Lower protein and higher carbohydrate intake are related with altering metabolic syndrome components in elderly women: A cross-sectional study

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ABSTRACT

Background: Metabolic Syndrome (MetS) is an energy-disturbance disease associated with insulin resistance. Hence, the intake of energy-rich macronutrients might affect some MetS components. The aim of this study was to explore the association of ingested macronutrients with MetS components in older women.
Methods: A cross sectional study was conducted in 245 older women (≥60 years). Whole-body dual-energy X-ray absorptiometry was used to assess total body fat, percentage body fat (absolute and relative), and skeletal muscle mass. Venous blood samples were collected after a 12 h fasting to determine glucose, high-density lipoprotein (HDL-c), and triglycerides. Anthropometric measurements and resting blood pressure were also evaluated. Food consumption was assessed through the 24-hour dietary recall method, and the macronutrients were distributed by tertiles of consumption. The Student *t*-test, Mann–Whitney *U* test, and logistic regression analysis were used for statistical analysis.
Results: The MetS and non-MetS groups demonstrated similar food-energy intake and fat consumption. The MetS group presented lower protein and higher carbohydrate intake than the non-MetS group. Individuals in the lowest protein intake (< 0.72 g/kg/d) had greater odds of presenting abdominal obesity and impaired glucose levels. Higher consumption of carbohydrates was associated with lower HDL levels and higher hypertriglyceridemia. The chances of having MetS were increased by three times when ingesting either a low protein or high carbohydrate diet.
Conclusion: Either high carbohydrate or low protein intake would be risk factors for altering MetS components and the presence of MetS in elderly women.

1. Introduction

Aging is a process characterized by several changes in the different components of body composition, especially a decline in muscle mass and subcutaneous fat, with concomitant increase in visceral fat and intramuscular fat (Cruz-Jentoft et al., 2010). These alterations are of greater magnitude in older women, since postmenopausal women present a reduction in estrogen, which is a protective hormone against these age-related changes (Pal and Ellis, 2011; Ben Ali et al., 2016). Thus, an atherogenic profile has been observed in women in this phase with an increase in total cholesterol and low-density lipoprotein (LDL-

c), a decrease in high-density lipoprotein cholesterol (HDL-c), elevated blood pressure, and insulin resistance (Pal and Ellis, 2011; Taleb-Belkadi et al., 2016), resulting in an increased risk of developing metabolic syndrome (MetS) (Stefanska et al., 2015).

MetS is a set of several factors that promote important metabolic alterations, and can lead to cardiovascular diseases, type 2 diabetes mellitus, chronic inflammation, hepatic steatosis, and an elevated risk of atherosclerosis, among other consequences (Grundy et al., 2005; de la Iglesia et al., 2016). The etiology of MetS is multifactorial, and both genetic and behavioral factors may favor the development of this metabolic disorder (de la Iglesia et al., 2016). Among behavioral factors,

diet plays a very important role, especially in the elderly, given that these individuals are more susceptible to nutritional inadequacy as a consequence of isolation, use of medications that may disrupt nutrient absorption, reduction in gastric juice production, difficulty in chewing and swallowing, and reduction in appetite and sensory capacity, among other factors (Brownie, 2006; Saffrey, 2013).

Nutrients and dietary pattern have been related to the most commonly studied metabolic risk factors, such as hypertension, dyslipidemia, hyperglycemia, and abdominal obesity (de la Iglesia et al., 2016; Hong et al., 2012; de Oliveira et al., 2012; Song et al., 2017; Cho et al., 2017; Damiao et al., 2006), demonstrating the importance of diet composition in the prevention and treatment of MetS and/or its components.

