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Original article

Leisure-time physical activity at moderate and high intensity is associated with parameters of body composition, muscle strength and sarcopenia in aged adults with obesity and metabolic syndrome from the PREDIMED-Plus study

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SUMMARY

Aims: We aimed to examine the associations of leisure-time physical activity (PA) and sedentary behavior (SB) with the prevalence of sarcopenia, body composition and muscle strength among older adults having overweight/obesity and metabolic syndrome, from the PREDIMED-Plus trial.
Methods: Cross-sectional baseline analysis including 1539 men and women (65 ± 5 y). Sarcopenia was defined as low muscle mass (according to FNIH cut-offs) plus low muscle strength (lowest sex-specific tertile for 30-s chair-stand test). We applied multivariable-adjusted Cox regression with robust variance and constant time (given the cross-sectional design) for the associations of self-reported leisure-time PA and SB with sarcopenia; and multivariable-linear regression for the associations with dual-energy X-ray absorptiometry (DXA)-derived bone mass, fat mass, lean mass and lower-limb muscle strength.
Results: Inverse associations were observed between sarcopenia and each hourly increment in total [prevalence ratio 0.81 (95% confidence interval, 0.70, 0.93)], moderate [0.80 (0.66, 0.97)], vigorous [0.51 (0.32, 0.84)], and moderate-vigorous PA (MVPA) [0.74 (0.62, 0.89)]. Incrementing 1-h/day total-PA and MVPA was inversely associated with body-mass-index, waist circumference (WC), fat mass, and positively associated with bone mass and lower-limb muscle strength (all $P < .05$). One h/day increase in total SB, screen-based SB and TV-viewing was positively associated with body-mass-index, WC and fat mass. Light-PA was not significantly associated with any outcome.

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Conclusions: Total-PA and PA at moderate and high intensities may protect against the prevalence of sarcopenia, have a beneficial role on body composition and prevent loss of muscle strength. SB, particularly TV-viewing, may have detrimental effects on body composition in older adults at high cardiovascular risk.

1. Introduction

Aging-related changes in body composition are characterized by increased fat mass, loss of skeletal muscle mass and declined muscle strength [1]. According to the European Working Group on Sarcopenia in Older People (EWGSOP) [2], the coexistence of low muscle mass and low muscle function (strength or performance) is referred as sarcopenia Although the criteria for sarcopenia remains under debate, a more recent consortium of the FNIH [3] has provided much insight in this topic, and has noted that among different methods measuring body composition and muscle strength and performance, dual-energy X-ray absorptiometry (DXA), handgrip or gait speed are the ones most suitable for measuring muscle mass, muscle strength and performance, respectively. Importantly, despite the differences in definition criteria and methodology used, the presence of sarcopenia and/or these aforementioned changes in body composition have been associated with increased risk of falls and fractures, and loss of independence [4].

Physical activity (PA) and sedentary behavior (SB) are major lifestyle factors known to impact metabolic processes involving body composition. The ability of PA to promote/preserve muscle mass and muscle strength while reducing fat mass has been reported cross-sectionally [5–8] and prospectively [1,9,10] across different populations of senior adults. Leisure-time PA consist of any recreational physical activity, also including structured physical exercise, and household activities during spare time which are not associated with regular occupation or transportation activities [11]. Consistent beneficial associations with the aforementioned outcomes have been shown with total leisure-time PA as well as with PA at moderate-vigorous intensities (MVPA), i.e. activities ≥4 METs [5–8,10], whereas evidence concerning light-PA (<4 METs) is currently unclear [6,7].

SB refers to activities with prolonged periods of sitting or lying and activities with ≤1.5 METs of energy expenditure [12]. In the light of the recent Systems of Sedentary behaviors consensus [13], priorities to foster SB research have been focused on home setting factors, such as TV and computer use, among a number of other identified system-based determinants. In fact, also recent studies have emphasized the importance of context-specific SB, including screen-based SB (i.e. TV-viewing and PC use) for body composition and muscular health [14,15]. While some authors have observed detrimental associations with total SB and TV-viewing concerning sarcopenia [15], lean mass [8,15] and muscle strength [6,14], others found no associations [7].

Despite these evidences and to the best of our knowledge, such associations of leisure-time PA and SB with body composition, functional performance and sarcopenia have never been explored in older adults with overweight/obesity and metabolic syndrome—a population at higher risk of cardiovascular morbimortality, typically sedentary and physically inactive. This population is likely to benefit from investigations addressing the relationships between PA, SB, body composition, muscle health and sarcopenia. Therefore, we aimed at examining the independent associations with leisure-time PA levels and SB subtypes concerning body composition, muscle strength, and sarcopenia prevalence among community-dwelling older adults with overweight/obesity and metabolic syndrome participating in the PREDIMED-Plus trial.

