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Original article

Associations of dynapenic abdominal obesity with metabolic health, falls, and physical performance in community-dwelling postmenopausal women: A cross-sectional study

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Abstract

Background: Dynapenia, defined as reduced muscle strength, is an independent predictor of adverse health outcomes and disability. The coexistence of dynapenia with abdominal obesity may exacerbate adverse metabolic and functional outcomes.

Objective: The aim of this cross-sectional study was to investigate the combined impact of dynapenia and abdominal obesity on metabolic risk factors, falls, and physical performance in community-dwelling postmenopausal women.

Methods: Dynapenia was defined as grip strength <18 kg and abdominal obesity was defined as waist circumference ≥ 85 cm. Participants were classified into four groups—normal, abdominal obesity, dynapenic, and dynapenic abdominal obesity. Metabolic parameters, clinical characteristics, grip strength, and physical performance were assessed. Logistic regression analyses were performed to examine associations between phenotypes and adverse outcomes.

Results: In adjusted models, dynapenic abdominal obesity was significantly associated with hyperglycemia (adjusted odds ratio [aOR] = 2.83; 95% CI = 1.25–6.42), hypertriglyceridemia (aOR = 2.41; 95% CI = 1.05–5.56), history of falls (aOR = 3.95; 95% CI = 1.61–9.67), reduced mobility (aOR = 3.27; 95% CI = 1.45–7.37), and an increased risk of fall (aOR = 2.89; 95% CI = 1.23–6.81). The dynapenic group was also identified as a risk factor for hyperglycemia (aOR = 2.15; 95% CI = 1.02–4.53), hypertriglyceridemia (aOR = 2.36; 95% CI = 1.05–5.32), history of falls (aOR = 2.97; 95% CI = 1.26–7.02), and reduced mobility (aOR = 2.32; 95% CI = 1.06–5.04).

Conclusion: Dynapenic abdominal obesity was associated with greater metabolic and functional impairment than dynapenia alone. Therefore, early screening and risk stratification can help to identify dynapenic abdominal obesity and facilitate targeted interventions in postmenopausal women.

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Keywords: Abdominal obesity, dynapenia, fall, handgrip strength, postmenopausal women.

Dynapenia, defined as the loss of muscle strength or the presence of muscle weakness, is a central component of sarcopenia.[1] Sarcopenia is an age-related musculoskeletal disorder characterized by progressive and generalized decline in muscle mass and function. In the revised criteria established by the Asian Working Group for Sarcopenia, low muscle mass is no longer considered the primary determinant for diagnosis. Greater emphasis is instead placed on reduced muscle strength, particularly handgrip strength, because it is more effective for the early identification of adverse outcomes.[2]

The prevalence of dynapenia is currently higher in developing countries than in developed countries.[3] Increasing age is associated with a slow decline in the function of the neuromuscular system, an accumulation of body fat, and a decrease in muscle mass. This decline in muscle mass, known to begin in the fourth decade of life and escalate after the sixth decade, is significantly worsened by a lack of exercise.[4] The concurrent presence of dynapenia and

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central obesity has recently been described as dynapenic abdominal obesity, a phenotype associated with potentially compounded health risks. A previous study suggested that women may be more susceptible to dynapenia because they typically have lower muscle strength than men. [5] The prevalence of dynapenia among postmenopausal women is estimated to range from 16.0% to 26.0%, [6] representing a substantial public health concern. In this population, muscle weakness is strongly linked to adverse outcomes, including sarcopenia, frailty, falls, hip fractures, and a poorer quality of life. [7-9]

The profound hormonal and metabolic changes associated with menopause alter both body composition and physical function. Estrogen deficiency contributes to increased visceral fat deposition, particularly in the abdominal region, as well as a decline in muscle strength. [10] Abdominal obesity is a significant indicator of metabolic disorders, including metabolic syndrome, [11] cardiovascular diseases, diabetes, and hypertension. [12] The combination of hormonal, metabolic, and musculoskeletal changes has increased the prevalence of dynapenic abdominal obesity in postmenopausal women. The co-occurrence of dynapenia and abdominal obesity has been associated with an unfavorable metabolic profile, [13, 14] impaired mobility, reduced walking endurance, [15] and an increased risk of falls in older adults. [16]

Despite growing interest in the dynapenic abdominal obesity phenotype, studies have mostly investigated either metabolic health or physical performance in isolation. Few have simultaneously explored the associations of this phenotype with metabolic risk factors and objectively measured physical performance within the same cohort of postmenopausal women. The identification of these associations is essential for recognizing high-risk subgroups and targeting prevention strategies. Therefore, aim of the present study was to investigate the associations between four phenotypes—normal, abdominal obesity, dynapenic, and dynapenic abdominal obesity—and metabolic risk factors, clinical status, and physical performance in community-dwelling postmenopausal women.