Several studies have evaluated the relation between macronutrients and MetS (de Oliveira et al., 2012; Cho et al., 2017; Damiao et al., 2006; Chen et al., 2009; Freire et al., 2005; Ahola et al., 2017; Lee et al., 2016; Khayyatzadeh et al., 2016; Bruscato et al., 2010), and shown conflicting results. Some researchers have found associations between dietary fat and MetS (de Oliveira et al., 2012; Chen et al., 2009; Freire et al., 2005), while others have shown a relation between protein and/or carbohydrate dietary intake and MetS (Cho et al., 2017; Damiao et al., 2006; Lee et al., 2016; Khayyatzadeh et al., 2016). On the other hand, in people with type I diabetes diet composition was not associated with the presence of MetS (Ahola et al., 2017). The majority of these studies were conducted in adults and older people together, which may contribute to a biased interpretation as metabolism and dietary intake are expected to change throughout life. Indeed, Lee et al. (2016) observed a negative association between dietary fat and MetS only in adult males, whereas this relationship was not found in women or older people. Moreover, the presence of MetS components may represent an increased risk of cardiovascular disease and type II diabetes and its early identification could eventually lead to targeted interventions that prevent MetS development and therefore reduce chronic diseases.

Taken together these results suggest further research is needed to elucidate this question. However, the association between macronutrients and MetS or its components has been little explored in an apparently healthy elderly population, mainly the association between diet components and MetS components in older people. Thus, the purpose of the present investigation was to analyze whether macronutrient intake is associated with MetS components in older women.

2. Methods

2.1. Participants

Two hundred forty-five Brazilian older women volunteered to participate in this investigation. Recruitment was carried out through newspaper and radio advertising, and home delivery of leaflets in the central area and residential neighborhoods. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy and not performing any regular physical exercise more than once a week in the six months preceding entry into the project. This study is part of the Active Aging Project, a longitudinal cohort study designed to examine the role of resistance training on older women's health. Participants underwent a diagnostic graded exercise stress test with a 12-lead electrocardiogram reviewed by a cardiologist and were released with no restrictions for participation in this investigation. Written informed consent was obtained from all participants after a detailed description of investigation procedures had been provided. This investigation was conducted according to the Declaration of Helsinki and was approved by the local University Ethics Committee.

2.2. Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, PR, Brazil), with subjects wearing light workout clothing and no shoes. Height was measured using a stadiometer to the nearest 0.1 cm while subjects were standing without shoes. Thereafter, body mass index (BMI) was calculated as the body mass in kilograms divided by the square of the height in meters.

2.3. Body composition

Whole-body dual-energy X-ray absorptiometry (DXA) scans (Lunar Prodigy, GE Healthcare, ID 14739, Madison, WI, USA) were used to assess total body fat (BF), percentage of body fat (%BF), and appendicular lean soft tissue, according to previously described procedures (Tomeleri et al., 2016). Total skeletal muscle mass (SMM) was estimated by the predictive equation proposed by Kim et al. (Kim et al., 2004). Obesity was defined as body fat mass of ≥35% (Batsis et al., 2015) assessed by DXA. Previous test-retest scans of 12 older women measured 24–48 h apart resulted in a standard error of measurement (SEM) of 0.24 kg for SMM, 0.10 kg for BF, and 0.25% for %BF, and an intraclass correlation coefficient (ICC) > 0.99 for the variables.

2.4. Dietary intake

Food consumption was assessed by the 24-hour dietary recall method applied on three non-consecutive days of the week during a personal interview. A photographic manual of food portion size was used to improve the precision of dietary intake reporting (Monego et al., 2013). The homemade measurements of the nutritional values of food and supplementation were converted into grams and milliliters by the online software Virtual Nutri Plus (Keeple®, Rio de Janeiro, Rio de Janeiro, Brazil) for diet analysis. Some foods were not found in the program database and were therefore added from food tables (Pinheiro et al., 2009).

In order to reduce errors in the estimation of the usual consumption, which were obtained through the 24-hour dietary recall, the Multiple Source Method - MSM (https://msm.dife.de/) statistical program was used, which is a new statistical method to estimate usual food consumption (Haubrock et al., 2011; Harttig et al., 2011). This program generates information regarding the estimated usual intake of an individual, from the combination of the probabilities, using repetitions of 24-hour dietary recall or food records (Haubrock et al., 2011).