2. Methods

2.1. Study design and population

This is a cross-sectional analysis of baseline data from the PREDIMED-Plus trial, a 6-year lifestyle intervention for the prevention of cardiovascular morbimortality on 6874 older adults. Detailed study information is available at http://predimedplus.com/. The trial was registered at the International Standard Randomized Controlled Trial (ISRCT: http://www.isrctn.com/ISRCTN89898870) with registration number 89898870 and date of 24 July 2014.

Eligible participants were community-dwelling adults (aged 55–75 in men; 60–75 in women) with body-mass-index (BMI) ≥27 and <40 kg/m^2, and meeting ≥3 metabolic syndrome individual components [16]. Briefly, exclusion criteria included previous history of cardiovascular disease, any chronic medical condition (cancer, inflammatory bowel disease, cirrhosis, etc), having acute infectious processes, any condition compromising physical activity, psychiatric disorders, alcohol and drug abuse, institutionalization, use of specific medications (cytotoxic agents, immune-suppressors, etc), important weight loss in short time and any food allergy to Mediterranean diet foods. Following the PREDIMED-Plus design and protocol, from the 6874 total participants enrolled in the PREDIMED-Plus trial, only a subsample underwent total dual-energy X-ray absorptiometry (DXA) scans (n = 1564) in 7 out of the 23 PREDIMED-Plus recruiting centers. From those 1564 participants with DXA measurements, we excluded participants with incomplete DXA data (n = 25), resulting in an effective sample size of 1539 for the present study.

Study protocol and procedures were approved following the ethical standards of the Declaration of Helsinki by the Institutional Review Boards of the 7 participating centers. All participants provided written informed consent.

2.2. Physical activity and sedentary behavior

Leisure-time PA was evaluated with the validated REGICOR questionnaire [17] which included questions to collect information about the type of activity, frequency (number of days) and duration (min/day) performed during a representative month. Time spent in moderate, vigorous and moderate-vigorous PA (min/day) was obtained as described previously [18]. Time spent in total-PA was computed as the sum of the time from all PA intensities.

SB were assessed on weekdays and weekends using the validated Nurses' Health Study questionnaire for Sedentary Behaviors [19], which evaluates the time spent over the last year in different sedentary domains according to 12 time-categories. Time spent in total SB and TV-watching (min/day) was further computed as described previously [18]. Screen-based SB was additionally estimated as the sum of the time spent watching TV and using PC.

2.3. Anthropometry and body composition

Body weight and height were determined and BMI was calculated from weight (kg) divided by height (meters) squared. Waist circumference (WC, cm) was measured with anthropometric tape following the PREDIMED-Plus operations protocol.

Dual-energy X-ray absorptiometry scans (DXA, Lunar iDXA and DXA Lunar Prodigy Primo, GE Healthcare) were performed by trained radiology technicians to ascertain body composition. In this analysis, total bone mass (g), fat mass (kg) and lean mass (kg) were evaluated. Appendicular skeletal muscle mass (ASM, kg) was determined as the sum of the muscle mass from the four limbs, divided by 1000. Skeletal muscle mass index (SMI) was calculated with the equation [ASM (kg)/BMI] [3].

2.4. Muscle strength

Lower-limb muscle strength was determined using the validated 30-s chair-stand test [20], based on the times participants stand-and-sit in a chair within 30 s, following an established protocol. The 30-s chair-stand test has been also considered a test for measuring performance [21] and its validity has been previously evaluated [20,21], showing good reliability across trials (90.2%) in community-dwelling Spanish seniors.

2.5. Sarcopenia

Sarcopenia was defined following the EWGSOP criteria [2] as low muscle mass simultaneously with low muscle strength. Low muscle mass was defined applying the recommended cut-offs according to the FNIH criteria [3]; while low muscle strength was considered as the lowest sex-specific tertile for the number of stands in the 30-s chair-stand test.

