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ORIGINAL ARTICLE

Dynapenic abdominal obesity and the incidence of falls in older women: a prospective study

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Abstract

Background Dynapenic abdominal obesity (D/AO) has been associated with negative outcomes in older people, including trait of falls.

Aims To assess the association between D/AO and the incidence of falls over 18 months in older community-dwelling women.

Methods A total of 201 older women (67.97 ± 6.02 years; 27.70 kg/m^2) underwent waist circumference measurement, and had handgrip strength assessed using a hydraulic dynamometer. Dynapenia was classified using the lower tertile of handgrip strength, while abdominal obesity was considered as a waist circumference > 88 cm. D/AO was the combination of both aforementioned criteria. Volunteers were classified into four groups: normal, abdominal obesity, dynapenic, and D/AO. Participants were then tracked by phone calls for ascertainment of falls during a follow-up period of 18 months. Chi-square and multivariable Cox proportional regressions were conducted.

Results The overall incidence of falls over the follow-up was 27.5%; and for normal, dynapenic, abdominal obesity, and D/AO were 14.7%, 17.2%, 27.5%, and 40.4% ($X^2 = 8.341$; $P = 0.039$), respectively. D/AO was associated with a higher risk of falls (hazard ratio: 3.595 [95% CI: 1.317–9.815], even after adjustments for age, body mass index, physical activity level, regular use of medications, peripheral sensation, chronic diseases, and history of lower-limbs pain.

Conclusions D/AO is more closely related to falls than either dynapenia or abdominal obesity alone, and is independently associated with an increased incidence of falls in older women. These results provide support for the concept that the combined evaluation of muscle strength and central obesity may be clinically relevant in this population.

Keywords Obesity · Sarcopenia · Accidental falls · Muscle strength · Hand strength

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Introduction

Falls events comprise a geriatric syndrome [1] that has been considered as the leading cause of hospitalization and accidental deaths among older people. Thus, falls are deemed as a major public health issue that imposes an important economic burden on health care costs [2, 3]. The etiology of falling is multifactorial, encompassing reduced balance, muscle weakness, and previous falls events [4, 5]. Salient features of the aging human phenotype include loss of both skeletal muscle mass and strength, and an increase in body fat mass [6]. When concomitant, these alterations have been referred to as sarcopenic obesity [7], an emerging cause of disability and frailty in older people [8, 9]. However, although the loss of muscle mass is associated with the decline in strength during aging, the decline in strength is more rapid than the loss in muscle mass [10, 11]. Of note, it has been postulated that women are more susceptible to falls-related outcomes [12–14], since they present lower muscle strength over the lifespan when compared to men [6, 13]. In fact, a growing body of evidence has emerged demonstrating that strength has a better prognostic value than muscle mass to predict health-related outcomes among older people [15–17]. In this regard, the term dynapenia has been used to particularly define the age-related loss of strength [17–19]. Dynapenia has been extensively investigated in recent years and its evaluation has been especially emphasized as an important tool in the management of older people at imminent risk of falls [17–19].

Another condition that merits attention in the field of falling among elderly people is body adiposity excess [20]. Obesity is consistently associated with a broad spectrum of clinical outcomes and is widely recognized as a relevant public health problem, including in aged adults [20–22]. Moreover, abdominal obesity has been highlighted as a worse condition when compared to whole body obesity, given the fact that excessive intra-abdominal fat accumulation has a better prognostic value to predict outcomes, including falls-related phenotypes [20, 21, 23]. Waist circumference has been considered as an important clinical criterion for identifying abdominal obesity, and provide valuable information regarding health-damaging events as falls [17–19, 24].

The coexistence of dynapenia and abdominal obesity has been recently introduced as dynapenic–abdominal obesity (D/AO) [17–19]. A report on the ELSA cohort recognized D/AO as a better criterion to predict functional decline in older adults when compared to abdominal obesity or strength evaluated separately [19]. In a cross-sectional study, Pereira et al. [17] demonstrated that D/AO was associated with dynamic balance ($P < 0.001$) and increased probability of falls in older women. These authors [17] also reported that D/AO condition is associated with higher fear of falling, when compared to the normal and dynapenic groups. Of relevant note, subjects with concurrent abdominal obesity and low muscle strength were at greater risk for worse health-related outcomes than individuals with solely dynapenia or central fat distribution [18, 25]. Recently, Máximo et al. [18] investigated the relationship D/AO and previous falls events in 1046 community-dwelling older adults. The authors reported that both central obesity and dynapenia, separately, were associated with a previous single event of falling; however, these authors underscored stronger association for their coexistence (i.e., D/AO). Nevertheless, no previous studies had explored the temporal relationship between D/AO and falls among aged people. Therefore, the aim of the present study was to assess the association between D/AO and the incidence of falls over 18-month follow-up period in older community-dwelling women.