2.5. Metabolic syndrome components

Venous blood samples were collected after a 12 h fast, according to previously described procedures (Tomeleri et al., 2016) to determine glucose, HDL-c, and triglycerides (TG). Waist circumference was obtained at the midpoint between the last rib and iliac crest at the time of expiration. Two measures were taken and in situations in which the difference between the measurements was > 0.5 cm a third measurement was performed, with the median value being adopted as the reference (SEM = 0.51; ICC ≥ 0.99) (Gordon et al., 1988). Resting blood pressure (BP) assessment was performed using automatic, oscillometric equipment (Omron HEM - 7113). Participants attended the laboratory on three different days and, during each visit, remained seated at rest for 5 min with the cuff of the equipment in place on the right arm. Subsequently, several BP measurements were performed at one-minute intervals in order to obtain three consecutive measurements where the difference in systolic BP (SBP) and diastolic BP (DBP) readings differed by no > 4 mm Hg. The mean of the three measurements for each day was averaged across the three visits. This procedure produces very high inter-session reliability for SBP (SEM = 1.33 mm Hg; ICC = 0.99) and DBP (SEM = 1.11 mm Hg; ICC = 0.98). The procedures followed the

recommendations of the VI Brazilian Guidelines on Hypertension (2010). Mean blood pressure (MBP) was calculated using the formula $MBP = DBP + [0.333 \times (SBP - DBP)]$. MetS was diagnosed according to The Adult Treatment Panel III (Grundy et al., 2005).

Participants with three or more of the following five criteria were defined as having MetS: (1) waist circumference ≥88 cm; (2) systolic blood pressure ≥130 mm Hg and/or diastolic blood pressure ≥85 mm Hg; (3) triglycerides ≥150 mg/dL; (4) HDL < 50 mg/dL; and (5) glucose > 110 mg/dL.

2.6. Statistical analyses

The Shapiro Wilk test was used to verify data distribution. All data are expressed as mean ± standard deviation or median and interquartile interval. Differences in general characteristics, biochemical measurements and protein intake (g/kg/day) according to MetS status were determined using Mann–Whitney U test and to evaluate the other nutrients intake and median of blood pressure the Student t-test was performed. Dietary intake was separated into tertiles of consumption for analyses. Logistic regression was used to calculate the odds ratios (ORs) and their 95% CIs for MetS and its components, with individuals in the lowest tertile category of carbohydrates and lipids as the reference category, while the highest tertile category of protein was used as the reference category. ORs were adjusted for age, SMM, and %BF. For all statistical analyses, significance was accepted at $P < .05$. The data were analyzed using SPSS software version 20.0 (SPSS, Inc., Chicago, IL, USA).

3. Results

Two hundred and forty-five older women participated in the study, with an average age of 67.5 ± 5.2 years, of which 62% were obese. Table 1 contains the general characteristics of the sample distributed by the presence and absence of MetS. As expected, the groups differed in all MetS components. Additionally, subjects with MetS presented higher

Table 1
Body composition, metabolic syndrome components, and total energy and macronutrient intake of older women according to MetS prevalence (n = 245).

