Relationship of vitamin D blood concentration with muscle mass and cognitive function in postmenopausal women

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Abstract

Introduction: Low levels of vitamin D have been associated with muscle mass loss and cognitive function alteration.

Objective: To find out the relationship of vitamin D blood levels with muscle mass and cognitive function in postmenopausal women. **Materials and methods:** Ninety-nine postmenopausal women aged ≥ 50 years were studied. Calf circumference, and tricipital, bicipital, subscapular and suprailiac skinfolds were measured. Arm muscle area, bone-free arm muscle area, and muscle mass were calculated. The short physical performance battery (SPPB) was performed, and the sarcopenia rapid diagnostic questionnaire (SARC-F), as well as the Mini Mental State Examination (MMSE) were applied. A blood sample was taken to measure vitamin D blood concentration. For statistical analysis, Mann-Whitney's U-test and Spearman's correlation analysis were used. **Results:** It was found that, the older the age, the higher the vitamin D levels, as well as higher SARC-F score. Vitamin D levels were negatively correlated with grip strength and SPPB. There was a negative correlation between vitamin D levels and MMSE global score. **Conclusions:** Vitamin D did not have a positive influence on muscle mass. A better MMSE performance was observed in those with lower vitamin D levels.

KEY WORDS: Sarcopenia. Muscular strength. Post-menopause. Vitamin D. Body fat. Cognition.

Relación de la concentración de vitamina D en sangre con la masa muscular y la función cognitiva en mujeres posmenopáusicas

Resumen

Introducción: Las concentraciones bajas de vitamina D se han asociado con la pérdida de masa muscular y la alteración de la función cognitiva. **Objetivo:** Conocer la relación de la concentración sanguínea de vitamina D con la masa muscular y la función cognitiva en mujeres posmenopáusicas. **Materiales y métodos:** Se estudiaron 99 mujeres posmenopáusicas ≥ 50 años. Se midió la circunferencia de la pantorrilla, los pliegues cutáneos tricipital, bicipital, subescapular y suprailíaco. Se calcularon: el área muscular del brazo, el área muscular libre de hueso y la masa muscular total. Se realizó la prueba corta de desempeño físico (PCDF), se aplicó el cuestionario de diagnóstico rápido de sarcopenia (SARC-F) y el Mini Examen del Estado Mental (MMSE). Se tomó una muestra de sangre para medir la concentración de vitamina D en sangre. Para el análisis estadístico se utilizó la prueba U de Mann-Whitney y análisis de correlación de Spearman. **Resultados:** Se encontró que a mayor edad hubieron mayores concentraciones de vitamina D y mayor puntaje SARC-F. Las concentraciones de vitamina D se correlacionaron negativamente con la

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fuerza de agarre, la PCDF y la puntuación total del MMSE. **Conclusiones:** La vitamina D no tuvo una influencia positiva sobre la masa muscular. Se observó un mejor desempeño en el MMSE en aquellas con concentraciones más bajas de vitamina D.

PALABRAS CLAVE: Sarcopenia. Fuerza muscular. Posmenopausia. Vitamina D. Grasa corporal. Cognición.

Introduction

Sarcopenia is characterized by a slow and progressive loss of muscle mass,¹⁻³ with a prevalence in people older than 60 years ranging from 3% to 52%.^{4,5} For its diagnosis, it is necessary for muscle mass, muscular strength and physical performance to be determined.⁶ Muscle mass can be measured by dual-energy X-ray densitometry or anthropometric measurements.⁷ There is also a questionnaire to rapidly diagnose sarcopenia (SARC-F) that allows muscle function impairment and sarcopenia to be excluded.^{8,9}

Muscle function can be assessed by hand grip strength,^{10,11} functional capacity, by measuring walking speed over a 10-m distance, and performance, by the time for sitting down and standing up five times.^{7,8,12-14} The short physical performance battery (SPPB) evaluates balance, time to walk four meters, and five times chair sit-to-stand time.¹³⁻¹⁵

Vitamin D [25(OH)D] low concentrations have been associated with unfavorable changes in muscle mass and physical performance,¹⁶ muscle mass increased loss¹⁷ and with increased fat mass and impaired glucose metabolism regardless of body mass index (BMI).^{18,19}

Menopause before 45 years of age has been reported to be associated with an increased risk of sarcopenia, without having been able to demonstrate that postmenopausal hormonal changes modify muscle deterioration.²⁰

Cognitive function is affected by age and hormone therapy use.^{21,22} 25(OH)D deficiency decreases the performance in cognitive function tests;²³⁻²⁸ however, in a Mexican study, no relationship was found between 25(OH)D and cognitive performance²⁹ and, in another, no relationship was found with dementia in men.³⁰

For cognitive impairment diagnosis, the Mini-Mental State Examination (MMSE)³¹ has been used, which quantifies global cognitive performance and allows dementia staging.³²

The purpose of the present work was to know the relationship between 25(OH)D blood concentration

and muscle mass and cognitive function in postmenopausal women.

