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ORIGINAL CONTRIBUTION

Alcohol consumption is associated with DXA measurement of adiposity: the Pró-Saúde Study, Brazil

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Abstract
Purpose Evaluate the association between alcohol consumption and body adiposity.
Methods We analyzed cross-sectional data from a longitudinal investigation (Pró-Saúde Study), comprising a sample of 514 civil servants of both sexes (35–64 years). Daily alcohol consumption (wine, beer, and other alcoholic drinks) over the previous 6 months was assessed via food frequency questionnaire and categorized as no doses, up to 1 dose, and ≥1 dose. The total body mass, total fat mass (TFM), android fat mass (AFM), and gynoid fat mass (GFM) were measured via dual-energy X-ray absorptiometry. AFM (AFM%) and GFM (GFM%) were expressed as percentages relative to TFM. The ratio of AFM% and GFM% was calculated. Multiple linear regression analyses were performed after adjusting for age, calories not originating from alcohol, leisure-time physical activity and education.
Results Among nondrinkers, 59 % were women, and the age range between 45 and 54 years was predominant (44.3 %); 63.7 % of the nondrinkers were overweight/obese. Among drinkers of 1 dose or more/day, 67 % were males aged between 45 and 54 years (43.7 %); 69.1 % were overweight/obese. Among men, the daily consumption of ≥1 alcohol dose (13 g) was associated with an approximately 2 % ($\beta = 2.2$, IC = 0.077; 4.303) adjusted for age, calories not originated from alcohol, leisure-time physical activity and education, increase in TFM, compared to those who reported no alcohol consumption during the previous 6 months. This association was not observed among women. In both sexes, no associations were observed between alcohol consumption and the other evaluated parameters of adiposity.
Conclusion Among men only, daily consumption of ≥1 alcohol dose was associated with increased adiposity, despite the relatively low average alcohol consumption in this study population.

Keywords Alcohol · Body composition · Adiposity

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Introduction

The obesity incidence has grown rapidly worldwide and has become a major challenge to public health [1]. According to the Brazilian Household Budget Survey (2008–2009) [2], 50.1 % of men and 48 % of women are overweight [body mass index (BMI) ≥25.0 kg/m^2] [3]. In addition, epidemiological studies have reported a strong association between total abdominal adiposity, estimated by waist circumference, and an increased incidence of noncommunicable diseases, mainly hypertension and other cardiovascular diseases [4, 5]. Waist circumference is frequently used to classify men and women at risk (if WC >94 and 80 cm, respectively) of developing cardiovascular diseases [3].

Regarding dietary patterns in this process, evidence supports an association between alcohol consumption and total and abdominal body fat accumulation [6]. Alcohol, which has a high-energy value (7.1 kcal/g), is generally added to (rather than substituted for) the total number of calories consumed by individuals throughout the day. In addition,

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alcohol intake is associated with the caloric intake often present during celebrations [7, 8]. A direct influence of alcohol consumption on body fat accumulation is biologically plausible, via the inhibition of lipid oxidation consequent to metabolic alcohol degradation [9, 10].

Studies on the association between alcohol consumption and adiposity have yielded inconsistent results. Some studies have shown that alcohol consumption is directly associated with body fat, especially abdominal fat [11–16]. Others have indicated an inverse association, more evident among women [6, 17–20]. Still, other authors have not observed an association, even when subjects were analyzed separately according to sex [21–23].

The controversy surrounding the association between alcohol consumption and body composition can be partly explained by the different methods used to measure alcohol consumption [7, 24], and obesity, usually evaluated based on doubly indirect (a method validated against an indirect method such as densitometry) anthropometric parameters such as BMI [6, 25], waist circumference (WC), the waist-to-hip ratio (WHR) [26, 27]. The dual-energy X-ray absorptiometry (DXA) method, which provides more accurate measurements of the body composition and fat distribution [28], has been rarely utilized in epidemiological studies.

The objective of this study was to evaluate the association between alcohol consumption and adiposity as measured via DXA.

Methods

This cross-sectional study was nested within the Pró-Saúde Study (EPS). The EPS is a longitudinal prospective study of nonfaculty civil servants at a university located in the state of Rio de Janeiro, Brazil, focusing on the investigation of health-related social and behavioral determinants [29]. Four waves of data collection have been conducted among 3253 participants (1999, 2001, 2006, and 2012). During the fourth data collection phase, a sample of 520 participants was randomly selected to perform additional assessments including body composition analysis by dual-energy X-ray absorptiometry (DXA). Six participants did not perform DXA measurements. Therefore, this study comprised a stratified (by sex, age, and education level) random sample of 514 employees from the Pró-Saúde baseline population, corresponding to 16 % of the cohort participants. Data collection occurred between July 2012 and October 2013.

