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ORIGINAL CONTRIBUTION

What is the relationship between physical fitness level and macro- and micronutrient intake in Spanish older adults?

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Abstract

Purpose The aim of this study was to assess the association between physical fitness (PF) and energy and nutrient intake in Spanish older adults.

Methods Three hundred and twenty-four participants (59.9% females, aged over 55 years) performed a battery of four validated PF tests and participants were divided into three: low, medium, and high PF. Dietary intake was assessed by two non-consecutive 24 h dietary recalls. Energy and nutrient intake was calculated using the ALIMENTA software. Energy expenditure (EE) was calculated using a validated questionnaire.

Results Median energy intake (EI) was 2135, 1999, and 2111 kcal/day in the low, medium, and high PF in males, respectively. In females, the median EI was 1576, 1564, and 1625 kcal/day in the low, medium, and high PF groups. There were significant and positive associations between participants in the high PF group and intake of phosphorous, selenium, vitamin B_6, C, D, E, niacin, and folates (all $p < 0.05$). However, subjects in the high PF group presented negative associations with thiamine and riboflavin intake (all $p < 0.05$). A total of 8.3% of participants presented inadequate intake of 11 micronutrients. PF seems to affect total nutrient intake.

Conclusions Higher protein and fat intake was observed in the high PF group compared to the other PF groups in males, although participants in the high PF group had also higher EE. However, females presented different patterns. In both sexes participants in the high PF group showed a better micronutrient intake profile than the other PF groups. There is a need to develop combined nutritional and fitness programs.

Keywords Physical fitness · Macronutrients · Micronutrients · Diet records · Aging · Energy expenditure

Introduction

The role of physical fitness (PF) and diet in reducing the progression of chronic disease is becoming increasingly crucial [1]. Diet has been described as the main modifiable behaviour and PF has also been defined as an important marker related to health [2]. Some authors suggest that improvements in these two factors could prevent the functional limitations that are strongly associated with advanced age, and could lead to a healthier, more active, and more independent aging process [3, 4].

Older adults are particularly at risk of deficient or suboptimal micronutrient status and they are also at risk of overconsumption of macronutrients which leads to overweight and non-communicable diseases [5, 6]. As energy expenditure (EE) decreases in the older populations [7], mainly because of less daily activity [8], a reduction of food intake

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leading to a proportional reduction of the intake of some nutrients is often the consequence [9]. Likewise, another reason is the role of drug intake on micronutrient intake availability or high intake based on drug intake consumption. Intake deficiency of several vitamins and minerals had already been observed previously in older adults [10]. Meanwhile, the prevalence of malnutrition is increasing in this kind of population [11], which is associated with a decline in functional status [12], impaired muscle function and sarcopenia [13], anemia [14], immune dysfunction [15], decreased bone mass, and reduced cognitive function [11].

PF is accepted as a health marker and is also considered an independent factor of all-cause diseases and mortality [16, 17]. A 50% of reduction in mortality has been observed among highly fit people compared to low fit people [18]. In addition, PF is dependent on several factors like nutritional habits, smoking habits, genetics, and socio-economic status [19].

Because the number of older adults is increasing in developed countries, it is essential to understand the effects of modifiable risk factors such as PF and diet [19]. There are few data analysing the association between PF level and diet in Spanish older adults [20]. Nevertheless, both PF and diet are a key for the development of public health policies to promote healthy lifestyles based on the evidence [21]. PF and diet can keep adults and older adults healthy, fit, and independent [18]. Therefore, the aim of this study was to investigate the relationship between energy and nutrient intake with PF level in Spanish older adults.

Methods

Study design, sample, and ethics

The present study was based on a cross-sectional multicentre study aiming at identifying cardiovascular risk factors in active and sedentary older adult participants (The PHYSMED Study). Data collection took place from April 2013 to May 2014 in Madrid and Mallorca (Spain). Volunteers were recruited through health centres, sport federations, sport facilities, and municipal clubs located at Madrid and Mallorca. The study population consisted of 433 participants, 184 male (43%), and 244 females (57%) aged 55–88 years. The exclusion criteria were age under 55 years, being institutionalized, suffering from a physical or mental illness which would have limited their participation in the PF tests or their ability to respond to the questionnaires or drug intake for clinical research. For the purpose of this study, participants who provided data on two non-consecutive 24 h dietary recalls were included in the analysis, resulting in 428 older adults. Likewise, underreporting was considered when the individual ratio of energy intake (EI) divided by the estimated basal metabolic rate was lower than 0.96 (EI/basal metabolic rate <0.96) [22]. Excluding the underreporting, valid reporters resulted in a final sample of 324 participants (59.9% females) for statistical analysis. The group of underreporting consisted of slightly higher percentage of females (57.0% compared to 59.9%, $p=0.035$) and had higher median body mass index (BMI) values (28.2 kg/m^2 compared to 26.5 kg/m^2), weight (77.0 kg compared to 68.4 kg), and fat mass (24.6 kg compared to 21.4 kg) (all $p<0.001$). No difference in age was observed. The number of participants in each group of PF and data comparing the whole sample vs. only underreporting is shown in Online Appendix (Table 1).

The study was performed according to the principles established in the Declaration of Helsinki and the final protocol was approved by the Ethical Committee of the Technical University of Madrid. All subjects were informed of the protocol and older adults signed a written informed consent prior to participation.

Physical activity assessment

The Minnesota Leisure-Time Physical Activity Questionnaire was carried out by trained interviewers. It has been validated for Spanish males [23] and females [24]. To calculate the total EE of physical activity (PA), an intensity value was assigned to all the items in the PA questionnaire, according to the metabolic equivalent (METs) classification proposed by Ainsworth [25]. Total PA was calculated by multiplying the total number of hours and their correspondent intensity performed for each activity.