Material and Methods

Postmenopausal women aged 50 years or older who attended the high-specialty medical unit were studied. Those with a history of breast cancer, heart disease, chronic obstructive pulmonary disease, kidney disease, malabsorption syndromes, hip replacement, osteoarthritis, history of trauma that prevented walking or hand grip were not included.

In all of them, the following was investigated: age (years), level of education, occupation, type of work, and if they practiced any sports. Obstetric history, diabetes mellitus, time since menopause onset and use of hormone replacement therapy were also documented.

Weight (kg), height (m), waist circumference (cm), hip circumference (cm) were determined in all of them, and body mass index (BMI, kg/m²) and waist-hip ratio (WHR, waist circumference: hip circumference) were calculated.

The following was also evaluated: arm muscle circumference = arm circumference - (triceps skinfold x π); arm muscle area (AMA) = arm muscle circumference²/4 π ; bone-free arm muscle area (BFAMA) = AMA - 6.5; total muscle mass (TMM) (kg): (height, cm) (0.0264) + (0.0029 x BFAMA). Tricipital, bicipital, subscapular and suprailiac skinfolds (mm) were measured with a Lange caliper.³³⁻³⁵

The percentage of fat was calculated after having measured all four skin folds (bicipital, tricipital, subscapular and suprailiac) with the Durnin & Wormersley formula to estimate body density (in kg/L). The formula was selected according to age: where D = body density (g/mL), L = log of the sum of all 4 skinfolds in mm, for women older than 50 years D = 1.1339 - (0.0645 x L), fat % = (495/body density) - 450. Calf circumference was also measured.

Grip force was measured with a Camry dynamometer (Model EH101), with two measurements being made and the average being considered for analysis.

Balance was assessed on a 0-4 scale, with a rating being considered for standing with both feet together, with the tip of one foot touching the side of the heel of the other, and standing with the tip of one foot touching the back of the heel of the other. The time to walk a 4-meter distance was evaluated on a 0-4 scale according to the time it took to walk it, and the time to stand up from a chair and sit five times was evaluated also on a 0-4 scale.

SPPB considers low performance when total score is 0-6 points, intermediate performance when it is 7-9 and high performance when it is 10-12.²⁰

Abdominal ultrasound was performed with a Voluson 730 Pro equipment (General Electric Healthcare, Austria GM GH), with a 3.5-MHz transducer to measure subcutaneous and visceral (intra-abdominal) fat.¹⁹

The SARC-F was applied, which evaluates five parameters: strength, assistance with walking, rising from a chair, climbing stairs and falls, with a score ≥ 4 being regarded as predictive of sarcopenia.⁸

The MMSE was applied, with dementia being considered when the score was lower than 12 points, cognitive deterioration when it was between 12 and 24, doubtful cognitive deterioration when it was 25 to 26 and normal when the score was ≥ 27 .³⁰

25(OH)D was measured by electrochemiluminescent fixation assay (Cobas®), and was considered normal when the level was ≥ 30 ng/mL.

Sample size calculation was as follows: given that available budget was for 100 tests, and in the demographic profiles of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) the population aged 50-59 years corresponds to 28.7%, from 60 to 69 to 18.6%, from 70 to 79 to 10.6% and of 80 or more to 5.7%, the group of 50-59 included 45 participants, the 60-69 group, 29, the 70-79 group, 17, and the group of 80 or more, 9 participants, respectively.

Statistical analysis: given the sample distribution, the comparison between groups was carried out with Mann-Whitney's U-test. Spearman correlation analysis was performed between 25(OH)D concentrations and sarcopenia and MMSE assessments.

The protocol was authorized by the Research Ethics Committee and the Local Health Research Committee

Table 1. General data in a population of 99 postmenopausal women older than 50 years*

Age, years	60.0 (50.0-90.0)
Times per week of physical activity	0.0 (0-7)
Weight, kg	66.0 (43.1-99.5)
Height, m	1.6 (1.4-1.7)
Body mass index, kg/m ²	27.4 (18.6-41.8)
Waist, cm	86.5 (66.9-120.0)
Hip, cm	102.0 (78.0-132.0)
Waist-hip ratio	0.86 (0.69-0.99)
Systolic blood pressure, mmHg	120.0 (95-150)
Diastolic blood pressure, mmHg	77.5 (50-90)

*Results expressed in medians (minimum and maximum values).

with registration number R-2019-3606-039, and all participants signed the informed consent letter.

