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RESEARCH ARTICLE

Metabolic syndrome and its association with changes in modifiable risk factors: Epifloripa aging study

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Abstract

Purpose To estimate the prevalence of Metabolic Syndrome (MetS) and its association with changes in modifiable risk factors in older adults from southern Brazil.

Methods A longitudinal study was performed with data from EpiFloripa Aging study. We defined MetS by the existence of three or more of the following risk factors for cardiovascular disease (CVD): waist circumference (WC) (≥ 92 cm in men and ≥ 87 cm in women); fasting glucose (≥100 mg/dl); decreased HDL cholesterol (<40 mg/dl in men and <50 mg/dl in women); hypertriglyceridemia (≥150 mg/dl) and blood pressure (≥130/85 mmHg). We evaluated the changes in modifiable risk factors (smoking, alcohol consumption, fruit and vegetable consumption, physical activity, and body mass index) between the two moments of the study (2009/10 and 2013/14). Directed acyclic graph and logistic regression models were used.

Results Among the 599 participants, the prevalence of MetS was 64.0% (95% CI, 58.7–68.9). In the adjusted analysis, those who remained or became persons who are overweight (OR = 4.59; 95% CI: 3.05–6.89) and those who remained or became insufficiently active (OR = 1.92; 95% CI: 1.23–2.98) were more likely to present MetS.

Conclusion Our findings suggest that being or becoming overweight and being or becoming insufficiently active are modifiable factors associated with MetS. These results highlight the need for developing preventive strategies for the observed risk indicators to mitigate the prevalence of MetS in older adults.

Keywords Elderly, healthy lifestyle · Public health surveillance · Health surveys · Brazil

Introduction

Metabolic Syndrome (MetS) is a complex disorder that comprises several cardiovascular risk factors related to central obesity, and those share mediators, pathophysiological pathways, and mechanisms. The main characteristics of MetS are hyperglycemia or insulin resistance, visceral fat, atherogenic dyslipidemia, and endothelial dysfunction [1].

Among the definitions of MetS, the newest proposition, Joint Interim Statement (JIS), recognizes that the risk associated with a certain length of waist circumference (WC) will vary according to the population, also criteria for changes

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in glucose and lipid metabolism, and high blood pressure. The document also asserts that drug treatment may be an alternative indicator for some risk factors [2].

Even though there is no universal criterion for its detection and regardless of the parameters adopted for its identification, the prevalence of MetS is high among older adults. Metabolic syndrome and Arteries REsearch (MARE) Consortium showed that the MetS presents an age-associated increase in its prevalence that was more than 30% in Europeans of and 70 years or more [3]. According to the National Health and Nutrition Examination Survey (NHANES 2003 and 2006), among Americans between 60 and 69 years old, 59.3% had MetS; and in those aged 70 and over, 44.9% had this disease [4]. For Brazil, data from the National Health Survey – 2013 (Portuguese acronym, PNS) estimated the prevalence of 23.2% among those aged 60 and over [5].

The MetS prevalence depends on non-modifiable and modifiable risk factors and has been associated with an increase in the risk for cardiovascular disease and type 2 diabetes [6]. Smoking, unhealthy dietary habits, physical inactivity, and alcohol abuse are the group of modifiable risk factors that account for a significant number of deaths from chronic non-communicable diseases (NCDs) and an essential fraction of the syndrome burden due to these illnesses [6].

In Brazil, the MetS context and its association with modifiable risk factors in older adults are little explored [7, 8], mainly at the population level [9]. Therefore, this study aims to estimate the prevalence of MetS and its association with changes in modifiable risk factors in older adults from Southern Brazil. The hypothesis of the present study is that, in older adults, tracking of smoking, drinking, physical inactivity, inadequate intake of fruits and vegetables, and obesity increases the likelihood for metabolic syndrome.

