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Original article

Dynapenic obesity as an associated factor to lipid and glucose metabolism disorders and metabolic syndrome in older adults – Findings from SABE Study

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SUMMARY

Background & aims: There is little evidence showing that dynapenic obesity is associated with lipid and glucose metabolism disorders, high blood pressure, chronic disease and metabolic syndrome. Our aim was to analyze whether dynapenic abdominal obesity can be associated with lipid and glucose metabolism disorders, high blood pressure, metabolic syndrome and cardiovascular diseases in older adults living in São Paulo.

Methods: This cross-sectional study included 833 older adults who took part of the third wave of the Health, Well-being and Aging Study in 2010. Based on waist circumference (>88 cm women and >102 cm men) and handgrip strength (<16 kg women and <26 kg men), four groups were identified: non-dynapenic/non-abdominal obese (ND/NAO), abdominal obese alone (AOA), dynapenic alone (DA) and dynapenic/abdominal obese (D/AO). Dependent variables were blood pressure, lipid profile, fasting glucose and glycated-haemoglobin, metabolic syndrome and cardiovascular diseases. Logistic regression was used to analyze the associations between dynapenia and abdominal obesity status and lipid and glucose metabolic profiles, blood pressure, cardiovascular diseases and metabolic syndrome.

Results: The fully adjusted models showed that D/AO individuals had higher prevalence of low HDL plasma concentrations (OR = 2.51, 95%CI: 1.40–4.48), hypertriglyceridemia (OR = 2.53, 95%CI: 1.43–4.47), hyperglycemia (OR = 2.05, 95%CI: 1.14–3.69), high glycated-haemoglobin concentrations (OR = 1.84, 95%CI: 1.03–3.30) and metabolic syndrome (OR = 12.39, 95%CI: 7.38–20.79) than ND/NAO. Dynapenic and D/AO individuals had higher prevalence of heart disease (OR = 2.05, 95%CI: 1.17–3.59 and OR = 1.92, 95%CI: 1.06–3.48, respectively) than ND/NAO.

Conclusion: D/AO was associated with high prevalence of lipid and glucose metabolism disorders and metabolic syndrome while dynapenia and D/AO were associated with high prevalence of heart disease.

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1. Introduction

The prevalence of obesity has been increasing worldwide across all age groups, including older adults [1]. Excessive body fat is associated with a higher risk of metabolic disorders [2], especially if this accumulation is featured as abdominal obesity [3].

Besides obesity, another important aspect of the body composition that changes with aging is the concomitant loss of muscle mass [4]. Sarcopenia is capable of partially mediate the decrease in muscle strength, along with the physiological neuromuscular adjustments and intramuscular fat accumulation, that naturally occur with aging [5]. However, several studies showed that the decline of muscle strength occurs much faster than muscle mass. Indeed, findings from some longitudinal studies of aging, evaluating total or appendicular lean mass, showed that muscle mass explains just a small variance of muscle strength capacity [6].

Furthermore, because muscle strength has been shown to be more associated with disability [6] than muscle mass itself, it has been suggested that evaluating muscle strength in older adults is important to prevent the development of negative outcomes related to muscle function [7]. Hence, in order to distinguish the concept of the decline of muscle strength and mass, Clark and Manini defined dynapenia as the age-related muscle strength reduction, which is also accompanied by changes in contractile properties and/or neurological function underlying this condition, rather than considering loss of muscle mass as the unique responsible of the capacity to generate force [5].

Because both obesity and dynapenia have been shown to be risk factors for disability [8,9] and death [10], recent studies have examined the effect of obesity associated with dynapenia on health-related disorders proposing that these two conditions may have a harmful additive effect [11,12]. Nevertheless, the effects of the dynapenic-obesity status on the metabolic profile, metabolic syndrome and cardiovascular disease risk were solely evidenced by Sénéchal et al. [13] and Albertin-Leheundre et al. [14]. However, the effects found were restricted to the US population showing controversial results. Therefore, the aim of this study was to investigate whether dynapenia combined with abdominal obesity can be associated with lipid and glucose metabolism disorders, high blood pressure, metabolic syndrome and cardiovascular disease in older adults living in São Paulo.

2. Methods

2.1. Population characterization

The data came from the SABE Study (Saúde, Bem-Estar e Envelhecimento/Health, Well-being and Ageing), a multiple cohort study that began in 2000 with a probabilistic sample of 2143 individuals representative of the urban population aged 60 years and older living in São Paulo, Brazil. All participants signed a statement of informed consent and the SABE study received the approval of the Ethics Committee (MS/315/99). More details about the study and its sampling were given previously [15].