Methods

Participants

Five hundred older women were recruited through flyers, phone calls, e-marketing, and visits to centers of leisure and physical activity for elderly people. A total of 335 individuals agreed to participate in this project developed at the University between 2014 and 2016, and completed a questionnaire to verify their eligibility. Eligible inclusion criteria were as follows: to voluntarily participate in the present study, to walk without assistance, and to be aged between 60 and 85 years old. Twenty-eight volunteers did not meet the inclusion criteria and as a result 307 participants were eligible for the study. Each participant answered the International Physical Activity Questionnaire (IPAQ) short version [26], and a face-to-face questionnaire addressing medical history, medication use, and co-morbidities. Also, reduced peripheral sensation was recorded if the volunteer was unable to feel two out of three trials using a single Semmes–Weinstein-type pressure monofilament at the lateral malleolus of the ankle. Exclusion criteria were as follows: musculoskeletal or neurological disorders (such as fibromyalgia syndrome, Parkinson disease, chronic myalgia, previous stroke, multiple sclerosis, severe rheumatoid arthritis, or uncontrolled epilepsy), lower limbs prosthesis, heart failure, postoperative condition, uncontrolled hypertension, and dominant lower limb pain that hinders strength ratings. The mini-mental state examination (MMSE) and the Katz index were also used to verify that none of the volunteers exhibited cognitive impairments 24 or functional dependency, 25 respectively. After exclusion criteria were applied, a total of 217 elderly women (68.03 ± 6.21 years) underwent the baseline assessments.

All volunteers were informed about the study procedures and voluntarily signed an informed consent form. All experiments on human subjects were conducted in accordance with the Declaration of Helsinki and the study protocol was previously approved by the Institutional Review Board (1.2223.636).

Anthropometrics and body composition assessments

All subjects were weighed on a digital scale to the nearest 50 g (Lider®, P150 M, São Paulo, Brazil) and height was measured with a wall stadiometer (Sanny®, São Paulo, Brazil). Body mass index was calculated by dividing body weight by the square of the height (kg/m^2) of the volunteers. WC was assessed at the level of umbilicus using an anthropometric tape (Sanny®, São Paulo, Brazil). All measurements were carried out by the same experienced researcher.

Body composition measurements were conducted at the University's Image Laboratory using Dual Energy X-ray Absorptiometry (General Electric-GE model 8548 BX1L, 2005, DPX lunar type, Encore 2010 software, Rommelsdorf, Germany) according to procedures specified elsewhere [27]. In brief, subjects laid face up on the DXA scanner table with body carefully centered. The system provides fat mass and fat-free mass (FFM) data. Whole body relative FFM was also calculated dividing FFM (kg) by height squared (m^2). The equipment was daily calibrated according to the manufacturer's specifications, and all evaluations were performed by a trained technician. A single individual was scanned for six consecutive days in the equipment and observed coefficients of variation were 0.9% for FFM and 1.9% for fat mass.

Handgrip strength

Handgrip strength (HGS) was measured with a Jamar® hydraulic hand dynamometer (Sammons Preston, Bolingbrook, USA) according to the American Society of Hand Therapists recommendations [28]. Measurements were performed with participants in sitting position, elbow joint at 90°, forearm in neutral position, and wrist between 0° and 30° of extension. The average of three trials in the dominant hand was used for subsequent analyses.

Classification of groups

Tertiles of handgrip strength were calculated and individuals in the lowest tertile (≤ 20.67 kg) were considered as dynapenic [17]. The cut-off value for WC specified by the World Health Organization (i.e., 88 cm for women) was used to classify individuals as abdominal obese [29]. D/AO was determined when the subject met both dynapenia and obesity criteria. Therefore, the study sample was categorized into four groups as follows: normal, dynapenia, abdominal obesity, and D/AO.

