significant variables ($p \leq 0.2$) were introduced into the stepwise regression to generate preliminary models, which included only variables with a p value ≤ 0.05, though other physiological variables were included despite having no significant association (Table 2; Model 2). This generated two models of the association between FMI and IPP. No interaction or collinearity was found. All continuous variables retained in the models fulfilled the linearity assumption with the response variable. Regression analysis showed a crude OR of 1.14 ($p \leq 0.05$). After adjusting for age, cognitive decline and comorbidity, the association remained significant and increased the OR (Model 1), indicating that the risk of having IPP was 1.25 times greater for each one-unit increment in the FMI (kg/m^2) ($p \leq 0.05$). Further

Table 1
General characteristics of older men and women Mexican subjects with impaired *vs.* normal physical performance status.

	Impaired physical performance (n = 31)	Normal physical performance (n = 186)	p-Value
Age, years	75.8 ± 6.4	70.9 ± 6.5	0.000*
Body weight, kg	74.8 ± 18.9	70.9 ± 11.8	0.132
Height, cm	1.6 ± 0.1	1.5 ± 0.1	0.145
BMI, kg/m²	30.1 ± 6.1	27.8 ± 4.2	0.011*
Waist circumference, cm	102.5 ± 14.9	95.3 ± 10.9	0.001*
FFM, kg	42.3 ± 10.3	42.2 ± 8.3	0.963
FM, kg	31.3 ± 10.2	27.6 ± 7.6	0.017*
ASM, kg	15.9 ± 4.2	15.5 ± 3.5	0.590
FFMI, kg/m²	16.9 ± 2.3	16.4 ± 2.0	0.217
FMI, kg/m²	12.7 ± 4.2	10.9 ± 3.4	0.011*
ASMI, kg/m²	6.2 ± 0.9	6.0 ± 0.9	0.215
PAL score	1.6 ± 0.0	1.6 ± 0.0	0.116
Handgrip strength, kg	19.4 ± 8.0	24.1 ± 8.5	0.004*
ADL score	95.0 ± 10.0	98.3 ± 3.7	0.0008*
IADL score	7.2 ± 1.0	7.8 ± 0.7	0.0003*
Sex (Men), %	25.8	36.02	0.268
Cognitive decline (yes), %	19.3	5.3	0.006*
Comorbidity (yes), %	58.0	45.7	0.202
Hypertension (yes), %	51.6	39.4	0.203
Osteoporosis/Osteopenia (yes), %	16.1	16.1	1.000
Digestion (yes), %	16.1	6.9	0.088
Polypharmacy (yes), %	51.6	30.6	0.022*
Smoking (yes), %	51.6	35.4	0.086
Alcohol (yes), %	19.3	38.1	0.043*
Socioeconomic level			0.418
Low, %	45.1	37.1	
Medium, %	48.3	48.3	
High, %	6.4	14.5	
Educational level			0.471
No schooling, %	3.2	4.3	
Primary, secondary and high school, %	41.9	52.6	
University and postgraduate, %	54.8	43.0	

BMI = Body mass index; FFM = fat-free mass; FM = fat mass; ASM = appendicular skeletal muscle mass; FFMI = fat-free mass index; FMI = fat mass index; ASMI = appendicular skeletal muscle mass index; PAL = physical activity level; ADL = activities of daily living; IADL = instrumental activities of daily living. p-value from a t-test for independent samples or a chi-square test, depending on the type of variable. *p ≤ 0.05. Continuous variables (mean ± SD) and categorical variables (percentage).

adjustments were applied in Model 2, including the ASMI covariate, since this variable could be involved in the association; results, however, remained significant (OR = 1.23; $p \leq 0.05$).

3.3. Association between FFMI and IPP

The procedures described above for FMI were applied in a similar fashion to test the association between FFMI and IPP. This generated an unadjusted OR of 1.1 ($p \geq 0.05$). When this model was adjusted for age, BMI, cognitive decline and comorbidity, the OR decreased to 0.87, but this association was not found to be significant ($p \geq 0.05$) (Table 3).