In 2010, third wave of study, 1344 older adults were interviewed and evaluated. To maintain compatibility with other studies, we included in this analysis only those participants aged 65 years and older ($n = 1053$). We excluded 220 due to missing data on waist circumference, handgrip strength, blood samples, systolic and/or diastolic blood pressure, weight, height, educational level and smoking habit information, resulting in a final sample of 833 individuals. These variables were needed to define abdominal obesity, dynapenia, metabolic syndrome criteria or to control the final models. These measurements were not taken in older adults who were bedridden, unable to remain in standing position, or incapable to perform the handgrip test.

The excluded subjects had lower means of fasting glucose, LDL-cholesterol, glycated-haemoglobin as well as lower proportion of individuals being above the limit of total cholesterol, glycated-haemoglobin, metabolic syndrome criteria and higher prevalence of stroke than the included ones ($p < 0.05$) (data not shown).

2.2. Anthropometric measurements and classification of the groups

The waist circumference measure was carried out by a trained evaluator with a flexible tape placed at the midpoint between the last rib and the iliac crest. The subjects remained upright with the arms alongside the body and without the upper portion of their clothes and were instructed to relax the abdomen and the measure was taken at the end of the expiratory phase of a breathing cycle. Abdominal obesity was classified as a waist circumference value > 88 cm for women and >102 cm for men [16].

Muscle strength was assessed with handgrip strength using a hand-held dynamometer (Takei Kiki Kogyio TK 1201). During the test, the participant was in a sitting position, with elbow and forearm resting in the table and with palm facing up. Maximum strength tests were performed twice with a 1-min rest between tests and the highest value was used [10]. Dynapenia was defined as a handgrip value <16 kg for women and <26 kg for men [17,18].

Dynapenic abdominal obese was defined as the association of dynapenia and abdominal obesity and subjects were then classified into four groups: (1) non dynapenic/non abdominal obese (ND/NAO); (2) abdominal obese alone (AOA); (3) dynapenic alone (DA); and (4) dynapenic-abdominal obese (D/AO).

2.3. Metabolic profile

Fasting plasma concentrations of total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides and glucose as well as the percentage of glycated-haemoglobin levels were measured. Systolic and diastolic blood pressure measures followed the Brazilian Guidelines on Hypertension recommendations [19].

Subjects were classified as having metabolic syndrome or not based on the definition of Alberti et al. [20] and the use of medications (Anatomical Therapeutic Chemical [ATC] Classification System codes). Individuals with at least three of the following criteria were considered to have metabolic syndrome: (A) fasting triglycerides ≥ 150 mg/dl or use of omega-3 and/or fibrates and/or nicotinic acid (ATC C10); (B) waist circumference ≥ 88 cm for women and ≥102 cm for men; (C) fasting glucose ≥ 100 mg/dl or use of oral hypoglycemic agents (ATC A10) and/or insulin; (D) low HDL-cholesterol < 50 mg/dl for women and <40 mg/dl for men or use of nicotinic acid to increase HDL-cholesterol (ATC C10) and/or fibrates and (E) Systolic blood pressure at rest ≥ 130 mmHg and/or diastolic blood pressure at rest ≥ 85 mmHg or use of antihypertensive drugs (ATC C02, C03, C04, C07, C08, C09)[19]. Other cut-off points were determined for total cholesterol (≥200 mg/dl) [21]; LDL-cholesterol (≥100 mg/dl) [21]; and glycated-haemoglobin (≥6.5%) [22].

2.4. Cardiovascular diseases

Heart disease and stroke were assessed by self report.

2.5. Covariates

Socio-demographic characteristics: sex, age, educational level and race (white, brown, mestizo, indigenous, Asian or other).

Smoking status was assessed by a question whose response options were current smokers, former smokers or non-smokers. Alcohol intake a week was investigated and participants were then rated as low drinkers (less than 1 day a week), moderate drinkers (1–3 days a week) or heavy drinkers (more than 3 days a week). Physical activity level was assessed using the International Physical Activity Questionnaire (validated in Brazil) [23]. Individuals were classified as sedentary when they did less than 150 min of moderate activity or less than 75 min of vigorous activity per week [24].

Body mass index (BMI) was evaluated using the classification of the Pan American Health Organization for older adults: BMI < 23 kg/m^2 = underweight; ≥ 23 and < 28 kg/m^2 = normal weight; ≥ 28 and < 30 kg/m^2 = overweight; and BMI ≥ 30 kg/m^2 = obesity [25].

Since the data were from a cluster sampling in multiple stages, sample weights were used in all analyzes. The comparisons between means in each group were performed by *Rao and Scott Wald test* and comparisons of proportions by the *chi-squared test* with Rao Scott correction. Logistic regression was used to analyze differences between the prevalence of the main variables. All regressions were adjusted for age, sex, race, education, alcohol intake, smoking status and physical activity level. Statistically significant associations were considered in the final model as those that presented a p-value <0.05. The STATA 14® software (Stata Corp., College Station, TX) was used for all analyzes.

