Impacts of Food Consumption on Biochemical Markers and Anthropometric Variables of Women With Metabolic Syndrome

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Abstract

Background: Metabolic syndrome (MetS) is a group of diseases characterized by insulin resistance. MetS has a high prevalence among women, and food intake impacts MetS. Also, MetS is related to a high level of inflammation in the individual; however, the impacts of whole diets in biochemical and anthropometrical markers and the effects on MetS need to be elucidated. In this case, the objective of this study was assess the relationship between food intake, biochemical and anthropometrical markers in women with MetS.

Methods: This is a cross-sectional study, in which one hundred and twenty-two women participated in the assessment of biochemical (glycated hemoglobin, glycaemia, insulin, uric acid, total cholesterol, HDL-c, LDL-c, triglycerides, C-reactive protein) and anthropometrical (body mass, height, waist circumference - WC) variables. The participants also completed blood pressure and the 24-hour dietary recall assessments. Out of the 122 participants, 44 (36%, age: 59 ± 11 years) had MetS and were included in the analysis.

Results: The consumption of monounsaturated fats had a direct relationship with glycaemia ($b=7.27$), whereas the consumption of fibers had an inverse relationship with body mass ($b=-0.71$) and WC ($b=-0.56$).

Conclusion: The intake of monounsaturated fats and fiber was related to higher blood sugar levels and lower body mass and WC, respectively. These relationships elucidate and highlight the significance and importance of adequate diet in women with MetS.

Introduction

There is a relationship between visceral adiposity and diabetes mellitus, and both are related to atherosclerosis (1, 2). In 1977, the combination of obesity, diabetes mellitus, and other clinical conditions was named metabolic syndrome (MetS) (3, 4). Many definitions were proposed highlighting visceral adiposity and insulin resistance causing metabolic abnormalities (5). Different criteria are used to classify MetS (6–9). In 2009, to facilitate the comparison between studies, a group of researchers proposed a common definition considering changes in fast glycaemia, hypertension, hypertriglyceridemia, low high-density lipoprotein, or the use of drugs to control any of these factors, and the presence of visceral obesity (10).

There are different interventions to reduce the risk of MetS (9). Changes in lifestyle and eating habits are important, including controlling caloric intake and the intake of saturated fat, cholesterol, salt, and sugar. Increased consumption of fruits, vegetables, and whole grains are also recommended (11). The risk of developing MetS is significantly affected by inadequate food consumption. In addition to food choices, food consumption patterns are also important. Identifying a diet that the individual with MetS is able to

adhere to, with moderate consumption of macronutrients, is critical (11, 12). Carbohydrate consumption influences glycaemia, lipidic profile, inflammatory markers, and insulin resistance (13, 14). Metabolic markers are used for clinical decisions; they provide essential information for preventing, diagnosing, treating diseases (15, 16). To prescribe or guide an individualized diet it is necessary to consider the metabolic markers for a better prescription. Anthropometric measurements and food consumption patterns are also important to manage health, eating, and nutritional conditions (17).

MetS increases systemic inflammation. The inflammation induced by MetS differs from others processes of inflammation because it involves the immunological system and impacts metabolic homeostasis. These impacts increase inflammatory markers, reduce daily energetic expenditure, promote disfunction in β cells from the pancreas, and increase hepatic and cardiovascular diseases (18, 19).

The influence of dietary habits on the control or prevention of many diseases is well known. However, more information is needed to elucidate the role of nutritional habits on inflammatory markers in people with MetS (9, 11). Moreover, there is a gap in the literature related to the impact of dietary components on different biochemical markers in individuals with MetS (20). Furthermore, there is still a need for information regarding the impact of diets on the components of MetS (21). Considering the scarcity of studies in this area, this study will provide knowledge regarding the potential effects of dietary habits in MetS and promote evidence-based practice. Therefore, this study aimed to assess the relationship between dietary components, biochemical markers, and anthropometric variables in women with MetS. The hypothesis was that adequate dietary intake would be associated with a better biochemical profile and anthropometric markers.