Results

One hundred postmenopausal women were included, but given that a sample was damaged and there were no resources to process it again, only 99 women were studied

Data of the overall study population are shown in tables 1 and 2.

When the population was divided according to 25(OH)D concentration, 3 groups were formed: group 1 (0 to < 11 ng/mL), group 2 (11 to < 30 ng/mL) and group 3 (≥ 30 ng/mL) (Table 3).

Grip strength was found to be significantly lower in group 3. SPPB score was lower at higher 25(OH)D concentration. Visceral fat/subcutaneous fat ratio was lower in group 2. SARC-F score was significantly higher in group 3 (Table 3). There was a higher proportion of women with normal SARC-F score (88.9%) in the group with 25(OH)D between 11 and < 30 ng/mL in comparison with the other two groups ($p < 0.006$).

When the population was divided by age groups (group 1, 50 to < 60 years; group 2, 60 to < 70 years; group 3, 70 to < 80 years; and group 4, ≥ 80 years), 25(OH)D levels were found to be higher at older age and lower MMSE score (Table 4).

Grip strength and SPPB score were higher in the < 60 years group. Visceral fat was higher in group 2. SARC-F score was higher in the ≥ 80 years group.

Table 2. Vitamin D concentrations, muscle mass, visceral fat, functional performance markers and MMSE in 99 postmenopausal patients older than 50 years*

Vitamin D, ng/mL	17.2 (3.5-37.1)
Arm muscle area, cm ²	28.7 (16.3-68.3)
Bone-free arm muscle area, cm ²	22.2 (10.1-61.8)
Total muscle mass, kg	16.9 (10.6-34.5)
Body density, g/cm ³	1.007 (0.994-1.039)
Fat percentage, %	41.6 (26.6-48.1)
Arm circumference, cm	27.0 (16.0-35.0)
Calf circumference, cm	32.5 (25.0-42.0)
Average grip strength, kg	19.8 (4.1-39.6)
Sitting-standing, s	10.7 (4.9-38.3)
Balance feet together, s	30.0 (10.5-30.0)
Balance tip-heel, s	30.0 (0.0-30.0)
Balance tip-heel side, s	30.0 (0.0-30.0)
Gait, s	3.9 (2.3-19.7)
Short physical performance battery score	11.0 (3.0-12.0)
Tricipital skinfold, mm	24.0 (5.0-45.0)
Bicipital skinfold, mm	17.0 (1.0-37.0)
Subscapular skinfold, mm	25.0 (10.0-40.0)
Suprailiac skinfold, mm	27.0 (5.0-52.0)
Subcutaneous fat, cm	2.0 (0.7-5.3)
Visceral fat, cm	4.2 (1.4-8.9)
Visceral fat/subcutaneous fat	1.8 (0.8-5.8)
SARC-F total score	1.0 (0.0-11.0)
MMSE orientation to time	5.0 (2.0-5.0)
MMSE orientation to place	5.0 (3.0-6.0)
MMSE immediate recall	1.0 (1.0-2.0)
MMSE registration	3.0 (2.0-5.0)
MMSE attention-calculation	5.0 (0.0-5.0)
MMSE delayed recall	2.0 (0.0-3.0)
MMSE language	9.0 (5.0-9.0)
MMSE total score	28.0 (19.0-30.0)

*Results expressed in medians (minimum and maximum values).

SARC-F: questionnaire to rapidly diagnose sarcopenia; MMSE: Mini-Mental State Examination.

The proportion of women with SARC-F suggestive of sarcopenia was higher in the older age group (75%; $p < 0.001$), and MMSE total score was lower in the same group (Table 4).

After the group was divided according to BMI: group 1 (≤ 27.0) and group 2 (> 27.0), body density and SPPB score were found to be higher in group 1. MMT, fat percentage, subcutaneous and visceral fat, 25(OH)D concentrations and MMSE score were higher in the BMI > 27 group (Table 5).

After dividing according to WHR: group 1 (≤ 0.85) group 2 (> 0.85), body density was found to be higher in group 2, and fat percentage, grip strength and SPPB total score were found to be higher in group 1 (Table 5).