A sensitivity analysis was performed to confirm whether dynapenic obesity increases the prevalence of lipid and glucose metabolism disorders, high blood pressure, metabolic syndrome and cardiovascular diseases by entering abdominal obesity and dynapenia separately in the models.

3. Results

Mean age of the older adults was 74 years, composed predominantly of females (61.6%) and white (63.1%). It was found an abdominal obesity prevalence of 48.0%, 27.2% of dynapenia and 43.3% of metabolic syndrome in the population studied (Table 1).

D/A individuals were older followed by D/AO. D/AO individuals had lower education but the difference was not statistically significant between the D/AO and D/A groups. The highest values of waist circumference were found in the AOA group while the D/AO group had the lowest handgrip strength (Table 2).

The highest prevalence of hypertriglyceridemia and metabolic syndrome was found in the D/AO group but the difference was not statistically significant between the D/AO and AOA groups. The prevalence of heart disease was higher in D/A and D/AO than in ND/NAO and AOA individuals. However, statistically significant differences were not found between the D/A and D/AO groups (Table 2).

The fully adjusted models showed that D/AO individuals had higher prevalence of low HDL plasma concentrations (OR = 2.51, 95% CI: 1.40–4.48), hypertriglyceridemia (OR = 2.53, 95% CI: 1.43–4.47), hyperglycemia (OR = 2.05, 95% CI: 1.14–3.69), high glycated-haemoglobin concentrations (OR = 1.84, 95% CI: 1.03–3.30) and metabolic syndrome (OR = 12.39, 95% CI: 7.38–20.79) compared to ND/NAO individuals (Table 3).

Dynapenic individuals had higher prevalence of heart disease (OR = 2.05, 95% CI: 1.17–3.59) than ND/NAO followed by D/AO individuals (OR = 1.92, 95% CI: 1.06–3.48). AOA individuals also had high prevalence of hypertriglyceridemia (OR = 1.91, 95% CI: 1.23–2.98), hyperglycemia (OR = 2.01, 95% CI: 1.25–3.22) and metabolic syndrome (OR = 9.92, 95% CI: 5.88–16.75) than ND/NAO but these prevalence were lower than to D/AO individuals (Table 3).

The sensitivity analyses confirmed that dynapenic abdominal obesity increases the prevalence of low HDL-cholesterol plasma concentrations, hypertriglyceridemia, hyperglycemia and metabolic syndrome. Furthermore, they also showed that when abdominal obesity and dynapenia are analyzed separately, the associations with obesity could be slightly overestimated for hypertriglyceridemia and low serum concentrations of HDL-cholesterol and underestimated for hyperglycemia and metabolic syndrome (Table 4). These findings suggest that changes in body composition i.e. an increase of abdominal fat and declines of muscle strength could affect both the glucose and lipid metabolisms and the prevalence of metabolic syndrome.

Table 1
Sample characteristics – SABE Study – São Paulo, Brazil, 2010 (n = 833).

Socioeconomic aspects	n = 833
Age, years (SE)	73.9 (0.6)
Sex (female) (%)	61.6
Race (%)	
White	63.1
Brown	24.8
Black	6.5
Indigenous	0.3
Asian	2.4
Other	2.9
Schooling, years (SE)	4.4 (0.3)
Behavioral aspects	
Alcohol intake (%)	
Low drinker	81.5
Moderate drinker	12.4
Heavy drinker	6.1
Smoking status (%)	
Non-smoker	54.1
Former smoker	36.5
Current smoker	9.4
Physical Activity (%)	
Sedentary	63.5
Anthropometry and physical performance	
Waist circumference, cm (SE)	93.9 (0.5)
≥ 102 cm for men and ≥88 cm for women (%)	48.0
Handgrip, kg (SE)	23.6 (0.4)
< 26 Kg for men and <16 Kg for women (%)	27.2
Body mass index, kg/m^2 (SE)	28.0 (0.2)
Underweight (%)	14.5
Normal weight (%)	39.9
Overweight (%)	14.5
Obesity (%)	31.1
Metabolic profile and blood pressure	
Fasting glucose, mg/dl (SE)	95.5 (1.4)
≥ 100 mg/dl (%)	25.8
HbA1c, % (SE)	6.1 (0.1)
≥ 6.5% (%)	16.6
Total cholesterol, mg/dl (SE)	206.8 (1.8)
≥200 mg/dl (%)	55.3
HDL cholesterol, mg/dl (SE)	50.2 (0.5)
< 40 mg/dl for men and <50 mg/dl for women (%)	39.1
LDL cholesterol, mg/dl (SE)	130.4 (1.5)
≥ 100 mg/dl (%)	80.8
Triglycerides, mg/dl (SE)	131.6 (2.3)
≥ 150 mg/dl (%)	28.6
Systolic Blood Pressure, mmHg (SE)	141.9 (0.9)
≥ 130 mmHg (%)	68.8
Diastolic Blood Pressure, mmHg (SE)	79.2 (0.5)
≥ 85 mmHg (%)	30.2
Metabolic syndrome (yes) (%)	43.3
Heart disease (yes) (%)	26.0
Stroke (yes) (%)	7.6

Data are presented as percentages, means and standard error (SE).