Variables	MetS		P
	No (n = 191)	Yes (n = 54)	
Age (years)	68 (64–71)	66 (64–69)	.08
Body mass (kg)	63 (55–71)	73 (67–83)	< .001
BMI (kg·m^{-2})	25.9 (23.3–28.5)	30.2 (26.7–34.5)	< .001
SMM (kg)	17.0 ± 2.5	19.5 ± 2.7	< .001
Total body fat (kg)	25.4 (20.1–35.0)	32.1 (26.4–40.8)	< .001
Body fat (%)	36.4 (30.4–41.2)	41.3 (35.5–44.0)	< .001
Total energy intake (kcal)	1307.0 ± 228.6	1444.5 ± 188.8	< .001
Carbohydrates (g)	180.5 (154.5–200.7)	201.7 (178.6–226.2)	< .001
Carbohydrates (%)	55.0 ± 6.9	56.0 ± 6.8	.91
Protein (g/kg/day)	0.88 (0.70–1.1)	0.75 (0.63–0.84)	< .001
Protein (%)	16.6 ± 3.2	15.4 ± 3.1	< .05
Lipids (g)	40.8 ± 12.7	46.2 ± 8.8	< .001
Lipids (%)	27.7 ± 5.9	28.8 ± 4.5	.185
Fibers (g)	12.4 ± 4.3	11.2 ± 4.0	.08
Glucose (mg/dL)	101 (94.5–108)	114 (105–121)	< .001
Waist circumference (cm)	83 (78–86)	92.5 (88–102)	< .001
HDL-c (mg/dL)	55 (49.5–64.5)	42 (37–47)	< .001
Triglycerides (mg/dL)	103 (84–130.5)	150 (130–152)	< .001
SBP (mm Hg)	118 (110–126)	126.5 (117–134)	< .001
DBP (mm Hg)	67 (61.5–71)	70 (64–75)	< .001
Median BP	83.4 ± 7.0	88.4 ± 7.8	< .001

Note. Data are expressed as mean ± SD or median and interquartile interval. BMI = body mass index; SMM = skeletal muscle mass; HDL = high-density lipoprotein; SBP = systolic blood pressure; DBP = diastolic blood pressure; BP = blood pressure.
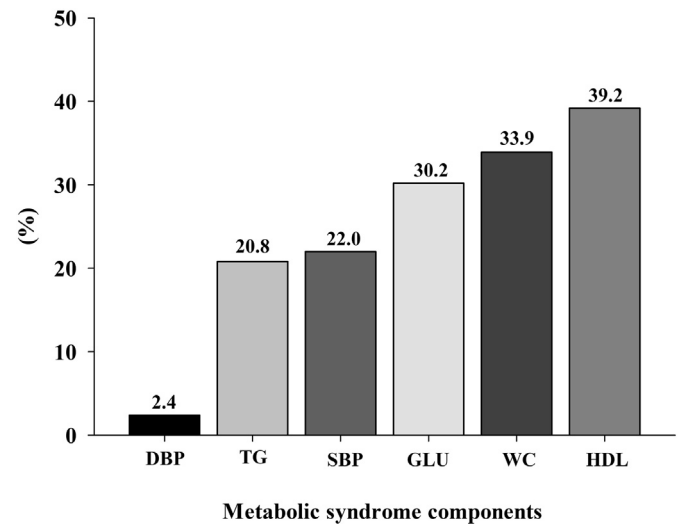

Fig. 1. Prevalence of metabolic syndrome components altered. Data are expressed in percentage. Note: DBP = diastolic blood pressure; TG = triglycerides; SBP = sytolic blood pressure; GLU = glucose; WC = waist circumference; HDL = high density lipoprotein.

body mass, BMI, SMM, and BF than those without MetS. Both groups presented similar fiber intake, however subjects with MetS showed higher intake of total energy, carbohydrates (g), and lipids (g), and lower intake of protein compared to subjects without MetS.

The prevalence of metabolic syndrome was 22%. The most frequently altered MS component was HDL (39.2) followed by waist circumference (33.9%) (Fig. 1). The percentage of older women who presented one altered MS component was 33.1% and two was 20.8% (Fig. 2).

Table 2 shows the results regarding the association between macronutrients consumed and the components of MetS. After adjustment by age, SMM, and %BF, the association between consumed macronutrients and components of MetS showed that participants with the lowest consumption of protein intake (third tertile) were more likely to demonstrate abdominal obesity (OR: 4.82; 95% CI: 2.04–11.33) and impaired glucose level (OR: 2.89; 95% CI: 1.37–6.24) than the reference group. On the other hand, participants in the second tertile of protein intake are less likely to develop hypertriglyceridemia (OR: 0.27; 95% CI: 0.11–0.68).