In Spearman's correlation analysis, significant correlations were recorded between 25(OH)D concentration and age (0.443; $p < 0.001$), grip strength (-0.242; $p < 0.016$), SPPB score (-0.590; $p < 0.001$) and MMSE score (-0.228; $p < 0.023$).

Age was correlated with grip strength (-0.497; $p < 0.001$), SPPB score (-0.683; $p < 0.001$), SARC-F score (0.429; $p < 0.001$) and MMSE score (-0.243; $p < 0.015$).

Grip strength was correlated with SPPB score (0.506; $p < 0.001$), SARC-F score (-0.423; $p < 0.001$) and MMSE score (0.284; $p < 0.004$).

SPPB score was correlated with SARC-F score (-0.587; $p < 0.001$) and MMSE score (0.298 $p < 0.003$).

Total muscle mass was correlated with MMSE (0.282; $p < 0.005$) (Table 6).

Discussion

In this study, 25(OH)D concentrations were negatively correlated with some muscle parameters (grip strength and SPPB score), but not with SARC-F score, which indicates that 25(OH)D is not related to sarcopenia.^{16,17} However, age negatively influenced on muscle parameters, which is consistent with what has already been reported.³⁵ The older patients were, they were observed to have higher 25(OH)D concentrations, for which we have no explanation. It should be pointed out that, in this study, only four women had 25(OH)D within normal parameters, according to what is described in the literature, where up to 90% of older adults have 25(OH)D deficiency.^{16,36,37} However, it is important to note that accurate information on multivitamin consumption may not have been obtained.

25(OH)D optimal concentration has not been defined, but it has been recommended that it should be > 30 ng/dL, with concentrations between 20-30 ng/dL

Table 3. Values obtained for muscle mass, visceral fat and functional performance markers and MMSE in 99 postmenopausal patients older than 50 years divided according to vitamin D concentrations

	0 to < 11 ng/mL (n = 11)	11 to < 30 ng/mL (n = 84)	≥ 30 ng/mL (n = 4)
Vitamin D, ng/mL	9.7 (3.5-10.9) ^{a, b}	17.6 (11.3-29.7) ^{a, c}	30.3 (30.1-37.1) ^{b, c}
Age, years	57.0 (51.0-68.0) ^{d, e}	60.5 (50.0-90.0) ^{d, f}	85.5 (72.0-88.0) ^{e, f}
Weight, kg	63.5 (48.6-9.50)	66.5 (43.1-90.1)	71.5 (55.0-82.0)
Height, m	1.56 (1.47-1.68)	1.54 (1.42-1.70)	1.56-1.40-1.69)
Body mass index, kg/m ²	25.9 (20-39.9)	27.5 (18.6-36.4)	29.4 (19.3-41.8)
Waist circumference, cm	83.0 (66.0-120.0)	86.5 (68.0-106.0)	95.0 (80.0-108.0)
Hip circumference, cm	96.0 (68.0-132.0)	102.0 (82.0-121.0)	109.50 (105.0-112.0)
Waist-hip ratio	0.86 (0.74-0.99)	0.86 (0.69-0.98)	0.87 (0.76-0.96)
Systolic blood pressure, mmHg	120 (100-140)	120 (95-150) ^g	135 (120-140) ^g
Diastolic blood pressure, mmHg	80 (60-90)	70 (50-90)	80 (60-90)
Arm muscle area, cm ²	31.2 (25.5-38.5)	28.1 (16.6-68.3)	31.0 (19.0-51.6)
Bone-free arm muscle area, cm ²	24.7 (19.0-32.0)	21.6 (10.1-61.8)	24.5 (12.5-45.1)
Total muscle mass, kg	18.2 (15.7-20.9)	16.7 (10.6-34.5)	17.7 (13.8-26.4)
Body density, g/cm ³	1.011 (0.998-1.031)	1.007 (0.994-1.039)	1.000 (0.996-1.009)
Fat percentage, %	39.4 (30.3-46.0)	41.6 (26.6-48.1)	44.4 (40.4-46.7)
Average grip strength, kg	20.9 (10.6-29.7) ^h	19.90 (4.1-39.6) ⁱ	11.6 (8.8-16.7) ^{h, i}
Short physical performance battery score	12.0 (6.0-12.0) ^{j, k}	11.0 (2.0-12.0) ^{j, l}	3.0 (2.0-4.0) ^{k, l}
Subcutaneous fat, cm	1.6 (1.0-4.9)	2.0 (0.7-5.3)	3.5 (1.2-3.8)
Visceral fat, cm	4.9 (2.6-8.9)	4.1 (1.4-8.5)	4.2 (3.0-6.5)
Visceral/subcutaneous fat	2.1 (1.8-5.0) ^m	1.8 (0.9-5.8) ^m	1.6 (0.8-3.0)
SARC-F	0.0 (0.0-6.0) ⁿ	1.0 (0.0-11.0) ^o	8.0 (0.0-10.0) ^{n, o}
MMSE orientation to time	5.0 (3.0-5.0)	5.0 (2.0-5.0)	5.0 (5.0-5.0)
MMSE orientation to place	5.0 (3.0-6.0)	5.0 (3.0-5.0)	5.0 (4.0-5.0)
MMSE immediate recall	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)
MMSE registration	3.0 (3.0-3.0)	3.0 (2.0-5.0)	3.0 (3.0-3.0)
MMSE attention-calculation	5.0 (2.0-5.0)	5.0 (0.0-5.0) ^p	3.0 (0.0-5.0) ^p
MMSE delayed recall	2.0 (1.0-3.0)	2.0 (0.0-3.0)	2.0 (1.0-2.0)
MMSE language	9.0 (9.0-9.0) ^{q, r}	9.0 (5.0-9.0) ^{q, s}	7.0 (6.0-9.0) ^{r, s}
MMSE total score	29.0 (26.0-30.0) ^t	28.0 (19.0-30.0) ^u	26.0 (21.0-26.0) ^{t, u}