Materials and methods

Study design and participants

This cross-sectional study included 326 postmenopausal women, 50 years of age and older. Participants were recruited from local communities using a community-based, non-probability sampling approach, including recruitment through community centers and primary care settings. The sample size calculations were performed using logistic regression in G*power 3.1.9.7 software. The following parameters were used: probability of error = 0.05, power of the test = 0.95, and odds ratio = 2.53. [17] All participants were community-dwelling individuals living in the Phayao and Lampang provinces in the north of Thailand. Participants were eligible for the study if they also met the following criteria: absence of menstruation for at least 12 consecutive months and no physical disability. Exclusion criteria included the presence of orthopedic diseases or a history of surgery affecting walking ability, myocardial infarction within 1 month before the study, unstable angina, resting heart rate higher than 120 bpm, resting systolic blood pressure (SBP) higher than 180 mmHg, or diastolic blood pressure (DBP) higher than 100 mmHg. [18] Ethical approval was obtained from the Institutional Review Board of the University of Phayao (UP-HEC 1.3/029/66). All participants were informed of their right to withdraw from the study at any time without penalty. Confidentiality was strictly maintained to protect participant privacy.

Outcome measures

- **General information**

Information was collected on age, self-reported history of falls in the previous year, medication use, and comorbidities. Participants' physical activity levels were evaluated using the Thai version of the Physical Activity Questionnaire for Elderly Japanese (PAQEJ).[19, 20] PAQ-EJ scores were converted to metabolic equivalent of task hours per week (MET h/week), with higher scores indicating higher levels of physical activity. The PAQ-EJ has shown moderate to good reliability, with intraclass correlation coefficient values ranging from 0.60 to 0.85.[21] Polypharmacy was defined as regularly taking five or more medications.[22]

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- **Metabolic risk factors**

Height and weight were measured using standard techniques. Body mass index (BMI) was calculated using the following formula: BMI = weight/height^2. Waist circumference (WC) was measured at the level of the umbilicus between the lower rib and iliac crest. Blood pressure was measured twice at 3-minute intervals after the participants had rested in a seated position for at least 5 minutes, and the two readings were averaged. Blood samples were collected after participants had fasted for a minimum of 8 hours. Fasting blood glucose (FBG), high-density lipoprotein (HDL) cholesterol, and triglycerides were assessed using an autoanalyzer. Metabolic risk factors were classified using the following values: SBP ≥130 mmHg, high DBP ≥ 85 mmHg, hyperglycemia (≥100 mg/dL), low HDL cholesterol (<50 mg/dL) and hypertriglyceridemia (≥150 mg/dL). [23]

- **Muscle strength**

Grip strength was assessed using a grip strength dynamometer (Takei Scientific Instruments Co. Ltd., Tokyo, Japan). The handgrip dynamometer demonstrated excellent reliability, with ICC values ranging from 0.93 to 0.97. [24] Participants stood with their arms by their sides and gripped the dynamometer as tightly as they could. The highest value from three tests of the dominant hand was used. Dynapenia was defined using the following cutoff: <18 kg. [25, 26]

- **Physical performance**

The Timed Up and Go Test (TUGT) was employed as a simple test of balance, mobility, and the risk of falling. Participants were asked to stand up from a chair, walk to a marker 3 meters away, return to the chair, and sit down again. [27] The TUGT has excellent interrater reliability (ICC = 0.94–0.99). [28] A cutoff point of 11 seconds is used to identify individuals with mobility impairments [29] and an increased risk of falling. [30]

In addition, the six-minute walk test (6MWT) was performed using a flat, 30-meter course. Participants were instructed to walk back and forth along the course for six minutes at a self-selected pace, resting as needed, and the total distance walked, in meters, was recorded. [18] The 6MWT has high test–retest reliability (ICC = 0.92–0.96). [31] A cutoff distance of 320 meters was used to identify individuals with an increased risk of falling. [32]

- **Classification of participants into groups**

Dynapenia was defined as grip strength <18 kg [25, 26] and abdominal obesity was defined as WC ≥ 85 cm. [16] Participants were classified into four categories based on dynapenia and abdominal obesity status: 1) normal (non-dynapenic and no abdominal obesity); 2) abdominal obesity; 3) dynapenic; and 4) dynapenic abdominal obesity.