4. Discussion

We found that D/AO individuals had higher prevalence of lipid and glucose metabolism disorders (low serum concentrations of HDL-cholesterol, hypertriglyceridemia, hyperglycemia and high

Table 2
Groups characteristics – SABE Study – São Paulo, Brazil, 2010 (n = 833).

	Non-Dynapenic/ Non-Abdominally Obese (n = 278)	Abdominally Obese Alone (n = 282)	Dynapenic Alone (n = 157)	Dynapenic/Abdominally Obese (n = 116)
Socioeconomic aspects				
Age, years (SE)	73.0 (0.6)	72.1 (0.6)[a]	78.4 (0.8)[a,b]	76.3 (1.0)[a,b,c]
Schooling, years (SE)	4.7 (0.4)	4.6 (0.3)	4.0 (0.5)	3.2 (0.3)[a,b]
Behavioral aspects				
Alcohol intake (%)				
Low drinker	74.4	83.5	84.5	93.2[a]
Moderate drinker	14.4	12.0	12.7	6.8
Heavy drinker	11.2	4.5	2.8[a]	–
Smoking status (%)				
Non-smoker	43.5	60.8[a]	53.0	67.7[a]
Former smoker	42.6	33.3	36.2	27.7
Current smoker	13.9	5.9[a]	10.8	4.6[a]
Physical Activity (%)				
Sedentary	61.1	61.3	70.2	68.9
Anthropometry and physical performance				
Waist circumference, cm (SE)	87.0	102.5[a]	85.6[b]	100.0[a,b,c]
Handgrip, kg (SE)	28.6 (0.5)	24.6 (0.5)[a]	17.0 (0.5)[a,b]	13.4 (0.3)[a,b,c]
BMI, kg/m^2 (SE)	24.9 (0.2)	32.0 (0.3)[a]	23.9 (0.3)[a,b]	30.8 (0.5)[a,b,c]
Metabolic profile and blood pressure				
Fasting glucose, mg/dl (SE)	93.3 (2.1)	98.1 (1.7)	91.7 (2.9)[b]	99.8 (3.9)
≥ 100 mg/dl (%)	19.5	31.4[a]	23.7	30.8
HbA1c, % (SE)	6.0 (0.1)	6.2 (0.1)[a]	6.2 (0.1)	6.2 (0.1)[a]
≥ 6.5% (%)	12.4	17.4	18.1	25.4[a]
Total cholesterol, mg/dl (SE)	202.8 (2.7)	213.6 (3.3)[a]	197.4 (3.9)[b]	210.5 (4.4)[c]
≥ 200 mg/dl (%)	49.7	63.8[a]	45.8[b]	58.6
HDL cholesterol, mg/dl (SE)	51.4 (1.0)	49.8 (0.8)	49.1 (1.3)	49.5 (1.4)
< 40 mg/dl for men and <50 mg/dl for women (%)	30.7	42.4	38.4	56.2[a]
LDL cholesterol, mg/dl (SE)	127.3 (2.3)	135.4 (2.8)[a]	125.1 (3.3)[b]	131.9 (3.5)
≥ 100 mg/dl (%)	79.5	82.9	76.4	84.0
Triglycerides, mg/dl (SE)	121.9 (4.0)	142.4 (4.3)[a]	116.1 (5.5)[b]	149.2 (8.7)[a,c]
≥ 150 mg/dl (%)	23.5	35.0[a]	18.0[b]	38.1[c]
Systolic blood pressure, mmHg (SE)	140.2 (1.8)	141.6 (1.2)	144.2 (2.4)	144.7 (2.5)
≥ 130 mmHg (%)	68.8	67.4	69.8	71.5
Diastolic blood pressure, mmHg (SE)	78.8 (0.8)	81.1 (0.8)[a]	75.7 (1.2)[a,b]	79.4 (0.9)[c]
≥ 85 mmHg (%)	29.0	34.2	25.7	27.7
Metabolic syndrome (yes) (%)	18.6	66.9[a]	24.7[b]	71.4[a,c]
Heart disease (yes) (%)	21.1	22.8	36.3[a,b]	37.8[a]
Stroke (yes) (%)	7.3	5.4	10.3	11.8

Data are presented as percentages, means and standard error (SE).
Significance was accepted as $p < 0.05$.
[a] Significantly different from non-dynapenic/non-abdominally obese.
[b] Significantly different from abdominally obese alone.
[c] Significantly different from dynapenic alone.

glycated-haemoglobin concentrations) and metabolic syndrome compared to ND/NAO individuals. Moreover, dynapenic and D/AO individuals had higher prevalence of heart disease than ND/NAO.