Physical fitness tests

Each participant completed a multi-component battery of PF test [26] and validated reference ranges for Spanish older adults proposed by Pedrero-Chamizo et al. [17]. Lower body strength was measured by the chair stand test, agility/dynamic balance by the 8-foot up-and-go test, aerobic endurance by the 6-min walk test and handgrip strength with a dynamometer (Takei TKK-5401, Tokyo, Japan, range 5–100 kg, precision 0.1 kg) [27]. The handgrip strength was assessed for both hands in a standing position. All tests were performed twice, except the 6-min walk test and the chair stand test, and the best score was retained.

The results of each PF test were stratified by sex and age groups (distributed by five years periods without truncating the last group) as previously proposed by Pedrero-Chamizo et al. [17]. Furthermore, the result of each PF test was divided into quartiles considering also the variables mentioned above (sex and age groups). The score for each test ranged from 0 (worst) to 3 (best) points. Thus, the maximum score was 12 points. Scores of PF tests were added together in a cluster and participants were divided into different levels of PF: low (0–3 points), medium (4–8 points), and high (9–12 points).

Anthropometric measurements

Height was measured to the nearest millimetre using a mobile stadiometer (SECA 213, Germany), with the participant's head in the Frankfurt plane. Weight and body composition (fat mass and fat free mass) was assessed by means of bioimpedance analysis (TANITA Corp, BC-418MA, Tokyo, Japan) in standardized conditions. In addition, BMI was calculated as weight (kg/height^2) (m^2). Waist and hip circumference were performed by a trained ISAK level II anthropometrist to minimize the inter-observer coefficients of variation according to ISAK Society [28].

Dietary intake assessment

Dietary intake was obtained by means of two 24 h dietary recalls by well-trained dieticians. The 24 h dietary recalls were collected on two non-consecutive days within a period of 2 weeks. Volumes and portion sizes were reported with the aid of a book of photographs [29]. Energy and nutrient intake were calculated using a computer program (ALIMENTA; NUCOX, Palma, Spain) based on Spanish [30, 31] and European [32] food composition tables, and complemented with food composition data available for Majorcan food items [33].

Furthermore, the estimate average requirements (EAR) cut-off point was applied to estimate the prevalence of nutrient intake adequacy [34]. When EAR was not defined for a specific micronutrient, such as pantothenic acid, potassium, and sodium, the adequate intake (AI) was chosen [34].

Statistical analyses

Statistical analyses were run on SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp). Descriptive characteristics were summarized by calculating median and 5th–95th percentiles unless otherwise stated. All PF tests and dietary intakes were checked for normality of distribution with the Kolmogorov–Smirnov test. Macro- and micronutrient results were transformed (log-transformation) except for energy, water, fat, and mono-unsaturated fatty acids. Comparisons between PF groups and sexes with nutrient intake were analyzed by One-Way Anova or Kruskal–Wallis test, according to the normality of the variables.

To determine the adequacy or inadequacies of nutrient intake, subjects were split into two groups taking into account EAR or AI: below EAR or AI (inadequate; coded as 0) and above EAR or AI (adequate; coded as 1).

Multilevel linear regression analysis was used to examine the relationship between the macro and micronutrient intake, energy expenditure, and PF groups. Confounders (age and sex) were entered as covariates. To adjust for multiple testing, a Bonferroni correction was applied to lower the significance level (α) taking into account the number of tests (0.05/number of tests). A p value of 0.0013 was used as threshold of significance for the association between macro- and micronutrient intake, energy expenditure, and PF groups.

Results

Table 1 shows descriptive characteristics of the sample divided by sex. Table 2 displays energy expenditure, macronutrients and micronutrients intake split by sex and PF groups. In Table 2 (Appendix) energy expenditure, macro-, and micronutrient for underreporting is shown.

Figure 1 presents the percentage of micronutrients below EAR or AI according to sex. More than 85% of males and females showed inadequate intake of potassium, vitamin D and vitamin E. Around 50% of males and females showed inadequate intake of folate and a total of 82% of females presented inadequate intake of calcium.

Figure 2a shows the percentage of micronutrients below EAR or AI split by PF groups in each sex. There were more participants within the low PF group compared to the high PF one which showed inadequate intake for potassium, vitamin D, and vitamin E; however, males in the high PF group presented higher inadequate calcium intake compared to low PF

Table 1 Descriptive characteristics of the sample according to sex

Variables	Male (n = 130) Mean ± SD Median (min–max)	Female (n = 194) Mean ± SD Median (min–max)
Age (year)	64.9 ± 6.5 64.2 (55.0–80.0)	67.2 ± 6.7 67.0 (55.1–87.8)
Weight (cm)	78.7 ± 11.1 78.3 (44.9–116.6)	63.8 ± 9.7 63.5 (44.0–97.9)
Height (cm)	169.8 ± 6.6 169.9 (151.7–185.5)	156.6 ± 5.6 156.5 (142.0–176.2)
BMI (kg/m^2)	27.2 ± 3.2 27.3 (17.1–37.6)	26.1 ± 4.0 25.8 (17.0–41.8)
Fat mass (kg)	20.7 ± 6.1 20.5 (6.4–39.9)	23.2 ± 7.1 22.7 (7.3–48.7)
Fat free mass (kg)	58.0 ± 6.7 58.0 (37.3–76.7)	40.6 ± 3.8 40.2 (33.7–55.1)
Waist circumference (cm)	95.3 ± 10.4 96.0 (67.0–124.7)	82.8 ± 9.5 82.2 (61.3–111.7)
Hip circumference (cm)	99.8 ± 6.0 100.0 (85.7–119.0)	100.9 ± 8.4 100.5 (82.7–136.8)

Data are presented as mean ± SD and median (min–max)

BMI body mass index

Table 2 Energy expenditure, macronutrients, and micronutrients intake according to sex and physical fitness groups