Regarding carbohydrate consumption, the participants with higher intake of consumption (in the third tertile) had twice the odds of
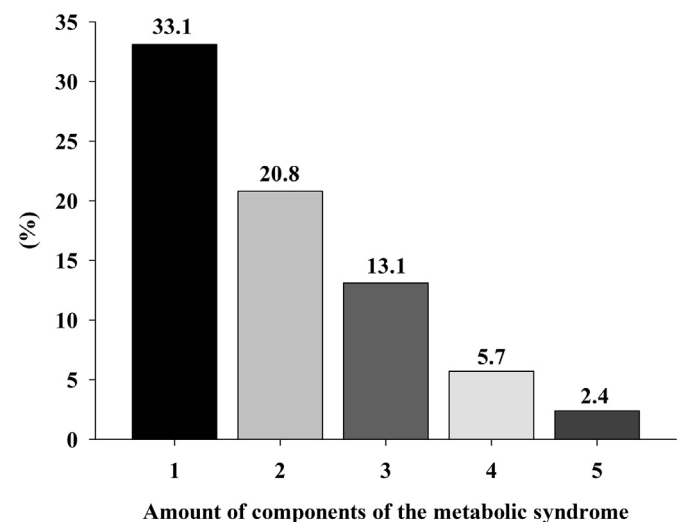

Fig. 2. Percentage of older women with one or multiple components of metabolic syndrome altered.

Table 2

OR and 95% CI for the association between macronutrients and MetS and its components (n = 245).

Variables	T1		T2		P	T3		P
	%	OR$_{adj}$ (95% CI)	%	OR$_{adj}$ (95% CI)		%	OR$_{adj}$ (95% CI)	
Protein (g/kg/d)	≥0.97		> 0.72 and < 0.97			≤0.72		
Low HDL cholesterol	26	1	32	0.85 (0.42–1.81)	.65	42	1.32 (0.64–2.75)	.48
Impaired fasting glucose	23	1	32	1.66 (0.80–3.60)	.18	45	2.89 (1.37–6.24)	< .05
Hypertriglyceridemia	35	1	20	0.27 (0.11–0.68)	< .05	45	1.62 (0.26–1.74)	.27
Elevated SBP	26	1	33	1.30 (0.57–2.95)	.52	41	1.56 (0.69–3.58)	.28
Elevated DBP	33	1	67	2.53 (0.20–31.54)	.46	0	–	–
Abdominal obesity	12	1	34	2.20 (0.96–5.33)	.07	54	4.81 (2.04–11.33)	< .001
MetS	13	1	35	1.87 (0.68–5.10)	.22	52	3.10 (1.14–8.46)	< .05
Carbohydrates (g)	≤172		> 172 and < 200			≥200		
Low HDL cholesterol	28	1	31	1.32 (0.66–2.67)	.43	41	2.52 (1.23–5.14)	< .05
Impaired fasting glucose	23	1	32	1.69 (0.86–3.40)	.13	45	1.61 (0.81–3.29)	.18
Hypertriglyceridemia	08	1	24	3.59 (1.08–11.00)	< .05	69	17.07 (5.51–52.93)	< .001
Elevated SBP	35	1	33	1.07 (0.51–2.25)	.85	32	0.99 (0.46–2.10)	.97
Elevated DBP	17	1	17	1.25 (0.05–28.3)	.88	68	7.89 (0.59–105.3)	.11
Abdominal obesity	37	1	33	0.81 (0.40–1.67)	.57	30	0.62 (0.29–1.31)	.21
MetS	19	1	31	1.86 (0.77–4.65)	.18	50	3.70 (1.52–9.02)	< .05
Lipids (g)	≤36		> 36 and < 46			≥46		
Low HDL cholesterol	34	1	33	0.84 (0.43–1.71)	.63	33	0.92 (0.47–1.84)	.82
Impaired fasting glucose	42	1	24	0.41 (0.21–0.84)	< .05	34	0.67 (0.35–1.30)	.24
Hypertriglyceridemia	31	1	33	1.11 (0.50–2.48)	.80	35	1.16 (0.52–2.54)	.71
Elevated SBP	31	1	39	1.37 (0.65–2.87)	.41	30	0.93 (0.43–2.00)	.85
Elevated DBP	0	1	83	–	–	17	–	–
Abdominal obesity	30	1	34	1.27 (0.61–2.66)	.53	36	1.43 (0.68–2.92)	.34
MetS	33	1	44	1.45 (0.66–3.25)	.36	23	0.59 (0.24–1.45)	.26