2.6. Other covariates

Participants self-reported data on age, sex, education, marital and employment status, smoking, diabetes and osteoporosis medication. Diabetes was defined as previous diagnosis of diabetes or glycated hemoglobin (HbA1c) ≥6.5%, use of antidiabetic medication or having fasting glucose >126 mg/dl in the screening visit plus fasting glucose >126 mg/dl at baseline. Dietary factors known to relate with body composition and sarcopenia [22–24] were determined using a semi-quantitative food frequency questionnaire [25]: daily intake of calcium (mg/day), vitamin D (μg/day), total protein (g/day), monounsaturated and polyunsaturated fats (mg/day), and consumption of olive oil (g/day) and alcohol (g/day). Nutrients intake was determined using Spanish food composition tables [26,27].

Age was classified into ≤65 and >65 y. Smoking was categorized as current, former and never smokers. Dichotomous variables were generated for current diabetes and osteoporosis medication. Quintiles of daily intake of nutrients and consumption of olive oil and alcohol were created.

2.7. Statistical analyses

Population baseline characteristics were presented as means ± standard deviations (SD) for quantitative variables, and percentages and numbers for categorical variables. One-way ANOVA and Chi-square tests were used for differences in baseline characteristics across sex categories and quartiles of time in total-PA. Linear regression models were employed to examine the associations with 95% confidence intervals (CI) of 1-h/day increment in time spent in PA levels and SB subtypes with BMI, WC, body composition and lower-limb muscle strength. Cox regression models with constant time of follow-up ($t = 1$) and robust variance, given the cross-sectional design, were fitted to assess the prevalence ratios (PR) for sarcopenia for 1-h/day increment in time spent in PA levels and SB subtypes. According to methodologists, this method is better suited than logistic regression for cross-sectional studies with frequent prevalent outcomes (>10% prevalence), such as the present study, since it avoids the overestimation of the prevalence ratios derived from the odds ratios when logistic regression is applied in analysis with frequent outcomes [28,29].

Three multivariable-adjusted models were examined. For all study outcomes, model 1 was adjusted for sex and age. Model 2 was further adjusted for diabetes, smoking and alcohol intake. Besides these covariates, and to avoid over-adjustment, model 2 in each outcome was specifically adjusted for factors that may affect these associations. Thus, model 2 for bone mass was further adjusted for osteoporosis medication, vitamin D, calcium, protein, mono and polyunsaturated fats and olive oil, and fat mass and lean mass. Model 2 for body fat mass and lower-limb muscle strength were further adjusted for lean mass. Model 2 for lean mass, ASM and SMI were further adjusted for fat mass. Model 2 for sarcopenia was further adjusted for BMI and consumption of protein. To precisely assess independent associations of a single activity, model 3 was fitted including variables in model 2 plus time spent on the rest of the activities. For instance, when evaluating the associations with total PA, model 3 included variables in model 2 plus time spent in total SB, and *vice versa*. All analyses were stratified by recruiting center.

Effect modification by sex, age (≤65 and >65 y) and diabetes on the associations between time spent in PA levels and SB regarding the study outcomes was evaluated with the likelihood ratio test between the fully adjusted model and the same model adding the interaction product-term. Because no effect modification was observed (P >.05) all analyses were pooled for the entire study population.

To test the robustness of our findings, the following sensitivity analyses were conducted: a) excluding participants engaging in zero minutes of light PA; b) excluding participants engaging in zero minutes of MVPA; and c) evaluating the associations with sarcopenia, body composition compartments and lower-limb muscle strength by fitting quartiles of time spent in total PA, light PA and MVPA.

All statistical analyses were conducted using the software Stata14 (StataCorp) and P-values <.05 were considered significant.

3. Results

On average, study participants were aged 65.3 ± 5.0 y, 52% were men and 14.2% were classified as sarcopenic. Participants spent 74 ± 60 min/day engaging in total leisure-time PA, of which 46 ± 54 min resulted from MVPA, contributing 62% of their total PA time. Mean time of total SB was 5.8 ± 1.8 h/day, of which 3.1 ± 1.6 h/day was for TV-viewing. A complete description of the general characteristics for the entire study population by sex categories is displayed in Table 1 and across quartiles of total PA in Supplementary Table 1.

In multivariable-regression analyses (Table 2 and Supplementary Table 2), 1-h/day increment in total-PA and MVPA was inversely associated with BMI, WC and fat mass, and positively associated with bone mass and lower-limb muscle strength. Regarding moderate-PA and vigorous-PA, similar results for these study outcomes were found (all P < .01), except for associations

Table 1
Baseline characteristics of study population in the whole study population and according to sex categories.