Previous studies showed that both abdominal obesity and dynapenia alone have a negative impact on serum concentrations of HDL-cholesterol, triglycerides, glucose metabolism and blood pressure at rest [2,26].

However, only two studies to date, examined the effect of dynapenic obesity on such outcomes as well as on cardiovascular disease [13,14]. Indeed, our results showed some similarities with a previous study conducted by Sénéchal et al. [13], using data from the National Health and Nutrition Examination Survey, which analyzed 3007 North-American women and men, aged 50 years and older. Like Sénéchal et al. [13] we also found a higher prevalence of low serum concentrations of HDL-cholesterol, hypertriglyceridemia, hyperglycemia and metabolic syndrome among D/AO individuals. However, while Sénechal et al. [13] found only a small prevalence of low serum concentrations of HDL-cholesterol and metabolic syndrome among dynapenic individuals compared to D/AO, our findings showed a higher prevalence of hypertriglyceridemia, hyperglycemia and metabolic syndrome in AOA individuals compared to ND/NAO. This finding allowed us to show a greater effect when abdominal obesity and dynapenia are combined on the lipid and glucose metabolism disorders and metabolic syndrome. Like Sénéchal et al. [13] we also found a high prevalence of cardiovascular disease in D/AO individuals. However, we found a higher prevalence of cardiovascular disease in dynapenic only individuals compared to Sénéchal et al. [13].

Some differences in sample characteristics can explain the differences between our and Sénéchal et al. [13] results. Firstly, all groups of our study were older, had higher proportion of non-smokers, low drinkers and higher proportion of sedentary individuals. The characteristics of our sample may have attenuated the effect of alcohol and smoke and potentiated the effect of sedentary lifestyle on muscle strength and obesity. Furthermore, the prevalence of low levels of HDL-cholesterol, hypertriglyceridemia, and metabolic syndrome were higher in the current study. In addition, the prevalence of heart disease was more than twice in our population which may explain our results. Finally, it is important to point out those methods of waist circumference and muscle strength measurements used were not the same. For abdominal circumference, Sénechal et al. [13] used the recommendations of Ardern et al. [27], while the present study used the NIH [16] recommendation. On the other hand, Sénechal et al. [13]

Table 3
Adjusted logistic regression models for the prevalence of lipid and glucose metabolism disorders, systolic and diastolic hypertension, metabolic syndrome, heart disease and stroke by group in elderly people living in São Paulo, Brazil, 2010 – SABE study (n = 833).

	Non-Dynapenic/ Non-Abdominally Obese (n = 278)	Abdominally Obese Alone (n = 282)	Dynapenic Alone (n = 157)	Dynapenic/Abdominally Obese (n = 116)
Low HDL cholesterol				
Adjusted model	1.00	1.54 (0.97–2.44)	1.36 (0.84–2.21)	2.51 (1.40–4.48)
High LDL cholesterol				
Adjusted model	1.00	1.07 (0.62–1.84)	1.05 (0.63–1.73)	1.22 (0.63–2.33)
High total cholesterol				
Adjusted model	1.00	1.47 (0.97–2.23)	0.98 (0.62–1.56)	1.12 (0.64–1.95)
Hypertriglyceridemia				
Adjusted model	1.00	1.91 (1.23–2.98)	0.87 (0.47–1.60)	2.53 (1.43–4.47)
Hyperglycemia				
Adjusted model	1.00	2.01 (1.25–3.22)	1.39 (0.76–2.52)	2.05 (1.14–3.69)
High HbA1c				
Adjusted model	1.00	1.27 (0.83–1.94)	1.51 (0.78–2.90)	1.84 (1.03–3.30)
High systolic blood pressure				
Adjusted model	1.00	1.04 (0.66–1.65)	0.91 (0.53–1.56)	1.08 (0.58–2.00)
High diastolic blood pressure				
Adjusted model	1.00	1.53 (0.95–2.47)	1.14 (0.67–1.97)	1.44 (0.76–2.71)
Metabolic syndrome				
Adjusted model	1.00	9.92 (5.88–16.75)	1.57 (0.91–2.71)	12.39 (7.38–20.79)
Heart disease				
Adjusted model	1.00	1.05 (0.65–1.70)	2.05 (1.17–3.59)	1.92 (1.06–3.48)
Stroke				
Adjusted model	1.00	0.89 (0.38–2.05)	1.13 (0.45–2.83)	1.69 (0.69–4.17)

Values of adjusted models denote odds ratio (95% confidence interval). Model adjusted for age, sex, race, schooling, alcohol intake, smoking and physical activity levels. Significance was accepted as $p < 0.05$.

used leg strength analyzed in tertile by sex while the present study used the cut-off points of handgrip strength according sex as recommended by the FNIH [17,18].