4. Discussion

Physical disability is a serious problem in older people in both developing and developed countries, where it reduces quality of life and increases rates of hospitalization and the risk of mortality [11]. For these reasons, priority must be given to early detection and treatment. In this study, the prevalence of IPP was relatively high (14.3%) and more common in older women. Our findings may be important for Mexico and other countries with similar health issues, given that data for Mexico at the national level show that

Table 2
Unadjusted and adjusted logistic regression models of impaired physical performance and FMI in older men and women Mexican subjects.

	Crude OR		Model 1		Model 2	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
FMI, kg/m^2	**1.1(1.0–1.2)**	**0.013**	**1.2 (1.1–1.4)**	**0.001**	**1.2 (1.0–1.4)**	**0.001**
Age, years			1.1 (1.0–1.2)	0.000	1.1 (1.0–1.2)	0.000
Cognitive decline, %			5.9 (1.6–21.7)	0.008	5.3 (1.4–19.5)	0.011
Comorbidity, %			1.5 (1.0–2.2)	0.050	1.5 (1.0–2.2)	0.042
ASMI, kg/m^2					1.3 (0.8–2.2)	0.267

Odds ratio (OR) with 95% confidence interval (CI). FMI= fat mass index.
Model 1: adjusted for age, cognitive decline and comorbidity (n = 217).
Model 2: adjusted for age, cognitive decline, comorbidity and appendicular skeletal muscle mass index (ASMI) (n = 217).

Table 3
Unadjusted and adjusted logistic regression models of impaired physical performance and FFMI in older men and women Mexican subjects.

	Crude OR		Model 1	
	OR (95% CI)	p-value	OR (95% CI)	p-value
FFMI, kg/m^2	**1.1(0.9–1.3)**	**0.217**	**0.8 (0.6–0.1)**	**0.356**
Age, years			1.1 (1.0–1.2)	0.000
BMI, kg/m^2			1.2 (1.0–1.3)	0.002
Cognitive decline, %			5.2 (1.4–19.5)	0.013
Comorbidity, %			2.7 (1.1–6.5)	0.028

Odds ratio (OR) with 95% confidence interval (CI). FFMI= fat-free mass index.
Model 1: adjusted for age, body mass index (BMI), cognitive decline and comorbidity (n = 217).

26.9% and 24.6% of older adults have problems with ADL and IADL, respectively [26]. In accordance with some longitudinal evidence which shows that IPP is a good predictor of PD, it is probable that most of these older people identified with IPP − or pre-clinical disability status − could potentially develop PD. It is well-known that subjects with pre-clinical disability status have a greater risk of developing difficulty to walk 0.5 miles and climb 10 stairs in a follow-up period of 18 months [40]. Regarding the causes of this condition, it seems that body composition compartments and components are particularly significant contributing factors for developing IPP and PD in older adults [4−10,16,17,39]. This study is the first to determine a significant association between FMI and IPP assessed by SPPB in a sample that included older men and women subjects.

In terms of the prevalence of IPP, the value determined herein was lower than the one reported for an older adult population in the United States (21.7%). Importantly, Visser et al.'s study (1998) assessed IPP simply by asking subjects whether they could walk 0.5 miles and climb 10 stairs [7]. Thus, it may be that the tests employed to assess physical performance in our study account for this difference in prevalence. With respect to the exposition variables or body composition − especially FMI and FFMI − the mean FMI values found were 12.5 kg/m^2 and 8.67 kg/m^2 for men and women, respectively. According to the cut-off proposed by Kelly et al. (2009), these two groups would fall into the 'excess fat mass' category [41]. These data are important for Mexico due to the clear trend towards increasing problems of overweight and obesity in the general population, including older people [25,29,41,42]. It is likely, therefore, that the prevalence of PD associated with excess fat mass or obesity will increase markedly in countries like Mexico and other Latin America nations that are undergoing important demographic and epidemiological transitions.