Alcohol consumption

A previously validated [30] food frequency questionnaire (FFQ) was utilized on the EPS and used to measure the exposure variable. The validation consisted in a comparison between FFQ and four 24-h recalls among 91 faculty and support staff from a Brazilian University. Participants were requested to indicate the frequency of alcoholic beverage consumption (8 options ranging from ≥3 times/day to never or almost never) and the average daily amount of alcoholic beverages, such as beer (1–2 glasses, 3–4 glasses, ≥5 glasses of 250 ml), wine (1 glass, 2 glasses, ≥3 glasses of 140 ml), and other alcoholic beverages (1 dose, 2 doses; ≥3 doses of 44 ml), consumed over the last 6 months. The amount of ethanol consumed (g/day) was calculated using data based on the food composition table from the *United States Department of Agriculture* (*USDA*). In Brazil, the National Secretary of Drug Policy adopts as standard 13 g of pure alcohol as being equal to 1 dose, which is equivalent to one 250-ml cup (beer); one 140-ml glass (wine). Daily consumption was subsequently categorized into no doses, less than 1 dose, and 1 dose or more.

Adiposity

The total body mass, total fat mass (TFM), and android and gynoid region fat masses (AFM and GFM, respectively) were measured via DXA with iDXA Lunar equipment (GE Healthcare, WI) and enCORE 2008 version 12.20 software [31].

For the full-body examination, participants were recommended to wear light clothing without metal accessories. Participants were placed in the dorsal recumbent position and asked to remain motionless until the end of the procedure. The android region was defined by the software as the region from the top of the iliac crest to 20 % of distance from chin to iliac crest; the gynoid region was defined as the upper limit below the pelvis cut line by 1.5 times the height of the android region. The height of the gynoid region was equal to two times the height of the android region. All scans were performed by the same, trained professional, and the equipment was calibrated daily according to the manufacturer's protocol. Measurements of the manufacturer-supplied calibration block (daily) and column calibration block (weekly) showed a <0.7 % coefficient of variation [31].

The TFM was expressed in kg and as a percentage. The AFM and GFM were expressed as percentages of the total fat mass obtained via DXA. The ratio of the AFM to GFM percentages (AFM/GFM) was derived.

Body mass index

Height in meters was measured using a stadiometer while individuals stood with bare feet in the orthostatic position and with their heads oriented according to Frankfurt's plan, creating an imaginary line from the outer ear channel to the inferior eye orbit [32]. Measurements were taken with the cursor at a 90° angle relative to the scale [32]. Subsequently, BMI was calculated using the ratio of body weight (in kilograms) to the square of height (in meters), and the cutoff points employed were those proposed by the World Health Organization for adults [3] and by Lipschitz [33] for the classification of participants older than 60 years. The BMI categories (overweight and obesity) have been grouped on the analysis due to two factors: the different BMI cut points proposed for adults and elderly and due to the low number of participants found in the most extreme obesity categories.

Co-variables

The following co-variables were investigated as potential confounders: sex, age, education, physical leisure activity, and calories not originating from alcohol. Age was categorized as 35–44, 45–54, 55–64, and 65–74 years. Education was categorized as "elementary or less", "high school", and "college education or higher". The leisure-time physical activity was investigated by a dichotomous question: "In the last 2 weeks, did you engage in any physical activity to improve your health and physical condition or for fitness or leisure purposes?" (yes vs. no). Calories not originating from alcohol consumption equal total calories minus calories originating from the alcohol consumption.

All researchers were trained, and all measurements underwent strict quality control with respect to the data collection process. In parallel with data collection, questionnaires were evaluated and coded by field supervisors, independently entered by 2 research assistants, and stored in EpiData 3.1 (EpiData Association, Odense, Denmark).

Data analysis

Continuous variables were expressed as median and percentile, and categorical variables were expressed as percentages. To compare averages of the endpoints in relation to stratified co-variables, Student *t* test was used for co-variables with only 2 categories and one-way ANOVA was used for categorical co-variables with ≥2 categories. Variables that reached statistical significance level at $p < 0.20$ were entered in the multivariate model. The variables leisure-time physical activity and education were kept in the final regression model, because of their known association with obesity.