	Male			Female			*p* value*	*p* value°
	Low fitness ($n=30$)	Medium fitness ($n=59$)	High fitness ($n=41$)	Low fitness ($n=37$)	Medium fitness ($n=95$)	High fitness ($n=62$)		
	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)		
Energy expenditure (METs min/week)	3485 (350.6–9510)	4607 (1256–11,141)	4901 (1788–10,708)	4142 (1085–8970)	4189 (1122–8182)	3966 (1701–8574)	> 0.05	< 0.05[d]
Energy (kcal/day)	2135 (1077–2659)	1999 (1247–2781)	2111 (1299–2965)	1576 (699.8–2136)	1564 (987.7–2143)	1625 (1001–2185)	< 0.001[a,b,c]	> 0.05
Water (ml/day)	2382 (1139–3624)	2223 (1251–3494)	2434 (1392–3396)	2029 (1321–3182)	2200 (1198–3350)	2062 (1152–3506)	> 0.05	> 0.05
Macronutrients								
Proteins (g/day)†	78.0 (44.0–161.1)	76.2 (48.3–113.9)	85.8 (47.6–139.4)	69.6 (30.0–89.9)	64.3 (38.7–105.0)	64.9 (41.0–99.7)	< 0.05[a]	> 0.05
Proteins (% E)	15.8	15.9	16.3	16.6	16.6	16.3		
Vegetable protein (g/day)†	22.8 (8.6–35.6)	22.0 (12.1–34.2)	25.8 (12.7–42.5)	21.1 (10.0–30.6)	18.6 (9.3–30.9)	20.5 (9.0–33.2)	< 0.001[b,c]	> 0.05
Animal protein (g/day)†	47.9 (25.2–140.0)	50.4 (26.5–84.6)	54.5 (24.0–110.0)	43.9 (17.6–71.3)	40.9 (19.6–78.1)	41.5 (21.9–77.9)	< 0.001[b,c]	> 0.05
Fiber (g/day)†	17.9 (8.5–29.2)	18.5 (8.3–35.2)	21.5 (9.0–36.8)	16.3 (7.5–25.9)	16.6 (8.1–29.3)	17.4 (9.3–30.9)	< 0.01[c]	> 0.05
Fiber (g/1000 kcal)	8.8	9.2	10.2	11.2	10.7	11.0		
Carbohydrates								
Total carbohydrates (g/day)†	249.7 (115.2–303.5)	212.9 (125.8–329.5)	219.3 (128.0–367.2)	179.9 (94.6–283.5)	172.7 (87.2–263.0)	189.8 (103.5–263.4)	< 0.05[a,b,c]	> 0.05
Total carbohydrates (% E)	44.6	43.7	42.0	47.6	44.3	46.3		
Mono and disaccharides (g/day)†	107.5 (54.0–144.3)	98.9 (40.9–169.0)	111.2 (56.6–210.4)	88.6 (39.3–137.1)	81.8 (36.0–141.6)	94.0 (52.9–152.6)	< 0.05[a,b,c]	> 0.05
Polysaccharides (g/day)†,b	105.2 (18.8–169.2)	93.6 (37.8–160.8)	94.7 (34.1–194.2)	81.0 (29.6–148.3)	75.1 (23.7–137.6)	80.6 (18.3–153.9)	< 0.001	> 0.05
Fats								
Fat (g/day)	81.1 (41.2–101.0)	78.7 (41.5–112.7)	83.9 (37.4–123.9)	61.1 (18.2–92.8)	61.8 (28.0–94.3)	65.2 (36.1–110.7)	< 0.001[a,b,c]	> 0.05
Fat (% E)	34.5	35.4	35.7	33.6	35.9	34.9		
SFA (g/day)†	26.2 (10.7–33.7)	21.5 (10.5–39.4)	23.7 (10.1–41.1)	18.5 (4.0–31.9)	18.7 (7.1–30.1)	18.7 (8.0–35.6)	< 0.001[a,b,c]	> 0.05
SFA (% E)	10.6	10.3	10.5	9.9	10.6	10.3		
MUFA (g/day)	37.3 (14.8–50.0)	35.8 (18.2–51.7)	39.1 (17.2–60.4)	27.4 (8.5–42.8)	28.4 (12.2–45.5)	27.9 (13.2–47.0)	< 0.001[a,b,c]	> 0.05
MUFA (% E)	15.2	16.2	16.2	15.2	16.3	15.9		
PUFA (g/day)†	10.0 (3.6–13.4)	10.0 (4.7–18.5)	11.6 (4.2–17.9)	7.1 (2.7–12.2)	7.7 (3.5–17.0)	7.7 (3.9–15.0)	< 0.001[a,b,c]	> 0.05
PUFA (% E)	4.4	4.7	4.7	4.1	4.7	4.5		
Cholesterol (mg/day)†	308.6 (86.1–845.6)	310.7 (109.8–594.2)	262.1 (88.6–678.9)	229.9 (69.5–473.0)	227.2 (77.6–545.0)	259.5 (82.6–505.4)	< 0.05[a,b]	> 0.05
Cholesterol (mg/1000 kcal)	165.0	163.6	156.0	144.4	163.5	163.6		
Alcohol (g/day)†	12.4 (0–42.3)	9.6 (0–36.7)	19.8 (0–42.7)	0.1 (0–18.6)	4.8 (0–23.0)	1.9 (0–22.3)	< 0.05[a,b,c]	> 0.05
Alcohol (% E)	5.4	5.0	5.9	2.1	3.0	2.0		
Minerals								
Sodium (mg/day)†	2095 (920.9–5596)	2088 (827.4–3153)	2008 (824.9–3689)	1535 (775.1–2816)	1552 (692.9–2622)	1547 (686.6–2989)	< 0.01[a,b,c]	> 0.05

Table 2 (continued)