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences, version 22.0 (SPSS Inc., Chicago, IL, USA). Participants with missing data were excluded from the relevant analyese, and complete-case analysis was performed. Descriptive statistics were presented as the mean ± standard deviation (SD) or the median (interquartile range) and percentages for categorical variables. Between-group comparisons across the four phenotypes were conducted using one-way analysis of variance or the Kruskal–Wallis test, depending on the distribution of the variables. For parametric tests, post hoc pairwise comparisons were performed using the Bonferroni correction. The chi-square test was applied to compare categorical variables.

Multivariate analysis of covariance (MANCOVA) was performed for physical performance outcomes and included age, BMI, and PAQ-EJ as covariates. Bonferroni post hoc tests were used to identify specific between-group differences. Multinomial logistic regression analysis was used to examine the independent associations between variables, using the normal group as the reference category and adjusting for potential confounders, including age, BMI, PAQ-EJ, and polypharmacy. Adjusted odds ratios with 95% confidence intervals were calculated. A $P < 0.05$ was considered statistically significant.

Results

This study included 326 participants. The demographic data of community-dwelling postmenopausal women are presented for each phenotype group in **Table 1.** Participants in the normal, abdominal obesity, dynapenic, and dynapenic abdominal obesity groups accounted for 30.7%, 35.9%, 15.6%, and 17.8% of the sampled patients, respectively.

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Demographic characteristics

As shown in **Table 1**, participants in the dynapenic and dynapenic abdominal obesity groups were significantly older and had lower grip strength compared with the normal and abdominal obesity groups ($P < 0.001$). In the abdominal obesity and dynapenic abdominal obesity groups, BMI was higher and physical activity levels (PAQ-EJ scores) were lower than in the other two groups ($P < 0.001$).

Metabolic risk factors

As shown in **Table 1**, WC was significantly greater in the abdominal obesity and dynapenic abdominal obesity groups than in the normal and dynapenic groups ($P < 0.001$). Fasting blood glucose (FBG) levels were significantly higher in both dynapenic groups and HDL cholesterol was lowest in the dynapenic abdominal obesity group ($P = 0.01$). Triglyceride levels were highest in the dynapenic abdominal obesity group and lowest in the normal group ($P < 0.001$). There were no significant differences in SBP or DBP among the groups.

Clinical status

As shown in **Table 1**, the prevalence of fall history was highest in the dynapenic abdominal obesity group (46.6%), followed by the dynapenic group (35.3%), the abdominal obesity (17.9%) and the normal group (14.0%) ($P < 0.001$). The dynapenic abdominal obesity group also had the smallest proportion of participants without comorbidities compared with the normal group ($P = 0.003$). There were no significant differences in polypharmacy among the four groups.

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Table 1. The demographic data of the post-menopausal women presence of abdominal obesity and dynapenia status (n = 326).

Variable	Normal (n = 100)	Abdominal obesity (n = 117)	Dynapenic (n = 51)	Dynapenic abdominal obesity (n = 58)	*P*
Demographic characteristics					
Age (years)	66.3 ± 5.5	65.6 ± 5.8	69.2 ± 6.9[a,b]	70.3 ± 6.2[a,b]	< 0.001
BMI (kg/m^2)	22.4 ± 2.5	26.7 ± 3.2[a,c]	21.0 ± 2.9	25.8 ± 3.2[a,c]	< 0.001
PAQ-EJ (MET hours/week)	44.7 (28.9–73.0)	41.1 (26.9–66.1)	28.0 (25.0–63.2) [a]	27.2 (25.0–46.4)[a,b]	< 0.001
Grip strength (kg)	21.8 ± 2.8	22.6 ± 3.6	14.2 ± 3.3[a,b]	14.4 ± 2.8[a,b]	< 0.001
Metabolic risk factors					
WC (cm)	78.2 ± 5.4	93.1 ± 5.7[a, c]	77.0 ± 5.8	92.2 ± 5.7[a,c]	< 0.001
SBP (mmHg)	130.6 ± 11.6	130.1 ± 10.3	129.7 ± 16.2	132.7 ± 12.3	0.52
DBP (mmHg)	77.0 ± 8.6	77.2 ± 7.6	73.6 ± 9.8	76.3 ± 10.3	0.08
FBG (mg/dl)	96.0 (88.0–107.8)	100.0 (91.5–111.0)	116.0 (93.0–137.0)[a,b]	113.0 (96.0–139.0)[a,b]	< 0.001
HDL cholesterol (mg/dl)	54.0 (41.0–64.0)	49.0 (42.0–58.0)	46.0 (37.0–60.0)	44.5 (39.0–54.0)[a]	0.01
Triglyceride (mg/dl)	101.0 (81.3–137.0)	129.0 (93.0–176.5)	130.0 (87.0–160.0)	138.0 (108.5–184.5)[a]	< 0.001
Clinical status					
Polypharmacy (%)	16.0	23.1	32.8	27.5	0.09
History of falls (%)	14.0	17.9	35.3[a]	46.6[a]	< 0.001
Comorbidities (%)					0.003
0	36.0	18.8	17.6	10.3[a]	
1 - 2	59.0	76.1[a]	70.6	79.3[a]	
≥ 3	5.0	5.1	11.8	10.4	