Methods

This epidemiological study analyzed data from EpiFloripa Aging survey, a longitudinal, population, and home-based study. EpiFloripa Aging survey was carried out in a coastline city (Florianópolis) in Southern Brazil. This manuscript used as the reference population the older adults of baseline (2009/2010) and follow-up in 2013/2014. Further information about the survey methods and sampling procedures of EpiFloripa Aging may be found in the previous manuscript [10].

In 2009–2010 (baseline data), interviews were carried out with a random sample of 1702 individuals (≥ 60 years). Of those, 217 died. For the second wave (2013–2014), 1485 first phase participants were considered eligible; 159 were considered losses, totaling 1197 interviews. All 1197 participants were invited to participate in the next stage of the study, in which complementary exams were carried out. Of the 604 older adults who completed the exams, 599 composed the analytical sample of this study.

The EpiFloripa Aging study was approved by Institutional Human Ethics Committee (CAAE: 731313.0.0000.0121), and all participants signed an informed consent form.

Outcome

We defined MetS according to Joint Interim Statement (JIS) criteria [2]. A diagnosis was established when there are ≥ 3 of these risk factors: i) waist circumference ≥ 92 cm for men and ≥ 87 cm for women [optimal cutoff points for waist circumference in the definition of Mets for Brazilians with 60 years and over] [11]; ii) fasting glucose ≥ 100 mg/dl or drug treatment for elevated glucose; iii) HDL-C < 40 mg/dL for men and < 50 mg/dL for women, or drug treatment for low HDL-C (fibrates and nicotinic acid); iv) triglycerides ≥150 mg/dl or drug treatment for this lipid abnormality (fibrates and nicotinic acid) and; v) Systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85 mmHg, or taking antihypertensive drug treatment.

Independent variables

The following were considered modifiable risk factors: smoking, alcohol consumption, fruit and vegetable consumption, physical activity, and body mass index. These variables were characterized according to the changes between the baseline (2009/10) and follow-up data (2013/14). We identified the individuals who remained in the same category as the baseline and those who changed categories to which category they changed [12].

a) Smoking - The valid answers were: no, smoked and quit, and currently smokes. For statistical purposes, individuals were classified as never smokers and ex-smokers/current smokers. The change variable was categorized as: remained without smoking or quit smoking; continued smoking, or started smoking.
b) Alcohol consumption according to the first three questions from the Alcohol Use Disorders Identification Test (AUDIT) [13] [remained without drinking or stopped drinking; continued drinking or started drinking (non-abusive and abusive consumption)].
c) Daily consumption of fruits and vegetables (continued consuming or started to consume ≤ 4 servings/day; continued consuming or started to consume ≥ 5 servings/day).
d) Body mass index (maintained the healthy weight or became persons who are normal weight; maintained the overweight or became persons who are overweight): BMI ≥ 27 kg/m^2, overweight and BMI < 27 kg/m^2, nor-

mal weight. These cutoff values have been adapted from Brazilian Food and Nutritional Surveillance System recommendations (Portuguese acronym, SISVAN) [14].

e) We used the long version of the International Physical Activity Questionnaire (IPAQ) [15] to assess leisure-time and commuting physical activity (remained or became physically active; remained or became physically inactive): yes, ≥ 150 min/week; no, < 150 min/week.

Adjustment variables (2009/2010)

Age (continuous variable); education level (without formal education; 1 to 4 years; 5 to 8 years; 9 to 11 years and ≥ 12 years); and family structure (live alone, live with others of the same generation [partner or others of the same age]; and live with others of a different generation [live with children or grandchildren]). Per capita income given in quartiles; expressed in the Brazilian currency of Reais, where R$ 1.76 was the equivalent of U$ 1 in July 2010: ≤ 1stquartile (R$ 356.66); > 1st quartile and ≤ 2nd quartile (R$ 356.67 to R$ 750.00); > 3rd quartile and ≤ 4th quartile (R$ 750.01 to R$ 1521.66); and > 4th quartile (≥ R$ 1521.67). The Mini-Mental State Examination (MMSE) n was employed to identify the cognitive function and used as a continuous variable [16].