	Male			Female			*p* value*	*p* value°
	Low fitness ($n=30$)	Medium fitness ($n=59$)	High fitness ($n=41$)	Low fitness ($n=37$)	Medium fitness ($n=95$)	High fitness ($n=62$)		
	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)		
Sodium (mg/1000 kcal)	1110.1	1041.8	922.4	1047.1	1019.9	999.9		
Potassium (mg/day)†	3145 (1876–4026)	2902 (1827–4904)	3627 (2184–5886)	2579 (1505–3933)	2812 (1650–4025)	2922 (1776–4252)	$<0.05^{a,c}$	$<0.05^{d}$
Potassium (mg/1000 kcal)	1478.9	1541.3	1656.4	1698.4	1793.1	1807.7		
Magnesium (mg/day)†	282.6 (150.5–985.3)	288.3 (169.8–515.9)	345.2 (203.4–600.6)	273.3 (144.8–623.3)	259.2 (162.4–401.1)	279.9 (169.9–424.3)	$<0.05^{b,c}$	$<0.01^{d}$
Magnesium (mg/1000 kcal)	175.8	149.1	164.8	185.5	171.3	172.9		
Phosphorus (mg/day)†	1252 (691.9–2074)	1202 (735.0–1840)	1324 (805.3–2201)	1083 (521.0–1503)	1028 (671.1–1399)	1087 (665.9–1652)	$<0.05^{a,b,c}$	>0.05
Phosphorous (mg/1000 kcal)	604.2	620.0	645.9	665.9	663.1	671.1		
Calcium (mg/day)†	818.8 (367.8–1284)	759.9 (457.2–1323)	761.8 (428.9–1353)	803.9 (252.5–1205)	736.6 (413.4–1193)	766.9 (367.0–1326)	>0.05	>0.05
Calcium (mg/1000 kcal)	415.6	388.7	383.1	492.9	478.6	485.6		
Iron (mg/day)†	19.0 (7.3–82.9)	17.8 (7.2–54.5)	14.9 (8.4–49.0)	13.7 (5.8–56.8)	12.1 (6.6–35.3)	12.5 (6.5–83.3)	$<0.05^{b,c}$	>0.05
Iron (mg/1000 kcal)	12.6	12.0	9.5	14.3	9.9	12.5		
Copper (mg/day)†	2.1 (1.0–4.4)	2.0 (0.9–3.5)	2.2 (1.1–4.0)	2.0 (0.7–3.1)	2.0 (0.8–3.5)	1.9 (0.9–4.1)	>0.05	>0.05
Copper (mg/1000 kcal)	1.1	1.1	1.1	1.3	1.4	1.3		
Selenium (μg/day)†	97.1 (45.0–239.6)	104.5 (44.1–176.0)	128.7 (52.0–205.2)	86.2 (31.3–137.9)	86.4 (40.0–149.1)	94.5 (45.0–170.6)	$<0.05^{a,b,c}$	$<0.01^{d}$
Selenium (mg/1000 kcal)	52.8	52.7	58.1	52.4	55.9	60.1		
Iodine (μg/day)†	133.6 (64.4–301.6)	134.7 (64.2–237.3)	132.2 (65.3–259.2)	134.8 (61.2–201.5)	134.6 (59.0–230.5)	122.4 (70.3–209.8)	>0.05	>0.05
Iodine (μg/1000 kcal)	68.1	68.1	65.2	86.3	86.9	81.2		
Zinc (mg/day)†	9.6 (5.0–17.7)	9.4 (5.7–19.9)	10.5 (6.0–16.1)	8.9 (3.7–14.4)	8.0 (4.3–17.1)	8.3 (4.4–20.5)	$<0.01^{b,c}$	>0.05
Zinc (mg/1000 kcal)	4.9	6.2	5.0	5.7	5.4	6.1		
Vitamins								
Retinol (μg/day)†	311.3 (61.5–6310)	273.8 (74.1–2024)	258.1 (75.0–582.7)	195.3 (22.3–395.2)	195.7 (37.1–459.3)	201.0 (38.3–445.5)	$<0.01^{a,b}$	>0.05
Retinol (μg/1000 kcal)	543.7	320.2	120.3	123.4	158.2	162.9		
Carotens (μg/day)†	2756 (493.3–10809)	2997 (540.0–9633)	4086 (724.3–11948)	2227 (453.4–8834)	2940 (479.9–10553)	2717 (757.2–11173)	>0.05	>0.05
Carotens (μg/1000 kcal)	1837.8	1842.6	2155.1	2125.3	2474.5	2559.9		
Vitamin A (RE/day)†	909.5 (308.5–2590)	875.8 (270.7–2321)	944.2 (277.7–2395)	654.3 (270.5–1753)	762.5 (284.4–2114)	688.5 (298.7–2655)	>0.05	>0.05
Vitamin A (RE/1000 kcal)	856.3	631.9	490.1	489.4	586.8	603.6		
Thiamine (mg/day)†	1.9 (0.7–20.3)	1.8 (0.7–21.9)	1.5 (0.8–13.2)	1.2 (0.5–16.7)	1.1 (0.6–9.5)	1.2 (0.6–7.2)	$<0.05^{b,c}$	>0.05

Table 2 (continued)