Ascertainment of falls

The primary outcome was the incidence of falls; however, other falls-related variables such as number of falls, and falls-induced hospitalization were also investigated as secondary outcomes. Outcomes were recorded through semi-structured telephone calls, in which survey was conducted at the end of the 18-month follow-up. This approach has been previously applied in a variety of prospective epidemiological studies, and has been shown to be reliable and sensitive to detect outcomes, including falls [30–34]. During the semi-structured interviews, participants were asked about any falls incident, defined as an unexpected event in which participants come to rest on the ground, floor, or other lower level. For each fall event reported, participants described the situation in maximum details. Specific information of interest included date of fall, participant description of how the fall occurred, consequences and injuries, and hospital admission. Also, falls events were categorized into intrinsic or extrinsic [35]. The first category included factors related to functional and health status (e.g., functional impairment, balance disorders, passed out, blacked out, or lost consciousness); while the second category included adverse drug reactions, prostheses, use of restraints and environmental influences (e.g., poor lighting or lack of bathroom safety equipment) [36]. At least ten contact attempts were made to each volunteer with missed calls. Finally, all telephone calls were made by the same person, who had experience with telephone interviews.

Statistical analysis

Descriptive characteristics are presented as means and standard deviations, unless otherwise noted. The Kolmogorov–Smirnov test was used to verify data distribution nature. X^2 tests were performed to compare categorical variables, while continuous variables were tested for significance by performing a one-way analysis of variance (ANOVA), followed by a Gabriel multiple comparisons post hoc analysis. Cox proportional hazard models were used to assess the association between each group and falls incidence. Models were subsequently adjusted for potential confounding factors, such as age, physical activity, regular use of four or more medications, reduced peripheral sensation, presence of two or more chronic diseases, and history of any lower-limbs pain [35, 37–39]. Cumulative incidence of falls over the follow-up period was analyzed using Kaplan–Meier curves and compared using log-rank tests. Results were considered significant at $P < 0.05$ and all statistical analyses were performed using SPSS 20.0.

Results

Descriptive characteristics of the participants stratified by groups are presented in Table 1. Proportions for normal, abdominal obesity, dynapenic, and D/AO were 16.9%, 45.3%, 14.4%, and 23.4%, respectively. As expected, both D/AO and obese volunteers showed higher waist circumference and BMI when compared to normal and dynapenia conditions ($P < 0.05$). Subjects classified as abdominal obese presented higher FFM and relative FFM when compared to the remaining groups ($P < 0.01$), while dynapenic individuals also showed lower both absolute and relative FFM when compared to normal ($P < 0.05$). Subjects classified as D/AO

Table 1 Descriptive characteristics stratified by groups (normal, abdominal obesity, dynapenic, and D/AO)

Variable	Normal	Dynapenic	Abdominal obesity	D/AO	*P*
n	34	29	91	47	
Age (years)	66.32 ± 5.82	68.52 ± 6.36	66.74 ± 5.02	71.34 ± 6.60*,†	< 0.01
Height (m)	1.58 ± 0.07	1.53 ± 0.06*	1.58 ± 0.06‡	1.54 ± 0.05†	< 0.01
Body mass (kg)	59.17 ± 5.36	53.94 ± 6.75	72.99 ± 10.19*,‡	71.33 ± 10.98*,‡	< 0.01
Waist circumference (cm)	82.31 ± 4.93	80.95 ± 5.12	98.91 ± 7.68*,‡	100.30 ± 9.08*,‡	< 0.01
Body mass index (kg/m^2)	23.81 ± 1.77	23.12 ± 2.51	29.30 ± 3.80*,‡	29.95 ± 4.12*,‡	< 0.01
Body fat percentage (%)	38.60 ± 3.92	39.45 ± 6.42	46.13 ± 4.67*,‡	47.36 ± 4.61*,‡	< 0.01
FFM (kg)	34.26 ± 3.42	30.38 ± 2.71*	37.16 ± 4.12*,‡	35.49 ± 3.83†,‡	< 0.01
Relative FFM (kg/m^2)	13.77 ± 1.01	13.08 ± 1.32*	14.91 ± 1.30*,‡	14.90 ± 1.36*,‡	< 0.01
Handgrip strength (kgf)	25.95 ± 3.91	17.39 ± 2.95*	25.78 ± 3.68‡	17.37 ± 3.22*,†	< 0.01

Data expressed as mean and standard deviation

D/AO dynapenic abdominal obesity, *FFM* fat-free mass

*Significant difference in relation to the normal group ($P < 0.05$)