General characteristics	Whole population N = 1539	Men n = 803	Women n = 736	*P*-value
Age, y	65.3 ± 5.0	63.9 ± 5.4	66.7 ± 4.1	<.001
BMI, kg/m^2	32.5 ± 3.3	32.3 ± 3.2	32.8 ± 3.5	.005
Waist circumference, cm	107.3 ± 9.3	110.8 ± 8.6	103.5 ± 8.6	<.001
Obesity, n (%)	1147 (74)	586 (73)	561 (76)	.144
Central obesity, n (%)	1440 (94)	714 (89)	726 (98)	<.001
Type 2 diabetes, n (%)	467 (30)	246 (31)	221 (30)	.796
Hypertriglyceridemia, n (%)	643 (42)	359 (45)	284 (39)	.015
High blood pressure, n (%)	1448 (94)	769 (96)	679 (92)	.004
Hyperglycemia, n (%)	1037 (67)	543 (67)	494 (67)	.834
Low HDL-c, n (%)	764 (49)	372 (46)	392 (53)	.007
Depression, n (%)	396 (26)	125 (16)	271 (37)	<.001
Sarcopenia, n (%)	219 (14.2)	131 (16)	88 (12)	.014
Body composition compartments				
Total bone mass, kg	2.6 ± 0.5	3.0 ± 0.4	2.1 ± 3.1	<.001
Total fat mass, kg	34.1 ± 7.3	3.2 ± 7.2	3.6 ± 6.9	<.001
Total lean mass, kg	48.3 ± 9.8	56.2 ± 6.3	39.8 ± 4.3	<.001
ASM, kg	21.5 ± 4.9	25.4 ± 3.3	17.3 ± 2.2	<.001
SMI	8.0 ± 1.2	8.8 ± 0.9	7.1 ± 0.7	<.001
30-s chair-stand test, n	13.1 ± 5.3	15.0 ± 5.3	13.4 ± 5.2	<.001
Smoking habit, n (%)				
Never	655 (43)	169 (21)	486 (66)	<.001
Former	692 (45)	495 (62)	197 (27)	
Current	192 (12)	139 (17)	53 (7)	
Education status, n (%)				
Primary education	745 (48)	310 (39)	435 (59)	<.001
Secondary education	466 (31)	271 (34)	195 (27)	
Academic/graduate	328 (21)	222 (27)	106 (14)	
Marital status, n (%)				
Single/divorced	210 (14)	97 (12)	113 (15)	<.001
Married	1170 (76)	679 (85)	491 (67)	
Widower	159 (10)	27 (3)	132 (18)	
Employment status, n (%)				
Working	324 (21)	234 (29)	90 (12)	<.001
Non-working	305 (20)	67 (8)	238 (32)	
Retired	910 (59)	502 (63)	408 (56)	
Osteoporosis medication, n (%)	9 (0.6)	1 (0.1)	8 (1.1)	.013
Dietary intake				
Alcohol, g/day	11.7 ± 15.6	18.1 ± 17.5	4.8 ± 8.2	<.001
Olive oil, g/day	43.2 ± 15.9	43.3 ± 15.6	43.1 ± 16.2	.831
Total protein, g/day	97.2 ± 22.6	98.3 ± 22.7	96.1 ± 22.5	.053
Monounsaturated fats, mg/day	56.1 ± 15.8	58.1 ± 15.2	53.9 ± 16.1	<.001
Polyunsaturated fats, mg/day	17.0 ± 6.7	17.1 ± 6.7	16.2 ± 6.6	<.001
Calcium, mg/day	1019.3 ± 353.5	1005.7 ± 350.9	1034.1 ± 356.0	.116
Vitamin D, μg/day	5.9 ± 3.2	5.8 ± 3.2	5.9 ± 3.3	.314
Total leisure-time physical activity, min/day	73.6 ± 60.3	84.7 ± 68.7	61.5 ± 46.6	<.001
Light PA, min/day	27.9 ± 33.4	29.5 ± 35.6	26.2 ± 30.8	.054
Moderate PA, min/day	32.7 ± 47.3	40.3 ± 55.3	24.5 ± 34.9	<.001
Vigorous PA, min/day	12.9 ± 22.2	14.9 ± 25.4	10.8 ± 17.8	.003
MVPA, min/day	45.7 ± 53.7	55.3 ± 61.9	35.3 ± 40.7	<.001
Sedentary time, h/day	5.8 ± 1.8	6.0 ± 1.9	5.6 ± 1.8	.004
Screen-based sedentary time,[a] h/day	4.1 ± 1.9	4.2 ± 2.0	3.9 ± 1.9	.032
TV-viewing time, h/day	3.1 ± 1.6	2.8 ± 1.5	3.3 ± 1.7	<.001