The Shapiro–Wilk test was carried out to assess the normality of distribution. Subsequently, a logarithmic transformation was performed to meet the assumptions of normality.

Linear regression analyses were performed. Model 1 was adjusted for age (by category), Model 2 was adjusted for age (by category) and calories not originating from alcohol, and Model 3 was adjusted for age, calories not originated from alcohol, leisure-time physical activity and education. The *p* values for linear trend were estimated for the observed measures of associations.

All statistical analyses were performed using R software version 2.15 [34].

This study was approved by the Ethics in Research Committee of the Institute of Social Medicine at the State University of Rio de Janeiro, on October 18th, 2011 with registry CAAE 0041.0.259.000-11. All the participants signed an informed consent form.

Results

The characteristics of participants categorized by alcoholic beverage consumption are presented in Table 1. Among the nondrinkers, 59 % were women, and the age range between 45 and 54 years was predominant (44.3 %); 60.9 % have college-level education or higher; 63.7 % were overweight/obese according to their BMI; and 61.3 % reported not performing physical leisure activities over the 15 days preceding the interview. Among the 1 dose or more/day drinkers, 67 % were males; the age range between 45 and 54 years was predominant (43.7 %); 44.8 % have college-level education or higher; 69.1 % are overweight/obese; and 62.8 % reported performing physical leisure activities (Table 1).

Among all study participants, 40.8 % reported no consumption of any type of alcoholic beverage; the mean daily consumption was 4.3 g (±3.2 SD) and 22.1 g (±12.2 SD) alcohol/day for those who consumed up to 1 dose/day and for those who consumed more than 1 dose, respectively (Table 2).

The 1 dose or more drinkers had lower mean total fat mass (34.9 ± 8.0 %) and higher android fat mass (9.8 ± 1.2 %) than both nondrinkers (36.7 ± 8.5 and 9.3 ± 1.7 %, respectively) and drinkers of up to 1 dose (36.3 ± 8.2 and 9.3 ± 1.7 %, respectively) (Table 2).

The mean daily alcohol consumption was higher among men (2.9 g/day) in comparison with women (1.3 g/day). No gender differences were observed for DXA-measured adiposity parameters, except for the median total and gynoid fat mass percentage that were higher among women (24.8 and 4.5 %, respectively) when compared to men (27.2 and 3.8 %, respectively).

In men, association between alcohol consumption and the TFM% was observed after adjusting for age and calories not originating from alcohol (Table 3, model 2) and adjusted for age, calories not originated from alcohol, leisure-time physical activity, and education (model 3). The alcohol consumption of 1 dose or more/day was associated with a 2.2 % increase in the TFM; however, there

Table 1 General characteristics of study population—socioeconomic and anthropometric profiles, by alcohol average daily intake

	Nondrinker		Up to 1 dose		1 dose or more	
	N	%	*N*	%	*N*	%
Sex	212		210		92	
Male	87	41	100	47.6	61	67.0
Female	125	59	110	52.4	31	33.0
Age (years)	212		210		92	
35–44	35	16.5	39	18.6	11	11.7
45–54	93	44.3	92	43.8	41	43.7
55–64	65	30.6	58	27.6	35	38.3
≥65	19	8.6	21	10.0	5	6.3
Education[a]	212		210		92	
Elementary or less	20	9.4	19	9.1	14	14.9
High school	63	29.7	66	31.5	37	40.3
College education or higher	129	60.9	125	59.4	41	44.8
BMI (WHO e Lipschitz >60 years)	212		210		92	
Low weight	7	3.3	6	2.9	4	4.3
Normal	70	33.0	57	27.1	25	26.6
Overweight/obesity	135	63.7	147	70.0	63	69.1
Waist circumference	212		210		92	
No risk (<94 cm male/<80 cm female)	45	21.2	45	21.4	20	21.3
At risk (≥94 cm male/≥80 cm female)	167	78.8	165	78.6	72	78.7
Leisure physical activity[a]	212		210		92	
Yes	82	38.7	92	43.8	58	62.8
No	130	61.3	118	56.2	34	37.2

Pro-Saúde Study—Rio de Janeiro, Brazil, 2012–2013

[a] Self-reported

Table 2 Characteristics of study population—DXA-measured adiposity parameters and consumption profiles, by alcohol average daily intake