Our findings differ from the ones found by Aubertin-Leheundre et al. [14] who showed that non-obese dynapenic individuals had lower prevalence of risk factors for metabolic diseases compared to those non-obese and non-dynapenic. In addition, in their study, among individuals who were obese, dynapenic people had lower prevalence of the criteria for metabolic syndrome i.e. larger waist circumference and higher diastolic blood pressure. However, it is important to mention that these differences between groups found by Aubertin-Leheundre et al. [14] were not confirmed in the adjusted models. Our findings, meanwhile, remained significant in the fully adjusted models by age, sex, race, level of education, alcohol consumption, smoking and physical activity.

The conflicting findings mentioned above could be attributed to methodological differences. In the Life-Study, obesity was defined by a BMI >30 kg/m^2 and grip strength ≤19.9 kg for women and ≤31.9 kg for men [14]. Central obesity has been associated with accumulation of visceral fat, metabolic disorders and increased

Table 4
Adjusted logistic regression models for the prevalence of lipid and glucose metabolism disorders, systolic and diastolic hypertension, metabolic syndrome, heart disease and stroke by abdominal obesity and dynapenia status in elderly people living in São Paulo, Brazil, 2010 –SABE study (n = 833) – Sensitivity Analysis.

	Non-Abdominally Obese (n = 435)	Abdominally Obese (n = 398)	Non-Dynapenic (n = 560)	Dynapenic (n = 273)
Low HDL cholesterol				
Adjusted model	1.00	1.61 (1.07–2.45)	1.00	1.48 (0.98–2.26)
High LDL cholesterol				
Adjusted model	1.00	1.09 (0.67–1.77)	1.00	1.08 (0.72–1.64)
High total cholesterol				
Adjusted model	1.00	1.38 (0.94–2.01)	1.00	0.87 (0.61–1.25)
Hypertriglyceridemia				
Adjusted model	1.00	2.13 (1.43–3.17)	1.00	1.09 (0.71–1.67)
Hyperglycemia				
Adjusted model	1.00	1.85 (1.27–2.69)	1.00	1.18 (0.79–1.77)
High HbA1c				
Adjusted model	1.00	1.25 (0.85–1.85)	1.00	1.48 (0.92–2.38)
High systolic blood pressure				
Adjusted model	1.00	1.08 (0.73–1.60)	1.00	0.97 (0.68–1.39)
High diastolic blood pressure				
Adjusted model	1.00	1.46 (0.97–2.20)	1.00	1.04 (0.71–1.52)
Metabolic syndrome				
Adjusted model	1.00	9.31 (6.08–14.26)	1.00	1.40 (0.94–2.09)
Heart disease				
Adjusted model	1.00	1.01 (0.70–1.47)	1.00	1.94 (1.31–2.88)
Stroke				
Adjusted model	1.00	1.07 (0.56–2.06)	1.00	1.43 (0.74–2.74)

Values of adjusted models denote odds ratio (95% confidence interval). Model adjusted for age, sex, race, schooling, alcohol intake, smoking and physical activity levels. Significance was accepted as $p < 0.05$.

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mortality risk in older adults [28,29], while high BMI values have been associated to lower mortality rates and better outcomes chronic diseases in older adults [30]. Such discrepancies highlight the problem of measuring obesity using BMI, which has been criticized by being a crude measure that fails to consider the relationship between lean mass and fat mass and the distribution of body fat [30]. Furthermore, the cut-off of 26/16 for handgrip strength has been recommended by the FNIH group as the best indicator of muscle weakness in older adults [18].

Our findings can be corroborated by a recent study using data from 4544 middle aged men and women from the US National Health and Nutrition Examination Survey and 6030 participants from the China Health and Retirement Longitudinal Study investigating whether grip strength normalized by BMI (grip strength in kg/BMI kg/m^2) could be a biomarker for cardio metabolic disease even using BMI instead of waist circumference in a alternative approach. The authors found that for each 0.05 reduction in this indicator there is an increase in the prevalence of hyperglycemia, hypertriglyceridemia and low HDL cholesterol serum concentrations [31].

The physiological mechanisms involved in this association between dynapenia obesity and metabolic syndrome are not yet completely understood. Many studies demonstrated that both low muscle strength and abdominal obesity are characterized by high levels of circulating pro-inflammatory cytokines that are recognized as risk factors for cardiovascular diseases [26,32]. Furthermore, Sayer et al. argued that muscles with less force generation capacity are generally smaller, and thus have lower glucose uptake capacity, which would lead to a hyperglycemic state and potentially trigger the metabolic syndrome cascade [33]. Other authors attribute the excessive accumulation of intramuscular triglyceride, frequently observed in individuals with loss of muscle strength, and the interruption of the glucose-fatty acid cycle as the potential causative factors of metabolic syndrome common to obesity and insulin resistance [6,33].

Barbat-Artigas et al. found that muscle strength is not always explained by muscle mass, mainly because of fat infiltration, among other factors [6]. Therefore, the present study provides new insights on the subject, since most of the studies to date has evaluated the role of sarcopenia in metabolic syndrome development, which generally is defined only by muscle mass and volume, without taken into consideration muscle strength.