Data analysis

Descriptive analyses were expressed as mean, standard deviations, absolute and relative frequencies and 95% confidence interval (CI). The association between independent variables and MetS was examined through crude and adjusted logistic regression [Odds Ratio (OR) and 95%CI]. The interaction between the independent variables and sex concerning the outcome (MetS) was tested using a term with the product between the modifiable variables and sex in a logistic regression model for each exposure. There was no interaction, and the sample was not stratified by sex.

We used the Directed Acyclic Graph (DAG) in DAGgitty software version 3.0 [17] to identify biases (confusion and selection of variables), helping to define the variables to be included in the adjustment to avoid interfering with identifying/interpreting the causal effect [18]. We chose to make one DAGs for each modifiable variable and its relationship with the outcome (MetS). The minimum adjustment obtained for each DAG, determined by the backdoor path criterium [17], was as follows (Supplementary material): MetS and leisure-time and commuting physical activity - adjusted for age, education, income, alcohol consumption, smoking, and cognition; MetS and consumption of fruits and vegetables - adjusted for age, education, income, alcohol consumption, and smoking; MetS and alcohol consumption - adjusted for age, education, income and smoking; MetS and smoking - adjusted for age, education, income, and alcohol consumption; MetS and BMI - adjusted for fruit and vegetable consumption, alcohol consumption, age, income, and leisure-time and commuting physical activity.

The data were analyzed using the Statistical Package for Social Sciences for Windows version 21.0 (SPSS, Chicago, IL) utilizing the "complex sample" module, incorporating sampling weights. The significance level was set at 5% ($p \leq 0.05$) and the confidence interval at 95%.

Results

The present study sample was composed of 599 individuals (391 women), aged between 63 and 93 years (72.3 ± 6.3 years), in 2013. The prevalence of MetS was 64.0% (95% CI: 58.7–68.9). Regarding cognitive function, the overall mean of MMSE was 26.3 ± 3.7 points in the baseline.

Table 1 shows the sample distribution according to the variables studied. Most of the participants had one to four years of education (33.8%) and lived with others of the same generation (44.0%). There was a higher prevalence of individuals who remained without smoking or who smoked and quit, who continued drinking or started drinking alcohol. Individuals who kept consuming or started to eat ≥ 5 daily servings of fruits and vegetables were more prevalent than who continued consuming or started to consume ≤ 4 servings. There was a higher prevalence of individuals who remained or became overweight and who remained or became physically active. The prevalence of MetS was statistically higher only for individuals who remained or became persons who are overweight (79.7% vs. 42.4% for maintained the healthy weight or became persons who are normal weight) (Table 1).

Table 2 shows the results of the associations between MetS and modifiable risk factors. First, there was a crude association between those who were overweight or became overweight (OR = 4.59; 95% CI: 3.05–6.89) and MetS. After adjusting for the minimum set of variables, the association remained, and those who were or became overweight were 4.71 (95% CI: 3.01–7.39) times more likely to have MetS when compared to their peers. Those who remained or became insufficiently active had 1.92 (95% CI: 1.23–2.98) more chances of having MetS, when the analysis was adjusted for age, education, income, alcohol consumption, smoking, and cognition.

Discussion

The present study examined the prevalence of MetS and its association with changes in modifiable risk factors in the older adults of Florianópolis in Southern Brazil. The MetS

Table 1 Sample distribution according to studied variables. Florianópolis, Santa Catarina, Brazil, 2009/2010 and 2013/2014