a = p < 0.001, b = p < 0.004, c = p < 0.001, d = p < 0.018, e = p < 0.001, f = p < 0.003, g = p < 0.028, h = p < 0.018, i = p < 0.012, j = p < 0.18, k = p < 0.001, l = p < 0.001, m = p < 0.017, n = p < 0.04, o = p < 0.054, p = p < 0.022, q = p < 0.038, r = p < 0.026, s = p < 0.029, t = p < 0.018, u = p < 0.013

*Results expressed in medians (minimum and maximum values).

MMSE: Mini-Mental State Examination; SARC-F: questionnaire to rapidly diagnose sarcopenia.

being considered to be insufficient. In this study, most participants were within a range of insufficiency similar to that reported in populations of other studies.^{36,37}

In this study, patients with higher BMI had higher 25(OH)D concentrations, conversely to findings reported in the literature,^{18,38} and higher MMSE score, similar to that already reported.³⁹

Table 4. Values obtained for muscle mass, visceral fat, functional performance and vitamin D markers and MMSE in 99 postmenopausal patients older than 50 years divided according to age*

	50 to < 60 years	60 to < 70 years	70 to < 80 years	≥ 80 years
Age, years	55.0 (50.0-59.0) ^{a, b, c}	64.0 (60.0-69.0) ^{a, d, e}	72.0 (70.0-76.0) ^{b, d, f}	85.5 (80.0-90.0) ^{c, e, f}
Weight, kg	65.0 (48.6-99.5)	69.5 (50.70-90.0) ^g	59.0 (46.0-81.0) ^g	57.0 (43.10-82.0)
Height, m	1.58 (1.43-1.68) ^h	1.55 (1.45-1.70) ⁱ	1.50 (1.42-1.60) ^{h, i}	1.49 (1.40-1.69)
Body mass index, kg/m ²	27.08 (19.9-39.8)	28.7 (20.8-36.3)	26.0 (21.6-34.2)	29.9 (18.7-41.8)
Waist circumference, cm	27.1 (19.9-39.8) ^j	92.0 (66.0-105.0) ^j	88.0 (74.0-97.0)	96.5 (73.0-108.0)
Hip circumference, cm	99.0 (78.0-132.0) ^k	105.8 (89.0-118.0) ^k	102.0 (82.0-116.0)	107.5 (86.0-113.0)
Waist-hip ratio	0.84 (0.75-0.99)	0.87 (0.69-0.97)	0.86 (0.79-0.93)	0.88 (0.76-0.96)
Systolic blood pressure, mmHg	120 (100-140) ^{l, m}	122.5 (100-140) ^l	120.0 (100-140)	125.0 (120-150) ^m
Diastolic blood pressure, mmHg	70 (60-90)	80 (60-90)	80 (70-90)	80 (50-90)
Arm muscle area, cm ²	29.8 (16.8-48.6)	30.7 (16.7-46.8)	26.6 (17.4-68.3)	27.6 (16.6-35.9)
BFAMA, cm ²	23.4 (10.3-42.1)	24.2 (10.2-40.3)	20.1 (10.9-61.8)	20.1 (10.1-29.4)
Total muscle mass, kg	17.5 (11.9-26.1)	18.0 (11.7-26.3) ^{n, o}	15.5 (11.5-34.5) ⁿ	15.8 (10.6-21.1) ^o