	Male			Female			*p* value*	*p* value°
	Low fitness ($n=30$)	Medium fitness ($n=59$)	High fitness ($n=41$)	Low fitness ($n=37$)	Medium fitness ($n=95$)	High fitness ($n=62$)		
	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)	Median (5th–95th)		
Thiamine (mg/1000 kcal)	2.8	2.8	1.5	2.1	1.4	1.2		
Riboflavin (mg/day)†	2.2 (0.9–30.3)	2.1 (1.0–28.4)	1.9 (0.9–17.0)	1.7 (0.7–22.1)	1.5 (0.8–13.8)	1.6 (0.7–10.3)	< 0.05[b,c]	> 0.05
Riboflavin (mg/1000 kcal)	3.8	3.6	2.0	2.8	1.9	1.7		
Vitamin B_6 (mg/day)†	1.8 (1.0–3.9)	1.8 (1.0–5.2)	2.3 (1.2–5.1)	1.6 (0.8–6.9)	1.6 (0.8–3.8)	1.8 (0.9–8.2)	< 0.01[b,c]	< 0.05[d]
Vitamin B_6 (mg/1000 kcal)	0.9	1.1	1.2	1.4	1.2	1.4		
Vitamin B_{12} (μg/day)†	5.5 (1.8–86.0)	6.9 (1.9–26.0)	6.5 (2.2–28.2)	4.5 (1.5–30.9)	3.7 (1.3–15.3)	4.9 (1.7–13.1)	< 0.01[b,c]	> 0.05
Vitamin B_{12} (μg/1000 kcal)	7.0	4.8	4.3	5.1	3.6	3.5		
Vitamin C (mg/day)†	141.6 (39.5–259.2)	105.7 (37.2–353.3)	163.5 (43.4–355.0)	131.7 (35.1–260.1)	133.6 (43.1–286.1)	151.1 (44.5–357.6)	> 0.05	< 0.05[d]
Vitamin C (mg/1000 kcal)	64.9	68.1	84.6	87.2	93.7	101.3		
Vitamin D (μg/day)†	1.6 (0.1–12.4)	2.3 (0.3–15.1)	2.8 (0.1–16.9)	1.1 (0.1–8.1)	1.4 (0.2–12.5)	1.9 (0.2–19.5)	< 0.05[b,c]	< 0.05[d]
Vitamin D (μg/1000 kcal)	1.1	2.7	2.3	1.2	3.4	3.8		
Vitamin E (mg/day)†	7.5 (3.4–14.6)	7.4 (3.3–13.2)	8.4 (3.6–17.2)	6.4 (2.2–11.9)	6.3 (3.0–11.7)	6.5 (4.9–12.2)	< 0.05[a,b,c]	> 0.05
Vitamin E (mg/100 kcal)	4.2	3.9	4.4	4.1	4.4	4.3		
Niacin (mg/day)†	18.4 (7.9–38.5)	21.2 (9.3–37.4)	23.6 (11.2–38.1)	15.6 (6.6–35.0)	15.9 (8.0–29.4)	17.4 (7.7–35.7)	< 0.01[b,c]	> 0.05
Niacin (mg/1000 kcal)	9.9	10.5	11.2	10.3	10.9	11.4		
Pantothenic acid (mg/day)†	5.3 (3.3–11.2)	5.2 (2.9–9.2)	5.4 (3.4–9.0)	4.4 (2.3–7.6)	4.6 (2.8–7.2)	4.8 (2.7–7.7)	< 0.05[a,b,c]	> 0.05
Pantothenic acid (mg/1000 kcal)	2.7	2.7	2.6	2.8	2.9	3.0		
Folates (μg/day)†	299.1 (125.9–588.3)	315.7 (156.8–620.7)	367.3 (173.0–716.9)	270.5 (124.8–455.2)	308.4 (145.6–531.6)	290.2 (151.2–638.8)	> 0.05	> 0.05
Folates (μg/1000 kcal)	149.9	164.6	178.7	186.4	201.0	205.9		

Data are presented as median (5th–95th percentile). Data are presented aas units/1000 kcal for all micronutrients, except for vitamin B_6 (units/g of proteins)

% E percentage of energy, *SFA* saturated fatty acids, *MUFA* mono-unsaturated fatty acids, *PUFA* polyunsaturated fatty acids, *RE* retinol equivalents

†Log-transformed data

*Differences between each level of physical fitness and sex

°Differences within in each sex group

[a]Significant differences between low physical fitness groups

[b]Significant differences between medium physical fitness groups

[c]Significant differences between high physical fitness groups

[d]Significant differences in males group. Comparisons between PF groups and sexes with nutrient intake were analyzed by One Way Anova or Kruskal–Wallis test, according to the normality of the variables