Data presented as mean ± SD unless otherwise indicated. BMI, body-mass-index; HDL-c, high-density lipoprotein-cholesterol; PA, physical activity; MVPA, moderate-vigorous physical activity; SB, sedentary behavior; ASM, appendicular skeletal muscle; SMI, skeletal muscle index.
Pearson's chi-square test for categorical and one-factor ANOVA for continuous variables.
P-value for differences between sex categories.
[a] Screen-based sedentary time defined as the sum of time spent watching TV plus using computer.

between vigorous-PA and bone mass. Only 1-h/day increase in vigorous-PA, but not other PA levels, was significantly associated with greater lean mass and ASM.

Associations of time spent across SB subtypes with body composition and lower-limb muscle strength are summarized in Table 3 and fully displayed in Supplementary Table 3. One h/day increase in SB subtypes was positively associated with BMI, WC and total fat mass (all $P < .01$). Only TV-watching was significantly associated with lower ASM. Otherwise, associations with other body composition compartments and lower-limb muscle strength remained non-significant.

No significant associations were found with light-PA and SMI (Tables 2 and 3).

Figure 1 highlights the multivariable-adjusted PR of sarcopenia concerning 1-h/day increment in PA levels and SB subtypes. Each daily hour increase of total, moderate, vigorous and MVPA was significantly associated with 19%–49% lower prevalence of sarcopenia—with vigorous-PA exhibiting the lowest prevalence [0.51 (0.32, 0.84)]. No significant associations with any SB subtype were observed.

Sensitivity analyses were consistent with the general results. When excluding participants engaging in zero minutes of light-PA

Table 2
Multivariable-adjusted β-coefficients (95% CI) for body composition and lower-limb muscle strength[a] per 60 min/day increase PA time.

	n	Total PA	*P*-value	Light PA	*P*-value	Moderate PA	*P*-value	Vigorous PA	*P*-value	MVPA	*P*-value
BMI, kg/m^2	1539	−0.47 (−0.64, −0.30)	<.001	−0.20 (−0.49, 0.09)	.188	−0.50 (−0.71, −0.29)	<.001	−0.83 (−1.27, −0.38)	<.001	−0.57 (−0.75, −0.38)	<.001
WC, cm	1539	−1.23 (−1.66, −0.80)	<.001	−0.47 (−1.24, 0.29)	.233	−1.28 (−1.83, −0.73)	<.001	−2.43 (−3.58, −1.27)	<.001	−1.50 (−1.99, −1.02)	<.001
Bone mass, g	1539	23.1 (8.1, 38.1)	.003	20.7 (−5.6, 47.1)	.124	24.6 (5.47, 43.6)	.012	21.5 (−18.5, 61.5)	.292	23.9 (6.98, 40.9)	.006
Fat mass, kg	1539	−0.90 (−1.22, −0.58)	<.001	−0.18 (−0.74, 0.39)	.548	−0.98 (−1.39, −0.57)	<.001	−1.88 (−2.73, −1.02)	<.001	−1.16 (−1.52, −0.79)	<.001
Lean mass, kg	1539	0.02 (−0.23, 0.27)	.865	−0.39 (−0.83, 0.04)	.079	0.05 (−0.26, 0.37)	.739	0.66 (0.02, 1.33)	.048	0.17 (−0.11, 0.45)	.228
ASM, kg	1537	0.03 (−0.10, 0.16)	.646	−0.19 (−0.42, 0.04)	.108	0.04 (−0.13, 0.21)	.634	0.41 (0.05, 0.76)	.024	0.11 (−0.04, 0.26)	.141
SMI, kg/m^2	1537	0.01 (−0.03, 0.05)	.773	−0.04 (−0.11, 0.03)	.272	0.01 (−0.04, 0.06)	.766	0.08 (−0.02, 0.19)	.127	0.02 (−0.02, 0.07)	.330
Lower-limb muscle strength, No. counts[a]	1539	0.56 (0.30, 0.82)	<.001	−0.04 (−0.51, 0.43)	.868	0.51 (0.17, 0.83)	.003	1.87 (1.17, 2.57)	<.001	0.77 (0.48, 1.07)	<.001

BMI, body-mass-index; CI, confidence interval; PA, physical activity; MVPA, moderate-vigorous PA; ASM, appendicular skeletal muscle; SMI, skeletal muscle index; WC, waist circumference. Adjusted for sex, age, study center, smoking, diabetes and quintiles of alcohol intake and time spend in other self-reported physical activities or sedentary behavior, as appropriate, for all study outcomes. For bone mass, the model was additionally adjusted for fat mass and lean mass, osteoporosis medication, and quintiles of intake of olive oil, protein, calcium, vitamin D and mono and polyunsaturated fats. For lean mass, ASM and SMI it was additionally adjusted for fat mass. For fat mass and 30-s chair-stand test, it was additionally adjusted for lean mass.