An important finding from our study was the association between dynapenia and cardiovascular disease which was also found for dynapenic obesity but not for obesity alone. Despite the poor evidence available considering this association, there is some research showing similar results to ours. A potential explanation could be that cardiovascular disease appears to change the anabolic and catabolic protein metabolisms of the skeletal muscle by reducing the synthesis of myosin and, therefore, increasing muscle fatigue. This process leads to sarcopenia and consequently loss of neuromuscular strength. Such imbalances in the skeletal muscle metabolism appear to be more evident during acute periods of the cardiovascular disease and its hospitalization caused, partly, by signals from a myocardium with lesion and/or dysfunctional [34].

This study has some limitations to be considered. First, SABE study is focused on community-dwelling older adults, thus, the estimates may be smoothed, as the institutionalized older adults generally have a higher prevalence of dynapenia. However, the institutionalized population in Brazil is relatively small, minimizing this potential bias. Second, the population excluded from the analysis had a lower average glucose, glycated-haemoglobin and LDL-cholesterol as well as lower rate of people with total cholesterol $\geq$200 mg/dl and the glycated-haemoglobin $\geq$6.5% and, finally, lower prevalence of metabolic syndrome and higher prevalence of stroke. This may have underestimated the associations between D/AO with hyperglycemia and glycated-haemoglobin concentration as well as prevent us to found associations between D/AO with LDL-cholesterol and total cholesterol. It may also have caused an overestimation of their associations with the presence of metabolic syndrome. However, it is worth noting that the excluded population was confined to bed and unable to stand, which is explained by the higher prevalence of stroke in this group. Finally, as in any cross-sectional analysis, the study cannot be used to establish cause and effect.

This study has some important strengths. First, it was conducted in a large sample of older adults residing in the community of a huge urban city. To our knowledge, this is the first study to examine the effect of dynapenic obesity on blood pressure, lipid and glucose metabolic profiles, metabolic syndrome and cardiovascular disease in Latin America by using the cutoff of handgrip strength, recently recommended by the FNIH [17,18], a measure already validated and widely used in many populations, according to recent literature. In addition, an easy, feasible and recognized recommended measurement of obesity was used in this study [16], getting the diagnosis of people with dynapenic obese closer to clinical practice.

5. Conclusions

Thus, we conclude that dynapenic abdominal obesity was associated with high prevalence of lipid and glucose metabolism disorders and metabolic syndrome while dynapenia and D/AO were associated with high prevalence of heart disease, independently of sociodemographic and behavioral characteristics. Thereby, public health strategies need to be aware of dynapenic obese older adults, accompanying them closely to prevent and minimize the chance of having lipid and glucose metabolic disorders, and ultimately the metabolic syndrome, which increases the likelihood of developing other deleterious, undesirable and costly health-related conditions.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authorship

TSA and MAL conceived and designed the study; JLFS, YAOL and MLL acquired the data, TSA and JLFS analyzed the data; TSA, LPC, DPN, TRPB and ROM interpreted the data, TSA, MAL, LPC, ROM, LPC, TRPB, DPN, JLFS, YAOD and MLL wrote and revised with important intellectual content the paper. All authors read and approved the final manuscript.

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References

[1] Samper-Ternent R, Al Snih S. Obesity in older adults: epidemiology and implications for disability and disease. Rev Clin Gerontol 2012;22:10–34.
[2] Polotsky HN, Polotsky AJ. Metabolic implications of menopause. Semin Reprod Med 2010;28:426–34.