Note. All analyzes were adjusted for chronological age, skeletal muscle mass, and % body fat. MetS = metabolic syndrome; HDL = high-density lipoprotein; SBP = systolic blood pressure; DBP = diastolic blood pressure.

presenting low serum HDL-c (OR: 2.52; 95% CI: 1.23–5.14) when compared to the group with the lowest consumption. Increased carbohydrate intake was also positively associated with elevated serum TG concentrations, in this case in both the second (OR: 3.59; 95% CI: 1.08–11.00) and third tertiles (OR: 17.07; 95% CI: 5.51–52.93). Moreover, participants in the second tertile of lipid intake had a 59% lower chance of presenting a higher glucose level (OR: 0.41; 95% CI: 0.21–0.84). Overall, the greatest prevalence of MetS was found in women with the lowest consumption of protein (OR: 3.10; 95% CI: 1.14–8.46) and the highest carbohydrate intake (OR: 3.70; 95% CI: 1.52–9.02).

4. Discussion

The main finding of this study was the increased risk of developing MetS in older women with lower levels of protein intake and/or higher consumption of carbohydrates. Indeed, our findings partially extend the results of previous studies (Mirmiran et al., 2012; Dehghan et al., 2017; Layman et al., 2003; Song et al., 2014). Mirmiran et al. (Mirmiran et al., 2012), for example, showed that dietary protein from animal sources may provide favorable effects on cardio metabolic risk factors, especially in women. In addition, a higher ratio of dietary protein to carbohydrates is related to more efficient glycemic control and satiety during weight loss (Layman et al., 2003). Likewise, investigators have shown that diets high in carbohydrates have been related with MetS and its components (Song et al., 2014; Kwon et al., 2017; Ahn et al., 2017). A recent prospective cohort study showed that higher consumption of carbohydrates is associated with a higher risk of total mortality (Dehghan et al., 2017). Although we did not evaluate the quality of the carbohydrate consumed, we speculated that the participants are consuming more carbohydrates that are refined and with high glycemic index, since this type of macronutrient has been related to the prevalence of MetS and its components (Kirwan et al., 2016; Juanola-Falgarona et al., 2015).

However, our results are not in agreement with other studies (Freire et al., 2005; Bruscato et al., 2010; Skilton et al., 2008; Shirani et al.,

2015). For example, Freire et al. (Freire et al., 2005) did not find associations between protein intake and MetS, and observed a positive association between fat intake and MetS. Skilton et al. (Skilton et al., 2008) showed that a diet with high carbohydrate intake and low protein and fat intake might be protective against MetS. Shirani et al. (Shirani et al., 2015) did not observe an association between carbohydrate consumption and MetS.