[a] Lower-limb muscle strength determined with 30-s chair-stand test based on the number of counts participants stand-and-sit within 30 s.

(n = 1091), all associations remained significant. Only associations between vigorous-PA and lean mass [β 0.68 kg/m^2 (−0.24, 1.59)] and ASM [β 0.39 kg/m^2 (−0.09, 0.88)] lost significance in model 3. Results excluding participants engaging in zero minutes of MVPA (n = 1306) were comparable to those from the general analyses. The exceptions where the associations for vigorous-PA with lean mass [β 0.56 kg/m^2 (−0.13, 1.24); *P* = .110] and ASM [β 0.36 kg/m^2 (−0.01, 0.72); *P* = .052] Associations with sarcopenia, body composition compartments and lower-limb muscle strength according to quartiles of time spent in total PA, light PA and MVPA were consistent with the general results (Supplementary Table 4).

4. Discussion

To the best of our knowledge, this is the first study conducted in Mediterranean old adults at high cardiovascular risk that has examined the associations between PA levels and SB subtypes with the prevalence of sarcopenia, body composition and muscle strength. Main findings revealed that each daily hour increase in total, moderate, vigorous and MVPA was significantly associated with 19%, 20%, 49% and 26%, respectively, lower prevalence of sarcopenia. Further inspection of body composition and muscle strength showed that increasing 1-h/day total-PA or MVPA was inversely associated with BMI, WC and fat mass, but positively associated with bone mass and lower-limb muscle strength.

Our findings regarding PA and sarcopenia are according to those from previous cross-sectional [5,6] and prospective studies [10,30] among old individuals. Cross-sectional analyses in 2264 Korean older adults revealed that individuals engaging moderate- and high-PA *vs.* light-PA, were 38% and 74%, respectively, less likely to present sarcopenia [5]. Similar findings have been reported in European adults cross-sectionally [6] as well as prospectively, like in the Reykjavik Study [10], where greater MVPA was associated with 36% protection against sarcopenia incidence after 5 years.

We did not observe significant associations between sarcopenia risk and SB subtypes, which partially supports some of the findings from previous studies in European and Australian healthy senior adults using accelerometer-derived and self-reported SB subtypes [6,15]. No significant higher risk for sarcopenia for each 30 min increase in accelerometer-derived sedentary time was reported among 1286 old British men [6]. Contrary, a 33% increased risk of sarcopenia for 1-h/day increased in self-reported total sitting time, but not with TV-watching was observed in healthy aged adults [15]. Of note, in the present study as well as in the aforementioned studies, these associations were independent from MVPA. These discrepancies may be due to differences in methodology used to quantify SB and to define sarcopenia or in the study population characteristics. In view of these conflicting results, more prospective studies and clinical trials evaluating the effect of time spent in SB on sarcopenia are warranted to clarify these results across different aged populations.

The ability of moderate- and vigorous-PA to improve age-related changes in body composition, have been cross-sectionally [7,8] and prospectively reported [1,9,10], among different populations of lean [6,9] and overweight old adults [8,10] using both self-reported and accelerometry-derived PA data. For instance, in a cohort of Australian women, total PA and PA at moderate and high intensities were beneficially associated with total lean mass, ASM and muscle strength [7]. In addition, a dose−response relationship between PA intensity and lean mass and lower-limb muscle strength have been reported among Tasmanian old adults [8]. Other Europeans and American cohorts have prospectively confirmed these associations regarding muscle mass and muscle strength with physical performance [9,10]. We also found support for this, yet only vigorous-PA was significantly associated with lean mass and ASM. In line with

Table 3
Multivariable-adjusted β-coefficients (95% CI) for body composition and lower-limb muscle strength[a] per 60 min/day increase SB time.