‡Significant difference in relation to the dynapenic group ($P < 0.05$)

†Significant difference in relation to the abdominal obesity group ($P < 0.05$)

were significantly older than both normal and abdominal obese ($P < 0.05$). Dynapenia and D/AO groups presented lower handgrip strength when compared to the other groups (normal and abdominal obesity), but with no significant differences between each other (Table 1). Physical activity level comparisons ($X^2 = 22.211$; $P = 0.008$) according to each classification were: normal (inactive: 2.9%; insufficiently active: 50%; active: 44.1%; and very active: 2.9%), abdominal obesity (inactive: 26.4%; insufficiently active: 53.8%; and active: 19.8%), dynapenic (inactive: 10.3%; insufficiently active: 51.7%; and active: 37.9%), and D/AO (inactive: 28.3%; insufficiently active: 52.2%; and active: 19.6%). Additionally, 30.4% subjects from the entire sample reported history of any lower-limbs pain, while 22.8% and 29.8% of fallers demanded any kind of post-fall hospitalization and presented any injury due to the fall, respectively.

Proportion of fallers over the 18-month follow-up period according to groups and its comparisons are presented in Fig. 1. The overall incidence of falls was 27.5% over the 18-month period. It was observed that the proportion of fallers subjects was similar between normal (14.7%) and dynapenic (17.2%) groups; however, the proportion of fallers increased progressively according to the presence of abdominal obesity and D/AO, being 27.5% and 40.4%, respectively ($X^2 = 8.341$; $P = 0.039$; Fig. 1). Among fallers subjects ($n = 56$), 64.3% presented a single fall event, 23.2% two events, and 12.5% more than two falls events. Also, 83.9% of falls events were classified as extrinsic. No difference among groups regarding the proportion of multiple fallers over follow-up period were found ($X^2 = 10.024$; $P > 0.614$), with normal (20%), abdominal obesity (38%), dynapenic (40%), and D/AO (42.1%); likewise, no differences among groups were observed regarding injuries due to the fall ($X^2 = 3.010$; $P = 0.390$), severity of injury ($X^2 = 5.404$; $P = 0.493$), or post-fall hospitalization ($X^2 = 1.673$; $P = 0.643$). Of note, the sample loss during follow-up was 7.4%.

Figure 2 shows a Kaplan–Meier curve for occurrence of falls over the 18-month follow-up period, according to groups. Subsequent analyses revealed that the presence of D/AO at baseline was related to a significantly higher incidence of falls over time (log rank *P* value = 0.018; Fig. 2).

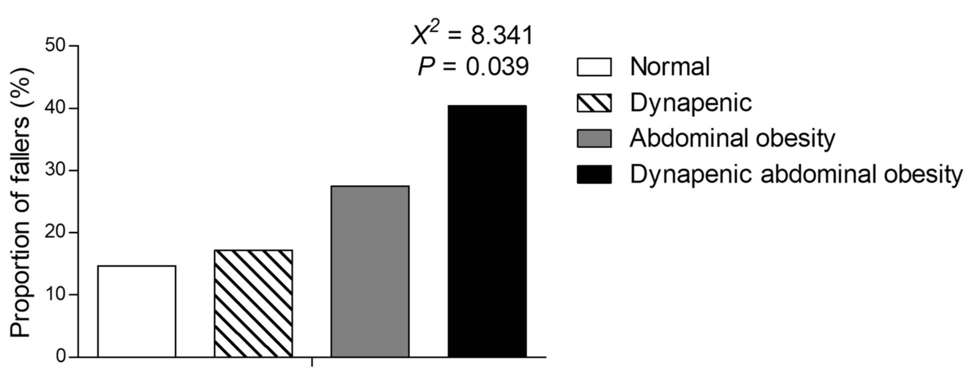
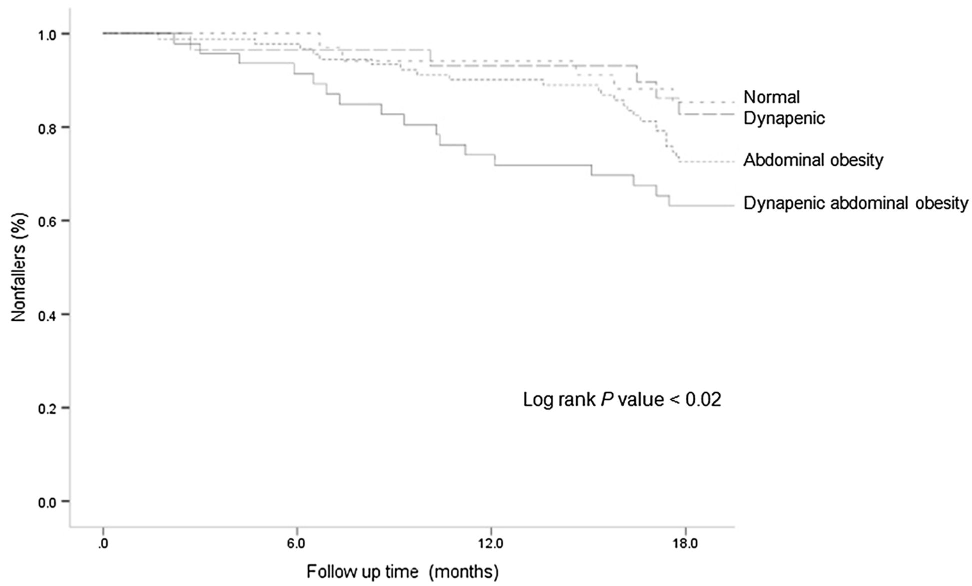