Variables	n (%)[a]	% MetS (CI95%)[a]	*p* value[*]
Sex (n=599)			0.901
Male	208 (37.1)	63.5 (54.4–71.8)	
Female	391 (62.9)	64.3 (57.4–70.6)	
Education (years) (n=598)			0.371
No formal education	41 (6.3)	63.9 (43.8–80.1)	
1 to 4	216 (33.8)	62.6 (54.4–70.3)	
5 to 8	105 (17.9)	68.6 (56.5–78.6)	
9 to 11	94 (18.7)	62.3 (50.1–73.1)	
≥ 12 years	142 (23.3)	64.0 (52.9–73.8)	
Per capita income (quartiles) (n=585) [§]			0.432
≤ 1st quartile	146 (22.4)	59.2 (48.3–69.3)	
> 1st quartile and ≤ 2nd quartile	147 (25.9)	67.4 (56.5–76.7)	
> 3rd quartile and ≤ 4th quartile	146 (25.4)	67.4 (58.0–75.5)	
> 4 th quartile	146 (26.3)	60.0 (51.5–67.9)	
Family structure (n=599)			0.953
Live alone	98 (16.8)	–	
Live with others of the same generation	237 (44.0)	63.3 (51.6–73.6)	
Live with others of a different generation	264 (39.2)	63.5 (56.1–70.4)	
Smoking (n=599) [†]			0.112
Remained without smoking or quit smoking	556 (91.9)	64.9 (59.2–70.2)	
Continued smoking or started smoking	43 (8.1)	53.3 (40.0–66.0)	
Alcohol consumption (n=599) [†]			0.296
Remained without drinking or stopped drinking	508 (81.0)	62.8 (57.4–67.9)	
Continued drinking or started drinking	91 (19.0)	69.1 (57.0–79.1)	
Consumption of fruits and vegetables (n=599)[†]			0.222
Continued consuming or started to consume ≥ 5 servings	468 (77.4)	62.3 (56.5–67.7)	
Continued consuming or started to consume ≤ 4 servings	131 (22.6)	70.0 (58.1–79.6)	
Body mass index (BMI) (n=590) [†]			≤0.001
Maintained the healthy weight or became normal weight	258 (42.2)	42.4 (35.5–49.7)	
Maintained the overweight or became overweight	332 (57.8)	79.7 (73.2–84.9)	
Physical Activity (n=599) [†]			0.154
Remained or became physically active	340 (59.2)	61.4 (54.8–67.6)	
Remained or became physically inactive	259 (40.8)	67.8 (60.3–74.4)	

Subtitles: MetS: Metabolic Syndrome; 95% CI: 95% Confidence Interval; [a] Percentage values weighted by the sampling plan; [*]p value of the chi-square test; [§]Minimum wage in 2010: R$ 510.00; [†]Variables with data referring to the baseline (2009/2010) and follow-up (2013/2014)

had a prevalence of 64.0% and were associated with remaining overweight or becoming overweight and remaining or becoming physically inactive.

The estimate of the high prevalence of MetS in older adults is compatible with findings from Asian countries [19, 20] and Western countries [21–23], including Brazil [5, 9, 24], regardless of the diagnostic criteria adopted. These estimates ranged from 22.8% to 72.9%, in China [20] and Mexico [23], respectively. It is noteworthy that the comparison between prevalence estimates concerns the sampling criteria, characteristics of the populations. Also, the prevalence of Mets is found to be different according to the diagnostic criteria. In the current study, we decided to use the JIS criteria, which considers cutoff points for WC specific to ethnicity and three or more risk factors for its determination, besides its use by several scientific entities [2].

Surveys with older adults that employed the same diagnostic criteria as this study found 23.2%, 54.9%, and 66.0% of estimated prevalences in Brazil ([5], Colombia [21], and Ecuador [22], respectively. It is essential to highlight that, unlike the present study and others [21, 22], in the Brazilian survey [5], medical diagnoses for diabetes and hypercholesterolemia were self-reported, which may underestimate the prevalence of MetS.