[a] Significantly different from normal, [b] Significantly different from abdominal obesity, [c] Significantly different from dynapenic. BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL, high-density lipoprotein; PAQ-EJ, Physical Activity Questionnaire for Elderly Japanese; MET, metabolic equivalent of task; SBP, systolic blood pressure; WC, waist circumference.

Table 2. Physical performance measures across four phenotypes.

Physical performance	Normal (n = 100)	Abdominal obesity (n = 117)	Dynapenic (n = 51)	Dynapenic abdominal obesity (n = 58)	*P*
TUGT (s)	10.29 ± 2.78	10.80 ± 2.99	12.73 ± 3.76[a]	12.55 ± 3.39[a]	< 0.001
6MWT (m)	373.22 ± 71.33	349.43 ± 82.47	310.56 ± 90.98[a]	283.70 ± 92.10[a,b]	< 0.001

MANCOVA was performed, with age, BMI, and PAQ-EJ included as a covariate. Bonferroni post hoc tests were used to determine specific group differences. 6MWT, six-minute walk test; TUGT, Timed Up and Go Test.
[a] Significantly different from normal, [b] Significantly different from abdominal obesity

Table 3. Odds ratio of metabolic risk factors, clinical status history and physical performance by category.

Variables		Normal	Abdominal obesity	Dynapenic	Dynapenic Abdominal obesity
Metabolic risk factors					
High SBP	Unadjusted	1.00 (Ref)	0.90 (0.53–1.54)	1.03 (0.52–2.04)	1.51 (0.78 –2.92)
(≥ 130 mmHg)	Adjusted	1.00 (Ref)	0.69 (0.35–1.34)	1.19 (0.57–2.46)	0.91 (0.42 –5.46)
High DBP	Unadjusted	1.00 (Ref)	0.89 (0.42–1.87)	0.97 (0.38–2.46)	1.37 (0.59– 3.14)
(≥ 85 mmHg)	Adjusted	1.00 (Ref)	0.53 (0.22–1.28)	1.45 (0.53–3.99)	0.84 (0.32– 2.21)
Hyperglycemia	Unadjusted	1.00 (Ref)	1.56 (0.91–2.68)	2.42 (1.21–4.84)*	4.12 (2.02– 8.39)*
(≥ 100 mg/dl)	Adjusted	1.00 (Ref)	1.41 (0.72–2.75)	2.15 (1.02–4.53)*	2.83 (1.25– 6.42)*
Low HDL cholesterol	Unadjusted	1.00 (Ref)	1.50 (0.87–2.57)	1.97 (0.99–3.91)	2.26 (1.16– 4.38)*
(< 50 mg/dl)	Adjusted	1.00 (Ref)	1.52 (0.78–2.95)	1.43 (0.68–2.99)	1.96 (0.90– 4.23)
Hypertriglyceridemia	Unadjusted	1.00 (Ref)	2.05 (1.09–3.85)*	2.32 (1.08–4.97)*	2.80 (1.35–5.78)*
(≥ 150 mg/dl)	Adjusted	1.00 (Ref)	1.62 (0.77–3.43)	2.36 (1.05–5.32)*	2.41 (1.05–5.56)*
Clinical status					
History of falls	Unadjusted	1.00 (Ref)	1.34 (0.64–2.80)	3.35 (1.49–7.49)*	5.35 (2.491–1.49)*
	Adjusted	1.00 (Ref)	1.10 (0.45–2.66)	2.97 (1.26–7.02)*	3.95 (1.61– 9.67)*
Physical performance					
Reduced mobility	Unadjusted	1.00 (Ref)	1.68 (0.95–2.95)	3.61 (1.78–7.32)*	4.11 (2.07– 8.15)*
(TUGT > 11 s)	Adjusted	1.00 (Ref)	1.93 (0.95–3.92)	2.32 (1.06–5.04)*	3.27 (1.45– 7.37)*
Risk of fall	Unadjusted	1.00 (Ref)	2.02 (1.09–3.74)*	3.09 (1.48–6.42)*	4.96 (2.44 –10.08)*
(6MWT < 320 m)	Adjusted	1.00 (Ref)	1.93 (0.87–4.24)	1.90 (0.82–4.42)	2.89 (1.23– 6.81)*