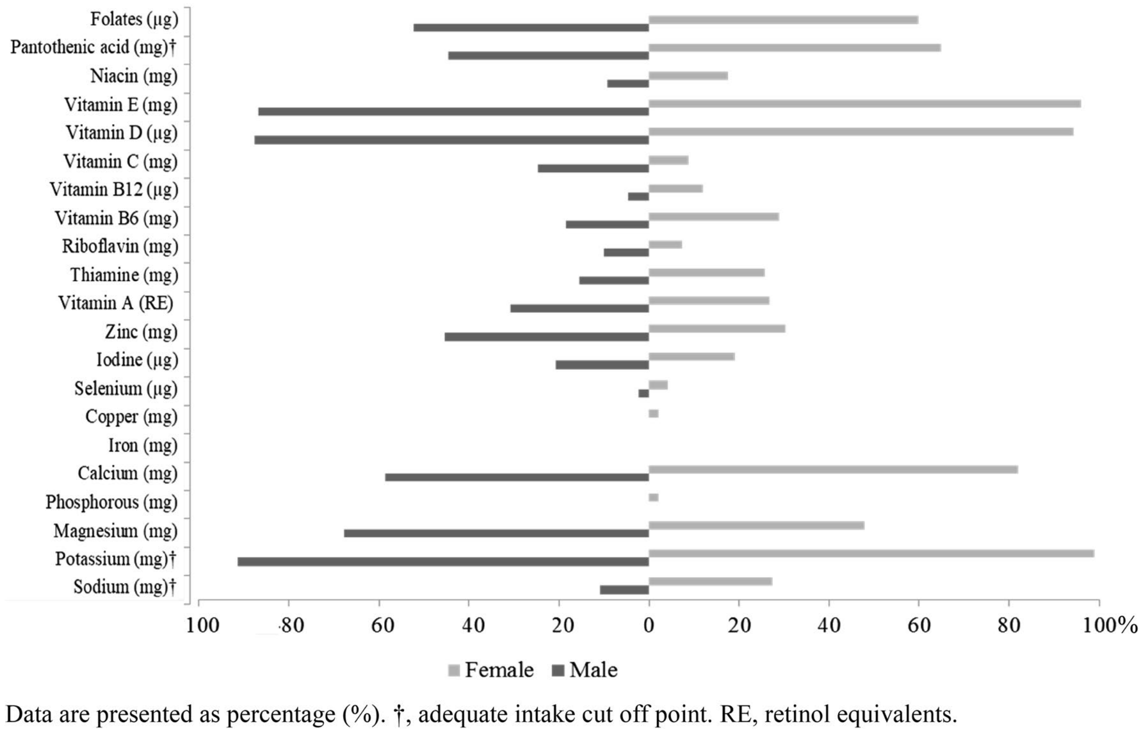

Fig. 1 Percentage of micronutrients below estimate average requirements or adequate intake according to sex. Data are presented as percentage (%)

group. Females in the low PF group showed lower inadequate intake for calcium, iodine, and phosphorous compared to the high PF group.

In addition, percentage of participants by number of micronutrients intake below EAR or AI is shown in Table 3. A total of 13.0 and 8.3% of the participants presented intakes below EAR or AI for 6 and 11 micronutrients, respectively. Only two participants were above EAR or AI for all micronutrients.

Multilevel regression analysis of the PF groups with the usual intake of macro- and micronutrients and energy expenditure is presented in Table 4. A positive association was observed for vegetable proteins and high PF group (all $p < 0.05$). Regarding minerals, there were significant and positive associations between subjects in the high PF group and phosphorous and selenium (all $p < 0.05$). Furthermore, positive and significant associations were found between high PF group and vitamin B_6, vitamin C, vitamin D, niacin, and folates. However, subjects in the high PF group presented significant negative associations with thiamine and riboflavin (both $p < 0.05$).

Discussion

The results from this cross-sectional study showed a remarkable inadequate intake of potassium, vitamin D, and vitamin E. It is important to highlight that participants in the low PF group showed inadequate intake only for potassium, vitamin D, and vitamin E; nevertheless, males in the high PF group presented higher inadequate intake compared to low PF group of calcium. Furthermore, higher macronutrient intakes were observed in the high PF group compared to the other PF groups in both sexes, but participants in the high PF group had also higher EE. Although the relationship between dietary patterns and PA has been studied [2, 35], there is a paucity of data analysing the association of diet and PF in older adults, concretely in Spain.

In our study, males in the high PF group and in the low PF group showed similar EI (2111 vs. 2135 kcal/day, respectively). In females, the median EI was 1576 kcal/day in the

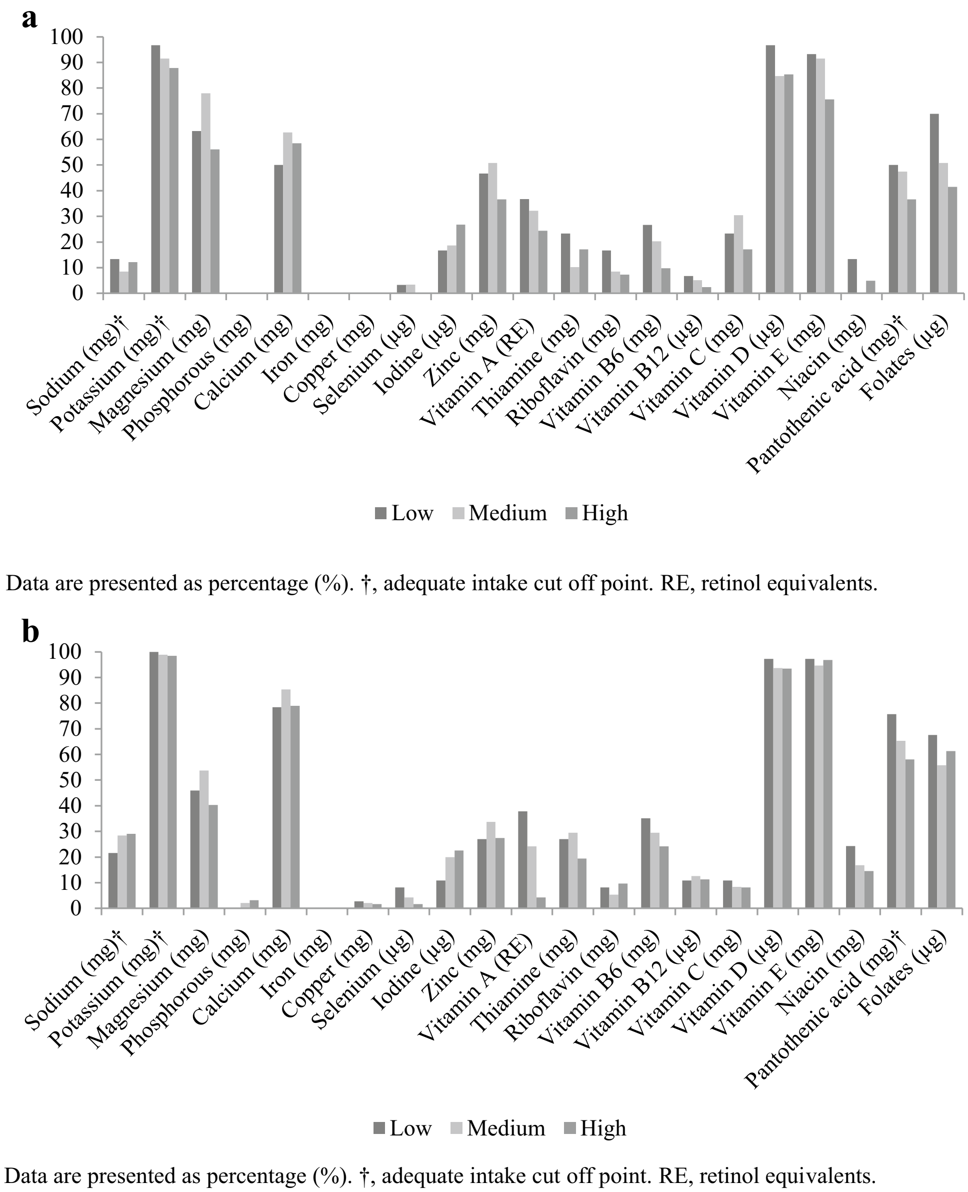

Fig. 2 **a** Percentage of micronutrients below estimate average requirements or adequate intake according to physical fitness groups in males. **b**. Percentage of micronutrients below estimate average requirements or adequate intake according to physical fitness groups in females. Data are presented as percentage (%)