Vitamin D, ng/mL	16.1 (3.5-23.1) ^{p, q}	16.2 (9.7-29.7) ^{r, s}	21.6 (13.3-30.1) ^{p, r, t}	26.7 (16.0-37.1) ^{q, s, t}
Body density, g/cm ³	1.007 (0.994-1.034)	1.008 (0.994-1.029)	1.007 (0.999-1.030)	1.008 (0.996-1.020)
Fat percentage, %	41.0 (28.6-47.2)	42.4 (26.6-48.1)	41.0 (35.0-45.0)	38.7 (30.3-46.8)
Average grip strength, kg	22.4 (8.0-39.7) ^{u, v}	20.5 (11.1-31.6) ^{w, x}	16.7 (11.7-29.3) ^{u, w, y}	10.7 (4.1-16.8) ^{v, x, y}
Short physical performance battery score	12.0 (7.0-12.0) ^{z, aa, bb}	11.6 (5.0-12.0) ^{z, cc}	10.0 (5.0-12.0) ^{aa, dd}	4.5 (3.0-10.0) ^{bb, cc, dd}
Subcutaneous fat, cm	2.0 (0.9-5.3)	2.1 (0.7-3.8)	2.0 (0.9-4.4)	2.1 (0.8-3.8)
Visceral fat, cm	3.6 (1.5-8.9)	4.6 (1.6-6.8)	4.1 (1.7-7.8)	3.6 (1.4-8.5)
Visceral fat/subcutaneous fat	1.8 (0.9-5.0)	2.2 (1.1-5.8)	1.9 (1.2-3.7)	1.5 (0.8-5.0)
SARC-F total score	0.0 (0.0-7.0) ^{ee, ff}	1.0 (0.0-4.0) ^{gg}	2.0 (0.0-9.0) ^{ee, hh}	8.0 (3.0-11.0) ^{ff, gg, hh}
Vitamin D (ng/mL)	16.1 (3.5-23.1) ^{ii, jj}	16.2 (9.7-29.7) ^{kk, ll}	21.6 (13.3-30.1) ^{jj, ll, mm}	26.7 (16.0-37.1) ^{kk, ll, mm}
MMSE orientation to time	5.0 (4.0-5.0) ⁿⁿ	5.0 (3.0-5.0)	5.0 (3.0-5.0) ⁿⁿ	5.0 (2.0-5.0)
MMSE orientation to place	5.0 (3.0-6.0) ^{oo}	5.0 (3.0-5.0)	5.0 (3.0-5.0)	4.5 (4.0-5.0) ^{oo}
MMSE immediate recall	1.0 (1.0-1.0)	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-1.0)
MMSE registration	3.0 (3.0-5.0)	3.0 (3.0-3.0)	3.0 (2.0-5.0)	3.0 (3.0-3.0)
MMSE attention-calculation	5.0 (0.0-5.0) ^{pp}	5.0 (3.0-5.0) ^{qq}	4.0 (0.0-5.0) ^{pp, qq}	5.0 (0.0-5.0)
MMSE delayed recall	2.0 (1.0-3.0)	2.0 (1.0-3.0)	2.0 (0.0-3.0)	2.0 (1.0-3.0)
MMSE language	9.0 (5.0-9.0) ^{rr, ss}	9.0 (7.0-9.0) ^{tt, uu}	8.0 (5.0-9.0) ^{rr, tt}	7.0 (6.0-9.0) ^{ss, uu}
MMSE total score	28.0 (21.0-30.0) ^{vv, ww}	29.0 (24.0-30.0) ^{xx, yy}	26.0 (19.0-30.0) ^{ww, xx}	25.5 (21.0-28.0) ^{ww, yy}

0.001, jj = p < 0.001, kk = p < 0.013, ll = p < 0.002, mm = p < 0.048, nn = p < 0.039, oo = p < 0.005, pp = p < 0.025, qq = p < 0.001, rr = p < 0.006, ss = p < 0.001, tt = p < 0.008, uu = p < 0.001, vv = p < 0.016, ww = p < 0.016, xx = p < 0.008, yy = p < 0.001

*Values expressed in medians (minimum and maximum values).