Methods

Participants

This was a cross-sectional study of women attending the Multiprofessional Outpatient Women's Health Clinic at the University Hospital. One hundred twenty-two patients were invited to participate during the years of 2018 and 2019. The patients received information about the study's objectives and procedures and signed an informed consent form. The local ethics committee approved the research (protocol # 2,837,313).

The participants completed a questionnaire (personal and clinical information) and anthropometric measurements, reported their 24-h dietary intake, and provided blood samples for biochemical analyses. The inclusion criteria were having metabolic syndrome (MetS) based on the assessment, and the exclusion criteria were having other acute or chronic diseases, renal impairment, neurological diseases or cancer, pregnancy or lactation. The diagnosis of MetS was based on three or more of the following characteristics: i) waist circumference (WC) ≥ 88 cm; ii) HDL <50 mg / dL or using antilipemic; iii) TG ≥ 150 mg/dl or using medication for dyslipidemia; iv) systolic blood pressure (BP) ≥ 130 and diastolic ≥ 85 mm / Hg or using antihypertensive drugs; v) Fasting venous glycaemia (FVG) ≥ 100 mg/dl or using a

hypoglycemic medication (10). Of the 122 women evaluated, 44 (36%) had MetS and were included in the analyses. The high prevalence of MetS may be explained by the fact that the participants were recruited from a clinical setting where they were receiving care for different health issues, including MetS and its complications.

Anthropometry

Body mass was measured with the subject standing barefoot and wearing light clothes using a calibrated scale with 0.1 kg precision. Height was measured using a stadiometer with an accuracy of 0.1 cm. The participants stood barefoot, with their feet together, with eyes gazing at the horizon without tilting or extending the head. BMI was calculated and was adopted the classification of the WHO reference standard [BMI: (weight/height²)] (22) for adult women and Lipschitz (23) for women aged 60 years or over. WC was measured at the midpoint between the costal arch and the iliac crest using an inextensible metric tape (24).

Biochemical analysis

Blood samples were collected after 12 hours of fasting in tubes without anticoagulant (to obtain serum) with separating gel; one tube containing sodium fluoride for blood glucose determination, and two tubes containing EDTA as anticoagulant and preservative. The plasma and serum were aliquoted and stored in a freezer at -80°C (Indrel®) until the tests were carried out.

The determination of serum levels of C-reactive protein (CRP) was performed by nephelometry (Dade-Behring), ELISA methodology using commercial kits with up to 5.00 mg / L of a reference value. The analyzes of total cholesterol (CT), HDL cholesterol, Triglycerides (TG), uric acid, glucose, and glycated hemoglobin (HbA1c) were performed in a biochemical autoanalyzer (Dimension-Siemens®), using Siemens kits. LDL-c was calculated using the following formula (25):

$$LDL-c = Cholesterol - HDL-c - (Triglycerides / 5).$$

Fasting insulin levels were determined by microparticle immunoassay enzyme on the AXSYN equipment (ABBOTT).

The estimation of insulin resistance and beta-cell function was performed from the calculations of the HOMA-IR index (26).

$$HOMA-IR = \text{fasting blood glucose (mmol / L)} \times \text{fasting insulinemia (mU / L)} / 22.5$$

The cut-off points for laboratory tests were in accordance with those already established, with the respective values for each test being considered acceptable. CRP (≤ 5 mg/dL), CT (< 200 mg/dL), HDL (> 50 mg/dL), LDL (< 130 mg/dL), TG (< 150 mg/dL), uric acid ($\geq 2,6 - \leq 6$ mg/dL), glucose ($\leq 70 - < 100$ mg/dL), HbA1c ($\leq 4,8 - \leq 6\%$), insulin ($\leq 2,7 - \leq 10,4$ $\mu\text{U/mL}$) e HOMA-IR ($< 2,5\%$).