	n	Total SB	*P*-value	Screen-based SB	*P*-value	TV-viewing	*P*-value
BMI, kg/m^2	1539	0.25 (0.16, 0.35)	<.001	0.12 (0.04, 0.21)	.004	0.20 (0.10, 0.31)	<.001
WC, cm	1539	0.60 (0.35, 0.83)	<.001	0.41 (0.19, 0.63)	<.001	0.43 (0.17, 0.70)	.001
Bone mass, g	1539	0.02 (−8.21, 8.24)	.993	−2.88 (−10.5, 4.72)	.460	−4.64 (−13.7, 4.45)	.315
Fat mass, kg	1539	0.47 (0.30, 0.65)	<.001	0.33 (0.17, 0.49)	<.001	0.26 (0.07, 0.46)	.008
Lean mass, kg	1539	−0.09 (−0.15, 0.13)	.900	−0.06 (−0.19, 0.06)	0.325	−0.13 (−0.28, 0.02)	.088
ASM, kg	1537	−0.01 (−0.08, 0.05)	.825	−0.01 (−0.08, 0.05)	0.683	−0.09 (−0.17, −0.01)	.026
SMI, kg/m^2	1537	0.00 (−0.02, 0.02)	.866	−0.01 (−0.03, 0.01)	.408	0.00 (−0.02, 0.03)	.882
Lower-limb muscle strength, No. counts[a]	1539	−0.13 (−0.27, 0.02)	.083	0.01 (−0.12, 0.15)	.877	−0.14 (−0.30, 0.03)	.098

BMI, body-mass-index; CI, confidence interval; ASM, appendicular skeletal muscle; SMI, skeletal muscle index; WC, waist circumference; SB, sedentary behavior. Adjusted for sex, age, study center, smoking, diabetes and quintiles of alcohol intake and time spend in other self-reported physical activities or sedentary behavior, as appropriate, for all study outcomes. For bone mass, the model was additionally adjusted for fat mass and lean mass, osteoporosis medication, and quintiles of intake of olive oil, protein, calcium, vitamin D and mono and polyunsaturated fats. For lean mass, ASM and SMI it was additionally adjusted for fat mass. For fat mass and 30-s chair-stand test, it was additionally adjusted for lean mass.

[a] Lower-limb muscle strength determined with 30-second chair-stand test based on the number of counts participants stand-and-sit within 30s.

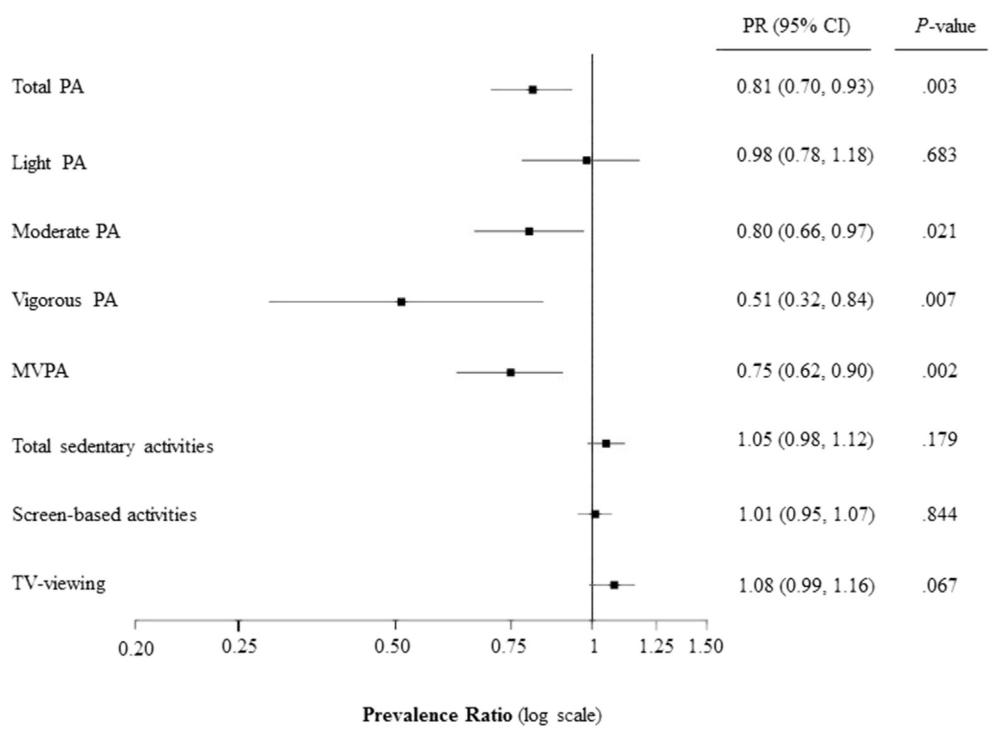

Fig. 1. Multivariable-adjusted PR (95%CI) for sarcopenia per 60 min/day increase time in PA and SB (n = 1537). CI, confidence interval; PA, physical activity; MVPA, moderate-vigorous PA; PR, prevalence ratios. The model corresponds to the fully adjusted model, including sex, age, study center, smoking, diabetes, body-mass-index, quintiles of alcohol and protein intake and the corresponding time spent in other self-reported physical activities or sedentary behavior, as appropriate.