low PF group and 1625 kcal/day in the high PF group. EE was higher in the high PF group compared to low PF group in males (4901 METs min/week vs. 3485 METs min/week, $p < 0.05$); however, females in the low PF group presented higher EE than females in the high PF group (4142 METs min/week vs. 3966 METs min/week, respectively). Camoes et al. found that active males had significantly higher mean intake of energy than sedentary males (2570.7 vs. 2336.9 kcal/day), respectively [2]. Cao et al. observed in a cross-sectional study that compliance with dietary recommendations for macronutrients is significantly associated with higher cardiovascular fitness levels in Japanese male adults [36]. Our findings showed that males in the high PF group presented higher relative intake (% of energy) of proteins, fat, mono-unsaturated fatty acids and polyunsaturated fatty acids than in the low PF group, while females in the high PF group did not displayed higher relative intake of all macronutrients than in the low PF group. On the other hand, Brodney et al. observed that subjects in the high fit category consumed a lower percentage of energy from total fat, saturated fat, mono-unsaturated fat, and cholesterol and a higher percentage of energy from carbohydrate, and fiber in both sexes [35]. Lee et al. observed that no significant differences between groups were obtained for energy and fat intake between PA groups split by METs hours/week [37]. Camoes et al. observed a significant lower level of protein consumption (16.9 vs. 17.6% of energy) when comparing active and sedentary males [2]. In an earlier study, Rolland et al. observed that active healthy older adult women did not have a better nutritional profile than their inactive peers [9].

Table 3 Percentage of participants by number of micronutrient (vitamins and minerals) below EAR or AI

Number of micronutrient <EAR or AI	Percentage of sample population
0	0.6
1	1.5
2	1.9
3	5.2
4	11.7
5	9.9
6	13.0
7	12.7
8	11.4
9	8.3
10	6.8
11	8.3
12	1.9
13	3.7
14	1.9
15	0.3
16	0.3
17	0.3
18	0
19	0
20	0
21	0

Data are presented as frequency (number of subjects) and percentage

EAR estimated average recommendations, *AI* adequate intake

The EAR cut-off point method has been accepted as the best method to estimate nutrient intake inadequacy [34]. For those nutrients for which an EAR could not be stated, AI was used. In our study, more than 85% of males and females showed inadequate intake of potassium, vitamin D, and vitamin E. Román-Viñas et al. observed that vitamin C, folic acid, calcium, selenium, and iodine showed a higher prevalence of inadequate intakes considering EAR cut-off in European older adults [38]. Cao et al. observed 25–35% of inadequate intakes for magnesium, calcium and zinc, and also a relatively high low intake for vitamin A (61.1%) and thiamine (81.0%) in the low PF group [36]. Fisberg et al. observed high prevalence of inadequate intake (> 50%) of vitamins D, E, $B_{6,}$ and A, calcium, and magnesium pyridoxine [39]. It is important to highlight that in our study participants in the low PF group showed inadequate intake for potassium, vitamin D, and vitamin E. Nevertheless, more males in the high PF group presented inadequate intake of calcium compared to the low PF group. In addition, around 8% of the participants presented inadequate intakes for 11 micronutrients in our study. Likewise, participants from the high PF groups showed greater mean intake of potassium, magnesium, phosphorous, selenium and vitamins (B_3, B_5, B_6, B_9, C, D, and E) and retinol (only females) than low PF groups. Cao et al. showed that males who had a poor overall micronutrient intake status have a significantly higher risk of being unfit compared to males with a good micronutrient intake status [36]. In this sense, Brodney et al. observed that subjects in the high fit category had higher intakes of calcium, folate, vitamin B_6, vitamin B_{12} (only female), vitamin A, vitamin C, and vitamin E than the low and moderate fit in both sexes [35]. Because micronutrients are essential for humans' health [40], it is important to take into account the inadequate intake of vitamins and minerals to prevent deficiencies and considering the influence in the different biological pathways of micronutrients over PF. Long periods of inadequate intake of one or some micronutrients may display clinical manifestations of deficiency [39].

The findings of our study also showed that a positive and significant association was observed for vegetable protein intake and the high PF group. There were significant and positive associations between high PF group with phosphorous and selenium. Furthermore, positive and significant associations were found between high PF group and vitamin B_6, vitamin C, vitamin D, niacin, and folates. However, high PF group presented negative associations with thiamine and riboflavin. Camoes et al. observed a significant and positive association between PA and intake of vitamin C. In addition, leisure-time activity was positively associated with intakes of vitamin E, folate, calcium, and magnesium in females [2]. Other authors who studied the association between PF and diet quality observed that diet-quality score was positively associated with cardiorespiratory fitness [41] and more physical exercise was associated with improvement in the Mediterranean Diet Adherence [42].

As shown above, data on micro- and macronutrient intake, obtained by different authors, were discrepant. This could be mainly due to different approaches when assessing the quantity of a particular micro and macronutrient in a particular kind of food, or differences in the dietary questionnaires used. A considerable heterogeneity exists in dietary patterns and nutritional status in older adults [19]. In addition, dietary intake tends to decline over time [43]. It should be highlighted that there are some nutrients with an adequate intake (iron, copper). Overall, diet and PF modifications seem to be strong promoters of healthy aging [19].