* $P < 0.05$; Adjusted model: age; BMI; PAQ-EJ; and Polypharmacy. DBP, diastolic blood pressure; HDL, high-density lipoprotein; SBP, systolic blood pressure; 6MWT, six-minute walk test; TUGT, Timed Up and Go Test.

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Physical performance

As shown in **Table 2**, the dynapenic and dynapenic abdominal obesity groups had significantly longer TUGT times and shorter 6MWT distances compared with the normal group after adjustment for age, BMI, and PAQ-EJ ($P < 0.001$).

Odds ratios of risk factors associated with dynapenia and dynapenic abdominal obesity

Logistic regression analysis **(Table 3)** revealed that dynapenic abdominal obesity was significantly associated with hyperglycemia (aOR = 2.83; 95% CI = 1.25–6.42; $P < 0.05$), hypertriglyceridemia (aOR = 2.41; 95% CI = 1.05–5.56; $P < 0.05$), history of falls (aOR = 3.95; 95% CI = 1.61–9.67; $P < 0.05$), reduced mobility (TUGT >11 s; aOR = 3.27; 95% CI = 1.45–7.37; $P < 0.05$), and fall risk (6MWT < 320 m; aOR = 2.89; 95% CI = 1.23–6.81; $P < 0.05$). Similarly, dynapenia was significantly associated with hyperglycemia (aOR = 2.15; 95% CI = 1.02–4.53; $P < 0.05$), hypertriglyceridemia (aOR = 2.36; 95% CI = 1.05–5.32; $P < 0.05$), history of falls (aOR = 2.97; 95% CI = 1.26–7.02; $P < 0.05$), and reduced mobility (aOR = 2.32; 95% CI = 1.06–5.04; $P < 0.05$).

Discussion

This cross sectional study investigated whether dynapenic abdominal obesity was associated with metabolic risk factors, clinical status, and physical performance in community-dwelling postmenopausal women. The key findings were that dynapenia and, in particular, dynapenic abdominal obesity were associated with unfavorable metabolic profiles, higher prevalence of falls, and reduced mobility and walking capacity.

In the study, 15.6% of participants were classified as dynapenic and 17.8% were classified as having dynapenic abdominal obesity. These prevalence rates are similar to previous reports, although variation across studies is evident. Gadelha, *et al*. observed rates of dynapenia (14.4%) and dynapenic abdominal obesity (23.4%) in older women, [33] whereas Leme, et *al*. reported a higher prevalence of both dynapenia (26.8%) and dynapenic abdominal obesity (25.2%) in middle-aged and older adults. [3] In contrast, Yang, *et al*. reported a higher prevalence of dynapenia (27.8%) but a lower prevalence of dynapenic abdominal obesity (6.0%) among older Chinese women. [15] These variations may arise from differences in demographic characteristics, diagnostic definitions, and lifestyle factors across populations.

Physical performance outcomes were supportive of these observations. After adjustment for age, BMI, and physical activity, women with dynapenia or dynapenic abdominal obesity had significantly longer TUGT times and shorter 6MWT distances than normal participants, which are indicators of limited mobility and reduced endurance. These impairments are well-established predictors of disability and loss of independence in older adults. Women in the abdominal obesity group had numerically lower 6MWT performance than the normal group; however, the difference was not statistically significant after adjustment for potential confounders. This may be attributable to limited statistical power, adjustment effects, or sample variability. Outcomes were most favorable in the normal group, which was characterized by younger age, healthier body composition, and higher physical activity.