Although the reasons for these conflicting results are not readily apparent, they may be related to factors such as the populations studied and type of analyses used. The majority of these studies did not separate adults from older people, which may lead to non-specific interpretations for each age group, since metabolism, body composition, and diet differ throughout life. In our study, for example, we decided to work only with elderly women, however our results didn't agree with Bruscato et al. (Bruscato et al., 2010) who also work with this population. These contradictory results can be explained by the methodology used to evaluate food consumption. Bruscato et al. (Bruscato et al., 2010) used a single 24-hour dietary recall to assess the diet, which may not reflect the usual consumption. In the present study, we used three 24-hour dietary recall and Multiple Source Method statistical program was used to reduce errors in the estimation of the usual consumption, generating information regarding the estimated usual intake of an individual. Moreover, Bruscato et al. (Bruscato et al., 2010) classified MetS according to International Diabetes Federation (IDF) while we use The Adult Treatment Panel III (ATP III), which may explain the difference in the prevalence of MetS in the Brazilian elderly population, since it are criteria with different cut points.

We also decided to separate the consumption into tertiles to identify how the quantity of macronutrients is related with MetS and its components, and we observed that this form of data analysis gave us interesting results. It should be noted that these results are important in diet prescription and management of macronutrient consumption in elderly women with the presence of the MetS and/or its components.

In the present study, it is not possible to establish causality between associations; however, we can speculate that these observed relationships may be related to several mechanisms. For example, higher

protein intake appears to increase satiety (Layman et al., 2003; Leidy et al., 2007), lean body mass (Leidy et al., 2007) and energy expenditure (Halton and Hu, 2004) and also reduce fat mass (Longland et al., 2016), leading to weight loss (Kim et al., 2016) and consequently a reduction in the risk of developing MetS. Although the mechanisms promoting protein-induced satiety are not clear, it is likely that the elevated leucine concentrations stimulate Mtorc1 in the hypothalamus resulting in decreased food intake (Cota et al., 2006). Moreover, an increase in energy expenditure from protein consumption can be provided through digestive processes and postprandial protein synthesis (Layman, 2013). Furthermore, higher protein diets are associated with improved insulin sensitivity and blood glucose levels (Tremblay et al., 2007). High protein intake also preserves SMM (Paddon-Jones and Leidy, 2014), and this is an important contribution since the loss of SMM (sarcopenia) is associated with insulin resistance, diabetes, hypertension, arterial stiffness, and the development of MetS (Moon, 2014; Sanada et al., 2010).

Higher carbohydrate intake was associated with an unfavorable lipid metabolism, with decreased HDL and increased triglycerides (Song et al., 2014). An excess of carbohydrate intake leads to increased production of triglycerides, possibly mediated by fructose. First, it serves as a substrate by adipocytes for de novo lipogenesis, generating new lipid vesicles and leading to hepatic TG synthesis and accumulation (Lim et al., 2010; Schwarz et al., 2015). Second, fructose does not suppress the hunger hormone ghrelin, resulting in excessive consumption (Van Name et al., 2015). Moreover, fat consumption has been associated with the glucose metabolism, however the mechanisms that explain this relationship need to be further elucidated, together with genetic factors and the type of fat intake (Huang et al., 2017; Hu et al., 2001). Despite this, Dehgan and colleagues (Dehghan et al., 2017) observed no effect of total fat or each type of fat on cardiovascular disease events.

The present study does have limitations that should be acknowledged. This study used a cross-sectional design which does not allow establishment of cause-and-effect relationships. Our sample was composed of only older women, so it cannot be assumed that the findings would be similar in other populations and we did not evaluate the level of physical activity, which could interfere with studied variables. We didn't evaluate the quality of food consumed, which could bring additional information to the present study.

Despite these limitations, a strong point of our study is the sample size (245 older women) and the significant relation between macronutrients (carbohydrates and protein) and MetS and its components, after adjusting for relevant covariates, specifically age and body composition, given the impact of certain body components on these variables.

5. Conclusion

Our findings indicated that in older women, the odds for the presence of MetS and its components are lower in women exposed to higher protein consumption and lower carbohydrate intake. Further studies using an adequate experimental design are required to elucidate these findings.

Disclosure statement

The authors report no conflicts of interest.

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