	Nondrinker		Up to 1 dose		1 dose or more	
	Mean	±SD	Mean	±SD	Mean	±SD
Age (years)	51.6	7.9	50.1	7.9	52.9	7.2
Height (m)	1.6	8.9	1.7	9.4	1.7	8.8
Total body mass (kg)	74.5	14.6	77.6	16.3	79.7	15.7
BMI (kg/m^2)	27.0	6.1	27.8	5.0	28.2	4.9
Waist circumference (cm)	96.3	12.3	97.0	12.3	99.7	12.6
Total fat mass (kg)	27.7	9.6	28.5	10.3	28.1	9.6
Android fat mass (kg)	2.5	1.1	2.7	1.2	2.8	1.2
Gynoid fat mass (kg)	4.8	1.8	4.9	1.9	4.5	1.7
AFM/GFM (ratio)	0.5	0.2	0.5	0.2	0.6	0.2
Fat mass (%)	36.7	8.5	36.3	8.2	34.9	8.0
Android fat mass (%)	9.3	1.7	9.3	1.7	9.8	1.2
Gynoid fat mass (%)	17.2	3.1	17.2	3.1	15.8	2.6
Alcohol consumption (g)[a]	0.0	0.0	4.3	3.2	22.1	12.2
Total calories (kcal)[a]	2420	944	2435	920	2929	1194

Pro-Saúde Study—Rio de Janeiro, Brazil, 2012–2013

[a] Self-reported

Table 3 Associations (multiple linear regression) between categories of daily alcohol consumption and proportions of total fat mass, android fat mass (AFM), gynoid fat mass (GFM), AFM and GFM percentages ratio and body mass index

Daily alcohol consumption[b] (dose)		Beta coefficient (IC) Crude				Beta coefficient (IC) Model 1[c]				Beta coefficient (IC) Model 2[d]			
		Male	*p* value*	Female	*p* value*	Male	*p* value*	Female	*p* value*	Male	*p* value*	Female	*p* value*
% of total fat mass	<1	1.393 (−0.470; 3.257)	0.167	−0.484 (−2.002; 1.033)	0.547	1.321 (−0.564; 3.206)	0.169	−0.574 (−2.081; 0.931)	0.540	1.321 (−0.547; 3.190)	0.163	−0.579 (−2.090; 0.930)	0.541
	1+	1.859 (−0.232; 3.951)		0.798 (−1536; 3.133)		1.808 (−0.294; 3.910)		0.573 (−1.748; 2.896)		2.126 (0.024; 4.229)		0.579 (−1.758; 2.896)	
% of android fat mass	<1	0.007[a] (−0.520; 0.065)	0.590	0.161 (−0.219; 0.541)	0.328	0.006[a] (−0.534; 0.065)	0.593	0.120 (−0.253; 0.494)	0.314	0.006[a] (0.006; 0.052)	0.589	0.125 (−0.249; 0.500)	0.314
	1+	0.029[a] (−0.036; 0.09)		0.426 (−0.158; 1.011)		0.028[a] (−0.037; 0.094)		0.365 (−0.210; 0.942)		0.037[a] (−0.287; 0.103)		0.371 (−0.206; 0.948)	
% of gynoid fat mass	<1	0.022[a] (0.017; 0.063)	0.123	0.008[a] (−0.030; 0.048)	0.551	0.024[a] (−0.016; 0.064)	0.122	0.011[a] (−0.026; 0.049)	0.527	0.024[a] (−0.016; 0.064)	0.124	0.017[a] (−0.026; 0.049)	0.528
	1+	−0.022[a] (−0.067; 0.022)		−0.022[a] (−0.082; 0.038)		−0.025[a] (−0.070; 0.019)		−0.015[a] (−0.074; 0.042)		−0.026[a] (−0.072; 0.019)		−0.015[a] (−0.074; 0.043)	
Ratio android fat mass/gynoid fat mass	<1	−0.018 (−0.068; 0.030)	0.242	0.013[a] (−0.056; 0.084)	0.491	−0.020 (−0.070; 0.029)	0.245	0.005[a] (−0.062; 0.073)	0.462	−0.020 (−0.070; 0.029)	0.243	0.006[a] (−0.062; 0.074)	0.463
	1+	0.027 (−0.027; 0.083)		0.075[a] (−0.033; 0.183)		0.029 (−0.026; 0.085)		0.061[a] (−0.043; 0.166)		0.035 (−0.021; 0.091)		0.061[a] (−0.043; 0.166)	
Body mass index	<1	0.037[a] (−0.068; 0.300)	0.133	−0.016[a] (−0.021; 0.321)	0.232	−0.001[a] (−0.070; 0.290)	0.145	−0.019[a] (−0.011; 0.435)	0.210	0.032[a] (−0.070; 0.294)	0.102	−0.018[a] (−0.017; 0.439)	0.198
	1+	0.044[a] (−0.027; 0.083)		0.021[a] (−0.031; 0.427)		−0.026[a] (−0.020; 0.850)		0.016[a] (−0.023; 0.767)		0.051[a] (−0.021; 0.091)		0.0181[a] (−0.017; 0.098)	