In the current study, those who maintained the overweight or became persons who are overweight were more likely to

Table 2 Crude and adjusted analysis on modifiable behavioral lifestyle factors associated with MetS. Florianópolis, Santa Catarina, Brazil, 2009/2010 and 2013/2014

Variables	Crude analysis OR(CI95%)	Adjusted analysis OR (IC95%)
Physical Activity ‡		
Remained or became physically active	1	**1**
Remained or became physically inactive	1.23 (0.84–1.80)	**1.92 (1.23–2.98)**
Consumption of fruits and vegetables **		
Continued consuming or started to consume ≥ 5 servings	1	1
Continued consuming or started to consume ≤ 4 servings	1.34 (0.79–2.28)	1.36 (0.80–2.30)
Alcohol consumption §		
Remained without drinking or stopped drinking	1	1
Continued drinking or started drinking	1.46 (0.87–2.46)	1.34 (0.73–2.45)
Smoking †		
Remained without smoking or quit smoking	1	1
Continued smoking or started smoking	0.72 (0.36–1.43)	0.60 (0.29–1.26)
Body mass index ⁘		
Maintained the healthy weight or became normal weight	**1**	**1**
Maintained the overweight or became overweight	**4.59 (3.05–6.89)**	**4.71 (3.01–7.39)**

OR: Odds Ratio; 95% CI: 95% Confidence Interval; MetS: Metabolic Syndrome; BMI: Body mass index; CVD: cardiovascular disease; ‡DAG model (directed acyclic graph) for MetS and Physical Activity (leisure-time and commuting): Adjusted for age, education, per capita income in quartiles, alcohol consumption, smoking, and cognition; **DAG model for SM and Fruit and vegetable consumption: Adjusted for age, per capita income in quartiles, alcohol consumption, smoking, CVD and education; §DAG model for MetS and alcohol consumption: Adjusted for age, education, per capita income in quartiles and smoking; †DAG model for SM and Smoking: Adjusted for age, education, alcohol consumption and per capita income in quartiles; ⁘DAG model for MetS and BMI: Adjusted for fruit and vegetable consumption, alcohol consumption, age, per capita income in quartiles and physical activity (leisure-time and commuting)

have MetS. Although body fat distribution in a peripheral pattern is metabolically less critical than a central accumulation of body fat, these results were expected. The literature confirms our data, which indicates an association between obesity and MetS [9, 25]. High body mass index is highly associated with diabetes [26], hypertension [27], and dyslipidemia [28], pathologies that, in turn, are components of MetS. It is well-known that the aging process is associated with changes in body composition, loss of lean body mass, and increased and redistributed body fat (accumulation in the trunk/visceral area and less in the peripheral/subcutaneous regions) [29]. The accumulation of visceral fat is associated with obesity and different cardiometabolic diseases, which may be enough to trigger the components of MetS [30]. Whatever may trigger the obesity-associated inflammation, its relevance in the pathogenesis of related comorbidities is undeniable [31].

Obesity without the occurrence of MetS, sometimes called metabolically healthy obesity, is not a stable and workable condition for extended periods. This metabolically favorable condition appears to be transitory, and most individuals with this condition end up developing MetS at some moment of life unless they lose body weight [31]. However, up to 30% of obese individuals are metabolically healthy and present insulin sensitivity similar to healthy normal-weight individuals [32].

The results showed that individuals who remained or became physically inactive were more likely to have MetS. This finding is consistent with data from the *SABE* survey that showed that active older adults were 33% less likely to have MetS when compared to physically inactive older adults [24]. It is known that physical activity improves individual risk factors for MetS. However, the domain and intensity of physical activity necessary to prevent or control MetS are controversial. Improving physical activity levels seems to be an effective goal for preventing and controlling MetS. Adult population data (18 to 75 years old) from the Canary Islands showed a gradual and inverse relationship of energy expenditure in leisure-time physical activity with MetS, except for light-intensity physical activity [33]. The results of a meta-analysis of prospective cohort studies showed that a higher level of leisure-time physical activity was associated with a lower risk of MetS. Also, the moderate leisure-time physical activity showed a poor association with incident MetS compared to those who were inactive [34]. The possible effects of regular physical activity on MetS include reducing glucose levels and visceral fat accumulation in the abdomen [35] and improving lipid profile and blood pressure [36].