Limitations and strength

This study has several limitations. First, one limitation of the study was the use of 24 h dietary recalls. The 24 h dietary recall method is one of the most widely used tools and validated methods [44]; however, the 24 h dietary recall method does not allow quantifying proportions of non-consumers for particular items, especially for infrequently

Table 4 Association between the physical fitness clusters and usual intake of macro- and micronutrients and energy expenditure

	Physical fitness groups			
	β	95% CI		*p* value
Energy expenditure (METs min/week)	0.000031	− 0.000004	0.000066	0.083
Energy (kcal)	0.000143	− 0.000105	0.000392	0.257
Water (mL)	− 0.000025	− 0.000160	0.000110	0.718
Macronutrients				
Proteins (g)[a]	0.298841	− 0.426493	1.024176	0.058
Vegetable protein (g)[a]	0.627534	0.021524	1.233545	**0.042**
Animal protein (g)[a]	0.167257	− 0.0303647	0.638160	0.485
Fiber (g)[a]	0.536173	− 0.006146	1.078492	0.053
Carbohydrates				
Total carbohydrates (g)[a]	0.078682	− 0.662097	0.819461	0.835
Mono and disaccharides (g)[a]	0.516633	− 0.033544	1.066810	0.066
Polysaccharides (g)[a]	− 0.026549	− 0.453841	0.400742	0.903
Fats				
Fat (g)	0.003046	− 0.001553	0.007644	0.193
SFA (g)[a]	0.018181	− 0.546022	0.582384	0.949
MUFA (g)	0.005593	− 0.003551	0.014737	0.230
PUFA (g)[a]	0.479058	− 0.062035	1.020152	0.082
Cholesterol (mg)[a]	0.205699	− 0.150604	0.562002	0.257
Alcohol (g)[a]	0.060786	− 0.177779	0.299351	0.616
Minerals				
Sodium (mg)[a]	− 0.334313	− 0.878169	0.209543	0.227
Potassium (mg)[a]	1.037949	0.310788	1.765110	**0.005**
Magnesium (mg)[a]	0.419496	− 0.201633	1.040625	0.185
Phosphorous (mg)[a]	0.803891	0.037866	1.569916	**0.040**
Calcium (mg)[a]	0.156393	− 0.412778	0.725565	0.589
Iron (mg)[a]	− 0.129037	− 0.451745	0.193670	0.432
Copper (mg)[a]	0.040334	− 0.446175	0.526843	0.871
Selenium (μg)[a]	0.832301	0.316702	1.347900	**0.002**
Iodine (μg)[a]	− 0.078807	− 0.616956	0.459341	0.773
Zinc (mg)[a]	0.189234	− 0.313060	0.691527	0.459
Vitamins				
Retinol (μg)[a]	− 0.087567	− 0.337782	0.162648	0.492
Carotens (μg)[a]	0.255292	0.028529	0.482054	**0.027**
Vitamin A (ER)[a]	0.124278	− 0.176778	0.425335	0.417
Thiamine (mg)[a]	− 0.221961	− 0.435925	− 0.007996	**0.042**
Riboflavin (mg)[a]	− 0.217434	− 0.422951	− 0.011917	**0.038**
Vitamin B_6 (mg)[a]	0.442502	0.042278	0.842726	**0.030**
Vitamin B_{12} (μg)[a]	− 0.054712	− 0.309036	0.199611	0.672
Vitamin C (mg)[a]	0.344050	0.015266	0.672834	**0.040**
Vitamin D (μg)[a]	0.244887	0.076441	0.413332	**0.005**
Vitamin E (mg)[a]	0.349512	− 0.177103	0.876126	0.193
Niacin (mg)[a]	0.621547	0.140954	1.102140	**0.011**
Pantothenic acid (mg)[a]	0.465826	− 0.187222	1.118875	0.161
Folates (μg)[a]	0.621584	0.147431	1.095736	**0.010**

Bold values indicate significant differences ($p < 0.05$)

Multilevel regression analyses with inclusion of age and sex as covariables. Bonferroni correction resulted in level of significance < 0.0013

SFA saturated fatty acids, *MUFA* mono-unsaturated fatty acids, *PUFA* polyunsaturated fatty acids, *RE* retinol equivalents

[a]Variable was log-transformed to obtain a normal distribution

consumed foods. Second, this study has a cross-sectional design, thus preventing the determination of cause–effect relationships. Moreover, only intake but no status data were measured. Nevertheless, according to this study, it seems reasonable to think that macro- and micronutrient status can be associated to PF, whereas the mechanism by which PF could determine higher or lower intake status is not so clear.

Despite the aforementioned, this study also has several strengths which included the use of objective, precise and validated methods for assessing PF. Furthermore, the use of clustering of activities produces an alternative approach to summarizing PF participation. Another strength is the sampling procedure and the strict standardization of the field work among the cities involved in the study, thus avoiding to a great extent the kind of confounding bias.

Conclusions

Participants in the high PF group show a better micronutrient intake profile than the other PF groups; nonetheless, there are a considerable number of participants who present inadequate intake of micronutrients below the EAR. The relationship between PF and nutrient present different patterns depending on the PF level showing higher relative protein and fat intake males in the high PF group than males in the low PF group. Nonetheless, females in the high PF group display lower relative macronutrient intake than the other PF groups. There is a requirement to develop combined nutritional and fitness programs among older adults and to consider supplementation for micronutrients at risk.

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Author contributions RAU, GP, and MGG analyzed the data, and drafted and wrote the manuscript. RLS, MB, EA, and JAT contributed to the analysis. MGG and JAT designed the study and wrote the protocol. All read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors do not declare any conflict of interest.

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