this, moderate-intensity exercise interventions have improved muscle strength/functionality, but not the reversion of age-related muscle loss [31,32] – suggesting that higher PA intensities may be necessary to achieve benefits in muscle mass among seniors [33,34].

In agreement with our findings regarding bone mass, prospective analyses in American [35] and European cohorts [32,36], and meta-analyses of randomized control trials [37] have also reported positive associations between PA and bone mineral density in seniors.

Light-PA was not significantly associated with any study outcome, which agrees with most of previous studies finding marginal [6] or no significant associations [36,38,39]. It is therefore plausible that an intensity threshold exists for PA to benefit body composition, muscle strength and eventually, reducing sarcopenia risk.

Similar to our study, a number of previous investigations across different cohorts have reported positive associations between SB subtypes and BMI, WC and fat mass [15,40], and inverse associations with lean mass or ASM [8,15], using self-reported [15] and accelerometer-derived data [8]. Although in the English Longitudinal Study of Ageing of 6228 old adults, Hamer et al. reported significantly lower grip strength in those participants watching TV ≥6 h/day had, compared to those watching TV <2 h/day [14], the associations with lower-limb performance/strength in this and other studies were consistently non-significant [7,8,15], regardless of the methodology used. This suggests that detrimental associations between SB and muscle strength may be site-specific, with particular vulnerability at the upper extremities.

A number of limitations in this study should be acknowledged. First, the cross-sectional design does not allow to make any causal inference of the observed associations, and therefore reverse causation cannot be excluded. Second, despite using validated questionnaires [17,19], the use of self-reported PA and SB data may be more subject to bias in comparison to more objective methods or due to the fact that the questionnaires used in our study captured different timeframes of habitual engagement of PA and SB. Third, the sole use of 30-s chair-stand test to evaluate lower-limb muscle strength represents a major limitation for the definition of sarcopenia in our study, since this test was not included as recommended methodology to assess low muscle strength by the last FNIH report 2014 [3]. However, this test has previously shown to reflect also the individual's physical performance, as it involves muscle mobilization requiring strength and further physical demands, such as balance. Along with this, the 30-s chair-stand test showed good validity/reliability in previous studies [20,21]. Fourth, directly-measured data on muscle performance was not determined in our study, thus we could not assess the prevalence of severe sarcopenia. Five, given the observational nature of the study, residual confounding may remain despite adjusting for several potential confounders; and finally, our findings are limited to Mediterranean old adults with overweight/obesity and metabolic syndrome, thus they cannot be extrapolated to other populations. Our study also has strengths: the large sample size of men and women, the control for potential confounders and the inclusion of sensitivity analyses; the use of low muscle mass and low strength to define sarcopenia as they are well recognized components for sarcopenia diagnosis according to EWGSOP [2], and finally, we included DXA-derived body composition, which is preferred over other methods due to its reliability.

5. Conclusion

The findings from the current study support the idea that the increment in daily time spent in total-PA and PA at moderate and high intensities may protect against sarcopenia, improve body composition and prevent muscle strength decline in Mediterranean older adults with overweight/obesity and metabolic syndrome. Contrary, increasing SB, particularly TV-watching, may exert detrimental effects on body composition. This illustrates the importance of addressing sarcopenia prevention with focus on MVPA in older adults at high cardiovascular risk.

Statement of authorship

FA, AB, DC, MD-R, VM-S, RE, MF, EG-G, JW, JL, JL-M, AM, MAM-G, JMO, XP, DR, IA, JK, PM-M, LS-M, CV, FT, JT, JV, JV-L and J.S.S collected all the data from the PREDIMED-PLUS trial. NR-E and J.S.S designed the study; NR-E, AD-L and J.S.S performed the analysis; NR.-E and J.S.S wrote the first draft of the manuscript and all authors contributed to the editing of the manuscript. All authors approved the final version of the manuscript.

Conflict of Interest

The authors have declared that no competing interest exists.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.clnu.2018.05.023.

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