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[3] Jansen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr 2004;79:379–84.
[4] Rosenberg IH. Summary comments: epidemiological and methodological problems in determining nutritional status of older persons. Am J Clin Nutr 1989;50:1231–3.
[5] Clark BC, Manini TM. Sarcopenia # dynapenia. J Gerontol A Biol Sci Med Sci 2008;63A:829–34.
[6] Barbat-Artigas S, Rolland Y, Vellas B, Aubertin-Leheudre M. Muscle quantity is not synonymous with muscle quality. JAMDA 2013;14. 852.e1-7.
[7] Delmonico MJ, Harris TB, Visser M, Park SW, Conroy MB, Velasquez-Mieyer P, et al. Longitudinal study of muscle strength, quality, and adipose tissue infiltration. Am J Clin Nutr 2009;90:1579–85.
[8] Alexandre TS, Duarte YAO, Santos JLF, Wong R, Lebrão ML. Sarcopenia according to the European Working Group on Sarcopenia in older people (EWGSOP) versus dynapenia as a risk factor for disability in the elderly. J Nutr Health Aging 2014;18:547–53.
[9] Corona LP, Brito TRP, Nunes DP, Alexandre TS, Santos JLF, Duarte YAO, et al. Nutritional status and risk for disability in instrumental activities of daily living in older Brazilians. Public Health Nutr 2012;17:390–5.
[10] Alexandre TS, Duarte YAO, Santos JLF, Wong R, Lebrão ML. Sarcopenia according to the european working group on sarcopenia in older people (EWGSOP) versus dynapenia as a risk factor for mortality in the elderly. J Nutr Health Aging 2014;18:751–6.
[11] Stenholm S, Alley D, Bandinelli S, Griswold ME, Koskinen S, Rantanen T, et al. The effect of obesity combined with low muscle strength on decline in mobility in older persons: results from the InCHIANTI study. Int J Obes 2009;33:635–44.
[12] Bouchard DR, Janssen I. Dynapenic-obesity and physical function in older adults. J Gerontol A Biol Sci Med Sci 2010;65:71–7.
[13] Sénéchal M, Dionne IJ, Brochu M. Dynapenic abdominal obesity and metabolic risk factors in adults 50 years of age and older. J Aging Health 2012;24:812–26.
[14] Aubertin-Leheundre M, Anton S, Beavers DP, Manini TM, Fielding R, Newman A, et al. Dynapenia and metabolic health in obese and nonobese adults aged 70 years and older: the LIFE Study. JAMDA 2017;18:312–9.
[15] Moura RF, Andrade FB, Duarte YAO, Antunes JLF. Factors associated with adherence to influenza vaccination among non-institutionalized elderly in São Paulo, Brazil. Cad Saúde Pública 2015;31:1–11.
[16] National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. Obes Res 1998;6:51S–209S.
[17] Studenski SA, Peters KW, Alley DE, Cawthon PM, McLean RR, Harris TB, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci 2014;69:547–58.
[18] Alley DE, Shardell MD, Peters KW, McLean RR, Dam TT, Kenny AM, et al. Grip strength cutpoints for the identification of clinically relevant weakness. J Gerontol A Biol Sci Med Sci 2014;69(5):559–66.
[19] Sociedade Brasileira de Cardiologia/Sociedade Brasileira de Hipertensão/Sociedade Brasileira de Nefrologia. VI Diretrizes Brasileiras de Hipertensão. Arq Bras Cardiol 2010;95:1–51.
[20] Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; american heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. Circulation 2009;120:1640–5.
[21] National Institutes of Health. National heart, lung and blood institute. Third report of the national cholesterol education program. Expert panel on detection, evaluation and treatment of high blood cholesterol in adults. Final Report. NIH Publication; 2002.
[22] World Health Organization. Use of glycated haemoglobin (HbA1c) in diagnosis of diabetes mellitus: abbreviated report of a WHO consultation. 2011.
[23] Guedes DP, Lopes CC, Guedes JERP. Reprodutibilidade e validade do Questionário Internacional de Atividade Física em adolescentes. Rev Bras Med Esporte 2005;11:151–7.
[24] World Health Organization. Global recommendations on physical activity for health. 2010.
[25] Organización Panamericana de La Salud. Guía clínica para atención primaria a las personas adultas mayores. Santiago. 2003.
[26] Jurca R, Lamonte MJ, Barlow CE, Kampert JB, Church TS, Blair SN, et al. Association of muscular strength with incidence of metabolic syndrome in men. Med Sci Sports Exerc 2005;37:1849–55.
[27] Ardern CI, Janssen I, Ross R, Katzmarzyk PT. Development of health-related WC thresholds within BMI categories. Obes Res 2004;12:1094–103.
[28] Van Gall LF, Mertens IL, De Block CE. Mechanisms linking obesity with cardiovascular disease. Nature 2006;44:878–80.
[29] Grundy SM. Obesity, metabolic syndrome, and cardiovascular disease. J Clin Endocrinol Metab 2004;89:2595–600.
[30] Hainer V, Aldhoon-Hainerová. Obesity paradox does exist. Diabetes Care 2013;36(S2):S276–81.
[31] Peterson MD, Duchowny K, Meng Q, Wang Y, Chen X, Zhao Y. Low normalized grip strength is a biomarker for cardiometabolic disease and physical disabilities among US and Chinese adults. J Gerontol A Biol Sci Med Sci 2017. http://dx.doi.org/10.1093/gerona/glx031.
[32] Mankowski RT, Anton SD, Aubertin-Leheudre M. The role of muscle mass, muscle quality, and body composition in risk for the metabolic syndrome and functional decline in older adults. Curr Geriatr Rep 2015;4:221–8.
[33] Sayer AA, Dennison EM, Syddall HE, Gilbody HL, Phillips DI, Cooper C. Type 2 diabetes, muscle strength, and impaired physical function: the tip of the iceberg? Diabetes Care 2005;28:2541–2.
[34] Callahan DM, Toth MJ. Skeletal muscle protein metabolism in human heart failure. Curr Opin Clin Nutr Metab Care 2013;16(1):66–71.