Several mechanisms may give rise to these associations. Metabolically, estrogen decline after menopause promotes visceral fat accumulation and is associated with reduced muscle mass and strength, which contribute to insulin resistance and dyslipidemia.[34-36] Inflammatory mechanisms may also be involved, as central obesity is characterized by chronic low-grade inflammation, and the elevation of adipokines and cytokines, such as TNF-α and IL-6, may adversely affect both metabolic and musculoskeletal health. [3, 13, 37] Neuromuscular dysfunction may also contribute because fat infiltration into the muscle can impair muscle quality and contractile function, leading to weakness and poorer physical performance. [38-41] Although these mechanisms were not directly examined in the present study, they may help explain the synergistic adverse effects observed in dynapenic abdominal obesity.

Our key findings suggest that women with dynapenic abdominal obesity were older, with a higher BMI and WC, and had lower physical activity, and adverse metabolic profiles, including elevated fasting glucose, triglycerides, and reduced HDL cholesterol. Logistic regression confirmed that this phenotype was associated with the highest risk of hyperglycemia, hypertriglyceridemia, impaired mobility, and falls. Women with dynapenia (but not abdominal obesity) also had metabolic disturbances, but these were associated with lower risks. These results are consistent with previous research showing that dynapenia is more strongly associated with metabolic risk than sarcopenia. [42] Other studies support these results, with lower HDL cholesterol and higher triglyceride and glucose levels reported in individuals with dynapenic abdominal obesity compared with those with dynapenia or normal profiles. [14] A longitudinal study also identified the dynapenic abdominal obesity phenotype as a predictor of hyperglycemia and low HDL cholesterol, whereas dynapenia alone was associated with a lower incidence of metabolic syndrome. [13] Although the diagnostic criteria for dynapenic abdominal obesity differed between studies, [13, 14] the overall pattern of adverse metabolic profiles was similar, supporting the consistency of this association across different definitions. Thus, dynapenic abdominal obesity appears to be associated with an increased risk of metabolic syndrome, which may contribute to cardiovascular disease, functional decline, and increased mortality.

Fall prevalence was highest among women with dynapenic abdominal obesity, followed by those with dynapenia; rates were considerably lower in the abdominal obesity and normal groups. Regression analysis confirmed independent associations of both dynapenia and dynapenic abdominal obesity with fall history, with the latter conferring the greatest risk. These findings are consistent with previous reports. [16, 33] The higher burden of comorbidities in this group also suggests increased frailty. The present contributes to the literature by performing a direct comparison of four phenotypes in postmenopausal women. The findings highlight dynapenic abdominal obesity as the most detrimental phenotype, with the greatest combined effects on metabolic health, fall risk, and physical performance. This supports the clinical value of early identification and intervention in this high-risk subgroup.

There are several limitations to our study. First, its cross-sectional design precludes conclusions about causality. Second, the participants were community-

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dwelling women over 50 years of age from specific provinces within a single geographical region; such a population may limit generalizability, and community-based recruitment may have introduced selection bias. Third, fall history was obtained using self-report, which is subject to recall bias and misclassification. Finally, reverse causality cannot be excluded, as physical activity may be lower in women with pre-existing comorbidities or mobility impairments, which increases their risk of dynapenia and obesity. Future longitudinal studies in more diverse populations are needed to confirm these associations and clarify causal pathways.

Conclusion

Dynapenia and dynapenic abdominal obesity were associated with adverse metabolic profiles, impaired balance, and fall history in postmenopausal women. Dynapenic abdominal obesity was most strongly associated with hyperglycemia, hypertriglyceridemia, mobility limitation, and fall risk. These findings highlight the potential value of early identification of the condition. Simple diagnostic tools, such as grip strength measurement and WC, are practical and cost-effective screening tools for primary care providers.

Author contributions

PM contributed substantially to the concept and design of this study, methodology, acquisition of data, analysis and interpretation, and drafting the manuscript. SS contributed substantially to the methodology and acquiring the data. AS contributed substantially to the methodology and writing review and editing. PP contributed to writing review and editing. NW contributed to the statistical analysis. All authors critically revised the manuscript and approved the final version for publication.

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Conflicts of interest statement

The authors declare no conflict of interest.

Data sharing statement

All data generated or analyzed during the present study are included in this published article. Further details are available for non-commercial purposes from the corresponding author on reasonable request.

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