Fig. 1 Proportion of fallers over 18-month follow-up period stratified by groups and its comparisons

Fig. 2 Kaplan–Meier curve showing cumulative rate of falls over the 18-month follow-up period according to each classification. Log rank adjusted for age, physical activity level, regular use of four or more medications, reduced peripheral sensation, two or more chronic diseases, and history of any lower-limbs pain



Cox proportional hazard models revealed that only D/AO ($P = 0.009$) presented significantly higher risk of falls when compared to normal subjects. Unadjusted hazard ratios for falls were 1.345 (95% CI: 0.382–4.733; $P = 0.645$), 2.275 (95% CI: 0.850–6.092; $P = 0.102$), and 3.749 (95% CI: 1.381–10.173; $P = 0.009$), for dynapenic, abdominal obesity, and D/AO, respectively. After adjustments for age, physical activity level, regular use of four or more medications, reduced peripheral sensation, presence of two or more chronic diseases, and history of lower-limbs pain, D/AO remained significantly associated with an increased incidence of falls (hazard ratio: 3.595 [95% CI: 1.317–9.815]; $P < 0.05$; Fig. 3).

Discussion

The purpose of the present study was to assess the association between the coexistence of low muscle strength and increased central adiposity, a condition referred to as D/AO, and the incidence of falls over an 18-month follow-up period in older community-dwelling women. Consistent with recent reports [17–19], the observed results support the concept that D/AO has negative clinical implications in this population. In particular, the salient findings of the present study showed that D/AO is independently associated with a greater incidence of falls when compared to normal, and to dynapenia or to obesity alone. The results presented here suggest that the combined information of muscle strength and central obesity measurements may have important clinical applications in geriatric evaluation, including when gauging individuals at greater risk of falls.

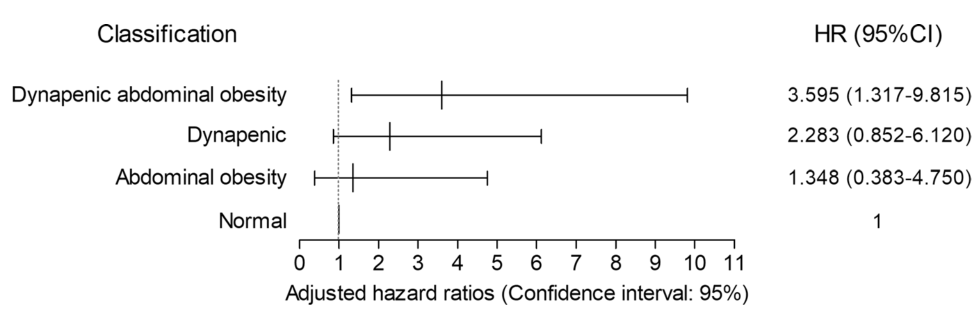


Fig. 3 Hazard ratios (confidence interval: 95%) for the occurrence of falls over 18-month follow-up period according to study groups. *CI* confidence interval. Adjusted for age, physical activity level, regular use of four or more medications, reduced peripheral sensation, two or more chronic diseases, and history of any lower-limbs pain