In the present study, no associations were found between changes in smoking and alcohol consumption habits and metabolic syndrome. The relationship between smoking, alcohol consumption, and MetS are controversial. Data from a large population-based cohort study (n = 59,467) showed that smoking was associated with a higher risk of MetS in both sexes and all BMI categories [37]. However, in a study conducted in Portugal with 4004 individuals (53.2 ± 16,3 years) MetS was significantly (p = 0.001) less frequent in smokers [38]. It is important to note that in this study, the percentage of smokers in the sample was small compared to data from other studies [37, 38], and smoking was not quantitatively evaluated. The inconsistent results between studies may be due to differences in study design, exposure levels, definition of outcome, and statistical analyses.

Concerning alcohol drinking and MetS, our findings agree with a previous population-based study with Italian older adults [39], although our study did not quantitatively assess alcohol consumption. The authors found no association between alcohol consumption and MetS prevalence and incidence (follow-up, ~ 3.5 years). Differently, data from 10,037 Korean adults showed associations between very light drinking (.1–5.0 g/day) and lower prevalence of MetS in both sexes [40]. Also, in a prospective study with the adult population of US men, all alcohol consumption levels were associated with a lower risk of MetS incidence [41]. The different definitions of MetS, ethnic aspects, divergence in measuring alcohol drinking, and interactions with other lifestyles aspects may explain the controversy in studies results.

This study has limitations and strengths. One limitation concerns the non-probabilistic sample, which makes it impossible to extrapolate the results. Although the EpiFloripa Aging survey was designed with a representative sample of the older adult population of Florianópolis, the attendance to perform clinical exams did not include the entire sample selected, resulting in participation bias. When comparing the follow-up respondents and those who underwent clinical examinations, there were no differences concerning sex, education, income, and marital status. However, those who underwent clinical examinations were older, less physically active, less dependent, had a better cognitive function, and had lower depressive symptoms [10].

The second limitation is that MetS was only evaluated in the follow-up, which made it impossible to compare it from the baseline. Another limitation is the modifiable characteristics that did not determine when the individual started or ended a specific activity/action. Although using self-reported measures to assess the aspects of change may lead to information bias, it is noteworthy that the instruments used were validated and widely used in epidemiological studies [42, 43].

Among the study's strengths, methodological rigor is emphasized in all stages of the EpiFloripa Idoso study. The assessment of MetS was conducted using the most current diagnostic criteria established in the literature. The second strength refers to the use of biochemical parameters that directly assessed fasting blood glucose, HDL cholesterol, and triglycerides, besides direct measures of WC, body mass, and height (to determine the BMI). Another strength was the use of Targeted Acyclic Graphics (DAGs), a visual tool that enables the identification of biases and assists in defining the minimum set of adjustments for confounders. It is also noteworthy that the modifiable characteristics investigated are considered modifiable risk factors for MetS and essential targets in developing strategies for the health promotion of the population.

Conclusion

The prevalence of MetS in the present study was high, and our findings partially confirm the study hypothesis. The findings suggest that staying overweight or becoming overweight and staying or becoming physically inactive are associated with MetS. These results highlight the need for developing preventive strategies for the observed risk indicators to mitigate the prevalence of MetS in older adults. Therefore, it is crucial to expand the multidisciplinary view of health promotion, considering the behavioral determinants and the biological and social determinants of MetS.

The adoption of coping measures means that even though it refers to a disease of complex management and multifactorial character, MetS is a changeable condition if treated early. Although in this study, no association was found between insufficient consumption of fruits and vegetables and MetS, these factors are likely to be encouraged in health promotion strategies. Likewise, the non-association between alcohol consumption, smoking, and MetS does not exempt the proposition of strategy to reduce the abusive consumption of alcohol and smoking. It is recommended to intensify community strategies to promote healthy lifestyle habits, encouraging individuals to make specific diet and physical activity changes. Encouraging participation in physical activity groups in the neighborhoods would be an extra step towards keeping body weight. Such propositions can improve health indicators, especially cardiometabolic indicators, reduce disabilities, public health expenses, and reduce mortality risk.

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