One of the main hypotheses of this study was that higher FMI values are more closely-associated with IPP than lower values. This hypothesis was tested, and results revealed that high FMI values were indeed associated with IPP after adjusting for several covariates, including ASM and ASMI. The following mechanisms may support our hypothesis: the positive relationship between adipose tissue and concentrations of leptin and pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor alpha (TNF-α) [43]. In addition, aging, and obesity − measured by the BMI − also independently increased the C-reactive protein (CRP) [44].

The imbalance in IL-6, TNF-α, and CRP concentrations in conditions of chronic inflammation and the aging process is associated with insulin resistance, disturbances in energy metabolism, and alterations of growth hormone secretion [45,46]. Some studies in humans have shown a clear, positive association between IL-6, TNF-α and other inflammatory markers − such as CRP values − with BMI and fat mass, accompanied by a negative association between high pro-inflammatory markers and loss of muscle mass in older adults [47]. Finally, skeletal muscle mass loss is strongly-associated with both IPP and PD [18−20]. This loss associated with high IL-6 levels is one of the underlying mechanisms of IPP and physical disability in old age. Also, a significant and direct association between pro-inflammatory markers, such as higher IL-6 concentrations and PD [48] and IPP [47,49], has been reported; indeed, it has been suggested that chronic sub-clinical inflammation may be a marker of functional disability in diseased older people.

Future studies conducted to explore this association should, therefore, include inflammation markers, while also examining other possible mechanisms related to PD that are not mediated by the loss of total or appendicular skeletal muscle mass. The lack of measurements of inflammation markers could be an important limitation of this study, since we found no differences in ASM and ASMI between the groups. Analyzing the cut-off points of the FM index that correspond to IPP is also advisable to detect early onset of IPP and, therefore, prevent PD in older adult populations.

Finally, there may be other, non-physiological, mechanisms that explain the loss of functionality in older people with high fat mass levels. Recently, it was suggested that physical performance − especially mobility and walking − is limited by the pain associated with a high BMI, but this reported clinical condition was not explored in this study [50]. With respect to the hypothesis that low FFMI values are associated with an increased risk of IPP, our findings do not support this in older people with the characteristics mentioned in our methodology and results sections. It is important to note that similar results have been reported when FFM is used as a continuous variable and index, even after adjusting for several associated covariates [5,7]. Also, there is no association between IPP assessed by walking speed at a normal pace and the one leg stand test and ASMI. This association was found only between FM and IPP using the aforementioned test, as reported in other studies [4,6,7,10,17].

In conclusion, the proportion of impaired physical performance was relatively high in this sample of older people from northwest Mexico, while FMI assessed by DXA and height squared, but *not* the fat-free mass index, was significantly associated with IPP evaluated by SPPB. Futures studies should include inflammation markers to explore a possible independent effect of this aspect as a

contributing factor to IPP. Our findings support the importance of reinforcing specific strategies designed to prevent overweight and obesity in older people nationwide, in an effort to prevent impaired physical performance and physical disability and, therefore, frailty. Improving the quality of life for this particularly vulnerable age group by preventing PD will constitute a very real challenge for Mexico and other Latin America countries in coming years.

Statement of authorship

Maribel Ramírez Torres participated in study design, fieldwork, statistical analysis and writing.

Roxana E. Ruiz Valenzuela, participated in study design, fieldwork and preliminary statistical analysis, and reviewed the manuscript.

Julián Esparza-Romero, participated in study design. He was the main advisor, verified the statistical analyses, and reviewed the manuscript.

Miriam T. López Teros' main contribution was in study design, but she was also a main advisor, verified the functional assessment, and reviewed the manuscript.

Heliodoro Alemán-Mateo was the project leader. He participated in study design, fieldwork, interpretation of statistical analyses, and writing.

All authors approved the final manuscript to send for publication to the Clinical Nutrition Journal.

Conflicts of interest

All authors of this study declare that they have no conflict of interest of any kind.

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