Daily alcohol consumption[a] (dose)		Beta coefficient (IC) Model 3[e]			
		Male	*p* value*	Female	*p* value*
% of total fat mass	<1	1.302 (−0.574; 3.179)	0.126	−0.490 (−2.029; 1.048)	0.578
	1+	2.190 (0.077; 4.303)		0.295 (−2.039; 2.630)	
% of android fat mass	<1	−0.016[a] (−0.546; 0.513)	0.599	0.157 (−0.219; 0.534)	0.310
	1+	0.323[a] (−0.272; 0.920)		0.319 (−0.254; 0.891)	

Table 3 continued

Daily alcohol consumption[a] (dose)		Beta coefficient (IC) Model 3[e]			
		Male	*p* value*	Female	*p* value*
% of gynoid fat mass	<1	0.309[a] (−0.317; 0.936)	0.139	0.129[a] (−0.026; 0.519)	0.517
	1+	−0.227[a] (−1.193; 0.218)		−0.128[a] (−0.720; 0.464)	
Ratio android fat mass/gynoid fat mass	<1	−0.021[a] (−0.071; 0.029)	0.258	0.008[a] (−0.060; 0.077)	0.491
	1+	0.036[a] (−0.020; 0.094)		0.053[a] (−0.050; 0.157)	
Body mass index	<1	0.210[a] (−0.133; 0.545)	0.101	0.477[a] (−0.118; 0.232)	0.189
	1+	−0.337[a] (−1.193; 0.218)		0.265[a] (−0.233; 0.018)	

Pró-Saúde Study—Rio de Janeiro, 2012–2013

* *p* values for linear trend

[a] Variable in log

[b] Reference category = no consumption

[c] Model 1—adjusted for age (categories)

[d] Model 2—adjusted for age (categories) and calories not originated from alcohol

[e] Model 3—adjusted for age (categories), calories not originated from alcohol, physical activity and education (categories)

was no statistically significant linear trend (p value for linear trend = 0.126). For both men and women, analyses of %AFM, %GFM, %AFM/GFM and BMI, crude and adjusted in model 1 (adjusted for age), in model 2 (adjusted for age and calories not originated from alcohol) and in model 3 (adjusted for age, calories not originated from alcohol, leisure-time physical activity and education) did not result in statistically significant associations. No association between alcohol consumption and DXA-measured adiposity was observed among women.

Discussion

This study aimed to contribute to a better understanding of the potential association between alcohol consumption and obesity using a highly precise method for measuring total body and area-specific adiposity. Although no statistically significant association was observed with the obesity markers routinely used in epidemiological studies, among men, a direct association was observed between alcohol consumption and the fat mass percentage obtained via DXA.

The investigation of the association between alcohol consumption and adiposity in several cross-sectional and longitudinal studies using doubly indirect anthropometric parameters, such as the total body mass, BMI, WC, and WHR yielded conflicting results. In women, some studies found an association with at least one of these indicators [12, 16, 23, 26]. However, the vast majority of studies, including one in Brazil, either found no association or observed an inverse association with alcohol consumption in women [6, 13, 17, 18, 20]. Among men, this association was found to be more consistent across several studies [12, 23, 26, 27], including studies in Brazil [13, 15]. Inverse or no associations between alcohol consumption among males have been less reported [35]. In a study of elderly men in which the TFM was assessed via DXA, increased total body fat was observed in drinkers compared to nondrinkers [36].

In our study population, the associations between alcohol consumption and body composition differed among men and women. Although the reported alcohol consumption was particularly low and may thus have contributed to the lack of associations among women, one must consider whether the differences in body composition between sexes might influence the strength and direction of these associations. The greater deposition of fat in women, compared to men and sex-specific differences in fat distribution in different body compartments has been well described [37, 38]. This distribution and mobilization of adiposity are associated with the physiological structure of each sex and are mainly influenced by characteristic hormones such as testosterone in men and progesterone and estrogen in women [37]. According to Vague [38], it is possible to classify body fat in two locations: android, in which excess fat is located around the abdominal region and of which a higher prevalence is observed among men and the gynoid (gluteofemoral), which is more prevalent among women.