BFAMA: bone-free arm muscle area; MMSE: Mini-Mental State Examination; SARC-F: questionnaire to rapidly diagnose sarcopenia.

Cognitive function was negatively affected by age as in other reports,²¹ and also by high 25(OH)D concentrations, conversely to previous reports.^{23,31} For the

above reasons, it is possible to conclude that high 25(OH)D concentrations are associated with lower scores in physical performance tests and MMSE.

Table 5. Values obtained for muscle mass, visceral fat, functional performance and vitamin D markers and MMSE in 99 postmenopausal patients older than 50 years divided according to body mass index and waist: hip ratio

	BMI $\leq$ 27 kg/m ²	BMI > 27 kg/m ²	WHR $\leq$ 0.85	WHR > 0.85
Age, years	60.0 (50.0-90.0)	61.0 (50.0-90.0)	59.5 (50.0-85.0)	62.0 (50.0-90.0)
Weight, kg	56.7 (43.1-73.0) ^a	73.5 (56.0-99.5) ^a	62.8 (43.1-90.0)	68.3 (48.60-99.5)
Height, m	1.55 (1.42-1.69)	1.54 (1.40-1.70)	1.56 (1.42-1.70)	1.54 (1.40-1.68)
Body mass index, kg/m ²	24.2 (18.7-26.8) ^b	30.4 (27.0-41.8) ^b	26.3 (18.7-34.6) ^c	28.4 (19.9-41.8) ^c
Waist circumference, cm	78.5 (66.0-100.0) ^d	92.0 (73.0-120.0) ^d	80.5 (66.0-98.0) ^e	92.5 (71.0-120.0) ^e
Hip circumference, cm	93.0 (78.0-113.0) ^f	107.5 (92.0-132.0) ^f	100.5 (82.0-118.0)	105.0 (78.0-132.0)
Waist-hip ratio	0.84 (0.73-0.99)	0.87 (0.69-0.98)	0.81 (0.69-0.85) ^g	0.89 (0.86-0.99) ^g
Systolic blood pressure, mmHg	120 (100-150) ^g	120 (95-140) ^g	120 (100-140) ^h	120 (95-150) ^h
Diastolic blood pressure, mmHg	70 (50-90) ⁱ	80 (60-90) ⁱ	70 (50-90) ⁱ	80 (60-90) ⁱ
Vitamin D, ng/mL	16.0 (6.1-30.4) ^k	18.0 (3.5-37.1) ^k	18.2 (6.5-30.4)	16.4 (3.5-37.1)
Arm muscle area, cm ²	28.4 (16.3-67.4) ^l	28.5 (17.6-50.9) ^l	28.7 (16.4-67.4) ^m	28.0 (16.3-50.9) ^m
BFAMA, cm ²	22.2 (10.1-61.8) ⁿ	22.4 (11.3-45.1) ⁿ	22.6 (10.2-61.8) ^o	21.8 (10.1-45.1) ^o
Total muscle mass, kg	12.3 (7.6-17.1) ^p	14.0 (6.8-30.2) ^p	12.4 (7.6-19.0)	13.6 (6.8-30.2)
Body density, g/cm ³	1.008 (0.994-1.039) ^q	1.007 (0.995-1.034) ^q	1.006 (0.994-1.039) ^r	1.008 (0.995-1.031) ^r
Fat percentage, %	41.0 (26.6-48.1) ^s	41.7 (28.6-47.2) ^s	41.8 (26.6-47.0) ^t	41.0 (30.3-47.2) ^t
Average grip strength, kg	19.9 (4.1-29.7)	11.0 (8.0-39.6)	21.0 (4.1-39.6) ^u	17.9 (8.0-31.6) ^u
Short physical performance battery score	12.0 (2.0-12.0) ^v	10.5 (2.0-12.0) ^v	12.0 (4.0-12.0) ^w	11.0 (3.0-12.0) ^w
Subcutaneous fat, cm	1.6 (0.7-3.8) ^x	2.6 (1.1-5.3) ^x	2.0 (0.8-4.4)	2.2 (0.7-5.3)
Visceral fat, cm	3.1 (1.4-8.5) ^y	5.1 (1.5-8.9) ^y	3.6 (1.4-7.2) ^z	4.9 (1.6-8.9) ^z
Visceral fat/subcutaneous fat	2.0 (1.1-5.0)	1.8 (0.8-5.8)	1.8 (0.9-5.0)	2.1 (0.8-5.8)
SARC-F total score	1.0 (0.0-11.0)	1.00 (0.0-9.0)	1.0 (0.0-10.0)	1.0 (0.0-11.0)
Vitamin D, ng/mL	16.0 (6.1-30.4) ^{aa}	18.0 (3.5-37.1) ^{aa}	18.2 (6.5-30.4)	16.4 (5.5-37.1)
MMSE orientation to time	5.0 (2.0-5.0) ^{bb}	5.0 (4.0-5.0) ^{bb}	0.001	5.0 (3.0-5.0)
MMSE orientation to place	5.0 (3.0-6.0)	5.0 (3.0-5.0)	NS	5.0 (3.0-5.0)
MMSE immediate recall	1.0 (1.0-2.0)	1.0 (1.0-2.0)	NS	1.0 (1.0-2.0)
MMSE registration	3.0 (2.0-5.0)	3.0 (2.0-3.0)	NS	3.0 (2.0-5.0)
MMSE attention-calculation	5.0 (0.0-5.0)	5.0 (3.0-5.0)	NS	5.0 (0.0-5.0)
MMSE delayed recall	2.0 (0.0-3.0)	2.0 (0.0-3.0)	NS	2.0 (0.0-3.0)
MMSE language	9.0 (5.0-9.0)	9.0 (5.0-9.0)	NS	9.0 (5.0-9.0)
MMSE total score	28.0 (19.0-30.0) ^{cc}	29.0 (24.0-30.0) ^{cc}	28.0 (19.0-30.0)	28.0 (19.0-30.0)