Essential features that might mediate the relationship between aging and falls are muscle strength and body composition, for instance, low handgrip strength [17] and body fat excess [20, 40]. Our findings strengthen the relationship between muscle strength and the incidence of falls in older community-dwelling women. Even though it was not in the scope of the present study to elucidate potential mechanisms, the relationship between strength and falls can be explained, at least partially, by an impaired ability of the muscular system to respond with adequate strength and speed when facing postural balance perturbations [41]. It has been demonstrated that older individuals exhibit limited ability of the muscles to react to changing balance threats when compared to young adults, and that unstable older adults present this impaired to a greater extent than yonger [42]. Nevertheless, our findings showed that central obesity may be even more strongly associated with the incidence of falls in older community-dwelling women.

Previous studies support the hypothesis that obesity is associated with an increased risk of falls in the elderly [20]. It has been postulated that the association between obesity and falls may be attributed to a greater proportion of body mass further away from the ankle axis of rotation, requiring a larger ankle torque to counter the greater gravitational torque [43]. Specifically regarding abdominal obese subjects, it is expected that the aforementioned mechanism may be exacerbated, since fat accumulation in the central region of the body would provide higher anterior displacement of the body mass, requiring even more torque from the ankle muscles [20, 43]. A recent report demonstrated that among a variety of adiposity indexes, waist circumference was the best measure in the prediction of postural instability, fear of falling, and risk of falls among older people [20]. In this sense, both muscle strength and central obesity interact in the maintenance of postural control, suggesting the importance of combining these assessments for the screening of falls in elderly.

The present study demonstrated that subjects classified as D/AO had significantly higher incidence of falls during an 18-month follow-up period, corroborating a recent cross-sectional observation of a significant association between D/AO and falls-related phenotypes [17–19]. Moreover, a report on the ELSA cohort recognized D/AO as a better criterion to predict functional decline in older adults when compared to abdominal obesity and strength evaluated separately [19]. Máximo et al. [18] investigated the relationship between D/AO and previous falls events in 1046 community-dwelling older adults. These authors reported that all aforementioned conditions were associated with a previous single event of falling, moreover, the study highlighted a stronger association for D/AO when compared to central obesity or dynapenia, separately (relative risk ratio: 2.06 [95% CI: 1.04–4.10]).

More recently, Pereira et al. [17] demonstrated that D/AO was negatively associated with dynamic balance ($P < 0.001$) and increased probability of falls ($X^2 = 32.392$; $P < 0.001$) in older women. The authors have also reported that D/AO condition is associated with higher fear of falling (30.08 ± 7.81 AU), evaluated by Falls Efficacy Scale (FES-I: a psycho geriatric tool to quantify fear of falling), when compared to the normal and dynapenic subjects (23.22 ± 5.50 AU and 26.61 ± 8.33 AU, respectively, $P < 0.05$). Of relevant note, subjects with concurrent abdominal obesity and low muscle strength were at greater risk for worse health-related outcomes than individuals with solely dynapenia or central fat distribution [18, 25]. To the best of our knowledge, this is the first study that investigated the temporal relationship between D/AO and falls among aged people, and provides further support to the concept that D/AO imposes a greater risk for falls than central obesity or dynapenia.

The present study has several strengths and limitations. Practical applications of the assessments (i.e., handgrip strength and waist circumference) for the screening of falls and novelty of the results are strengths. The follow-up procedure was conducted by phone calls which might raise the question as to whether the records were accurate. As an attempt to address this issue, telephone calls were conducted by an investigator experienced in telephone interviews, and the observed incidence is in consonance with the literature [44, 45]. The study sample was composed by functionally independent community-dwelling women, and thus, the results application to more frail sections of the older population needs to be addressed in future studies. Finally, future prospective and experimental studies are needed to further investigate the temporal relationship between D/AO and falls-related complications in aged people.

Conclusion

Based on the observed results, it is concluded that D/AO is more closely related to falls than either dynapenia or abdominal obesity alone, and is independently associated with an increased incidence of falls in older women. These results provide support for the concept that the combined information of muscle strength and central obesity measurements may be clinically relevant, including in the assessment of falls risks.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Statement of human and animal rights All experiments on human subjects were conducted in accordance with the Declaration of Helsinki and the study protocol was previously approved by the Institutional Review Board (1.2223.636).

Informed consent All volunteers were informed about the study procedures and voluntarily signed an informed consent form.

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