Trunk fat comprises both subcutaneous and visceral fat and is strongly associated with the occurrence of some individual health complications, as well as a prognosis of cardiovascular disease, decreased life expectancy and associations with the secretion of inflammatory markers such as C-reactive protein [39]. Leg fat has been shown to be protective against heart and metabolic diseases [40, 41].

Studies have shown that among the various adipose tissue compartments, visceral adipocytes from the android region express higher levels of some receptors such as catecholamines and glucocorticoids, thus exhibiting greater susceptibility to lipolysis and a more unstable dynamic equilibrium; this differs from the predominantly subcutaneous fat in the gynoid region, which features lower receptor expression levels and performs more efficient storage functions [42–44].

A daily energy intake that exceeds the daily energy expenditure is predictive of weight gain. In turn, alcohol may represent an increase of 5–10 % of adult energy consumption, as it is the second-largest source of energy among all macronutrients [45]. The intake of a daily ethanol dose >25 g has been reported to stimulate lipogenesis and inhibit lipolysis in the peripheral tissues of healthy subjects [46]. In fact, studies that have assessed heavy drinkers (>2 doses/day or >30 g/day) or those who undergo repeated episodes of intoxication (*binge;* the consumption of >5 doses) have demonstrated direct associations with adiposity, especially in the abdominal area [26, 27, 47]. In our study, no associations were observed between android or gynoid adiposity and daily low-to-moderate alcohol consumption.

Studies that have evaluated the effect of moderate alcohol consumption (<2 doses) on health have demonstrated reduced risks of general mortality, cardiovascular disease, and thrombotic stroke [48–50]. This finding might be related to the action of ethanol on decreasing platelet aggregation and its effect on increasing high-density lipoproteins (HDL-C) [50, 51], in addition to the antioxidant activities in some drinks.

Anthropometric parameters such as BMI, WC, and WHR, which are used in most epidemiological studies, are good indicators of nutritional status and predictors of cardiovascular disease-related mortality and morbidity. These parameters can be measured inexpensively, rapidly, and simply, especially in large epidemiological studies. However, the specific localization and quantity of fat and the employed cutoff points have been questioned, since their sensitivity in identifying risk factors associated with obesity may vary among populations and age groups [52, 53]. Therefore, in epidemiological studies, the use of indirect evaluation methods that allow accurate quantifications of total body fat as well as its distribution and location using equipment such as DXA, reflects the determinants of adiposity. The DXA is considered the gold standard in validation studies of methods and equations, and it is noninvasive, accurate, and automatic [28].

The present study has both strengths and limitations. Its main strength has been the assessment of total body, abdominal, android, and gynoid fat as well as the AFM/GFM ratio as measured via DXA, which is considered the gold standard for body composition measurement [28], therefore overcoming the limitations of previous studies that used reported weights and doubly indirect anthropometric measurements such as BMI, WC, and WHR. Assessments of alcohol intake and food consumption are difficult to perform and prone to failure. The instrument we utilized has been validated in Brazilian populations, and according to Midanik [24], although frequent alcohol drinkers tend to underreport their consumption, self-reported alcohol consumption is one of the most specific [24] evaluation methods.

It should be noted that the interviews were conducted in the participants' work environment, possibly leading to an underestimation of alcohol consumption. Because our study did not include the assessment of additional potentially confounding factors, such as smoking status, medication use and menopause, we cannot rule out the possibility of residual confounding effects. Being a cross-sectional study, another limitation is the inability to establish temporality.

In addition, an exploration of the type of beverage consumed and a more detailed categorization of alcohol consumption could also improve the understanding of the mechanisms involved in the association between alcohol consumption and adiposity, but the low alcohol consumption reported by our study participants did not allow us to conduct such analyses, which might help to understand the mechanisms involved in the development of noncommunicable diseases related to alcohol consumption.

Our results suggest that low-to-moderate daily alcohol consumption was associated with increased adiposity in men, independently of age, nonalcohol calories intake, physical activity and education (categories). Statistically significant association was restricted to total body fat mass evaluated via DXA, with no evidence of association with fat distribution neither with the measured anthropometric indices. Given the high validity of our outcome measurements, this study findings strengthen available evidence about the influence of alcohol intake on fat accumulation, not necessarily restricted to abdominal region.

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

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