a = p < 0.001, b = p < 0.001 c = p < 0.004 d = p < 0.001 e = p < 0.001, f = p < 0.001, g = p < 0.001, h = p < 0.007, i = p < 0.004, j = p < 0.041, k = p < 0.010, l = p < 0.023, m = p < 0.036, n = p < 0.023, o = p < 0.036, p = p < 0.03, q = p < 0.023, r = p < 0.001, s = p < 0.02, t = p < 0.001, u = p < 0.02, v = p < 0.048, w = p < 0.003, x = p < 0.024, y = p < 0.001, z = p < 0.012, aa = p < 0.023, bb = p < 0.001, cc = p < 0.011

*Values expressed in medians (minimum and maximum values).

BFAMA: bone-free arm muscle area; WHR: waist-hip ratio; BMI: body mass index; MMSE: Mini-Mental State Examination; SARC-F: questionnaire to rapidly diagnose sarcopenia.

Table 6. Spearman's correlation analysis between muscle mass, subcutaneous fat, visceral fat, functional performance and vitamin D markers and MMSE in postmenopausal women

	Vitamin D	BMI	WHR	TMM	Grip strength	SPPB	Subcutaneous fat	Visceral fat	VF/SF	SARC-F	MMSE
Age	0.443 p < 0.001				-0.497 p < 0.001	-0.683 p < 0.001				0.429 p < 0.001	-0.243 p < 0.015
BMI			0.236 p < 0.019			-0.271 p < 0.007	0.661 p < 0.001	0.655 p < 0.001			0.224 p < 0.026
WHR								0.216 p < 0.032	0.228 p < 0.023	0.194 p < 0.055	
AMA		0.295 p < 0.003	0.215 p < 0.033	0.965 p < 0.001					0.221 p < 0.028		0.267 p < 0.008
BFAMA		0.295 p < 0.003	0.215 p < 0.033	0.965 p < 0.001					0.221 p < 0.028		0.267 p < 0.008
TMM		0.268 p < 0.007							0.205 p < 0.042		0.282 p < 0.005
Grip strength	-0.242 p < 0.016		-0.341 p < 0.001			0.506 p < 0.001				-0.423 p < 0.001	0.284 p < 0.004
SPPB	-0.590 p < 0.001		-0.245 p < 0.014							-0.587 p < 0.001	0.298 p < 0.003
Calf circumference		0.537 p < 0.001					0.328 p < 0.003	0.426 p < 0.001			
Visceral fat							0.639 p < 0.001				
MMSE	-0.228 p < 0.023									-0.245 p < 0.015	

BMI: body mass index; WHR: waist-hip ratio; VF/SF: visceral fat/subcutaneous fat; AMA: arm muscle area; BFAMA: bone-free arm muscle area; TMM: total muscle mass; SARC-F: questionnaire to rapidly diagnose sarcopenia; SPPB: short physical performance battery; MMSE: Mini-Mental State Examination.

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Conflict of interests

The authors declare that they have no conflicts of interest.

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Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this research.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained informed consent from the patients and/or subjects referred to in the article. This document is in the possession of the corresponding author.

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