Dietary intake assessment

Dietary intake was determined using a 24-hour recall (27) with the aid of the Dietbox® software to define and quantify all the food and beverages consumed in the 24-hour period before the interview (28). The 24-hour recall has good reproducibility with correlation coefficients between 0.36 to 0.69 and the weighted Kappa over 0.4. The validity has correlation coefficients between 0.21 and 0.74 (29).

Information on dietary intake was obtained regarding the consumption of proteins, carbohydrates, sugars, fibers, total fats, polyunsaturated fats, monounsaturated, saturated, trans, cholesterol, fibers, and micronutrients. The researcher encouraged the women to remember the food intake with a detailed description of the foods and amounts during the interview. The researcher also revised the information at the end of the interview.

To characterize the food intake as adequate or not, the total intake of macronutrients follows the recommendations of the Update of the Brazilian Guideline on Dyslipidemia and Atherosclerosis Prevention of the Brazilian Society of Cardiology (30).

Statistical Analysis

Sample characteristics were presented as means and standard deviations (SD). The Shapiro-Wilk test was used to verify data normality. Food consumption was presented by total amounts or daily percentages. The associations between food consumption, anthropometrical and biochemical variables were assessed using multiple linear regression controlled by medications (hypoglycemic, hypolipemic, and insulin or similar) and age. The regressions were expressed as regression coefficients (β) and standard errors (SE). Residual analyses were performed to verify the regression's adequacy. A significance of 5% was adopted, and the data were analyzed using SPSS software version 25.0.

Results

Medications were used by 98% of the participants ($n = 43$) to manage MetS. A total of 61% ($n = 27$) used oral hypoglycemic agents, and 32% ($n = 14$) used insulins and analogues. Age and anthropometrical, biochemical, and nutritional markers are shown in the Table 1. Blood pressure was within normal levels for MetS patients. As for body composition, 43% ($n = 19$) were overweight and 53% ($n = 23$) were obese.

Table 1

– Age, Biochemical markers, anthropometric values, and dietary intake of women with metabolic syndrome.

Variables	Mean $\pm$ SD	Adequate	
		%	n
Age (years)	59.0 $\pm$ 10.8		
Anthropometric			
Body mass (kg)	83.3 $\pm$ 12.7		
Height (cm)	155.9 $\pm$ 5.4		
BMI (kg/m ²)	34 $\pm$ 5	3	2
Waist Circumference (cm)	109 $\pm$ 13	2	1
Biochemical markers			
HbA1c (%)	7 $\pm$ 1	36	16
Glycaemia (mg/dL)	133 $\pm$ 57	27	12
Insulin (μ U/mL)	16 $\pm$ 9	25	11
Homa – RI index	5 $\pm$ 4	23	10
Uric acid (mg/dL)	5 $\pm$ 1	71	31
Total cholesterol (mg/dL)	188 $\pm$ 40	66	29
HDL-c (mg/dL)	45 $\pm$ 9	27	12
LDL-c (mg/dL)	112 $\pm$ 35	71	31
TGL-c (mg/dL)	179 $\pm$ 89	46	20
C-reactive protein (CRP) (mg/L)	6 $\pm$ 5	59	26
Dietary intake			
Energy (kcal/day)	1354 $\pm$ 485	16	7
Protein (g/day)	59 $\pm$ 30	34	15
Carbohydrate (g/day)	168 $\pm$ 60	34	15
Total fat (g/day)	52 $\pm$ 28	39	17
Saturated fat (g/day)	17 $\pm$ 12	18	8
The energetic adequation follow the recommendation of DRI's (59). Adequate: Values in accordance to describe in methods for each category. BMI: body mass index; HbA1c: glycated hemoglobin; Homa (IR): <i>Homeostatic Model Assessment</i> – Insulin resistance; HDL-c: High-density lipoprotein; LDL-c: Low-density lipoprotein; TGL: Triglycerides. Values expressed as mean and standard deviation			

Variables	Mean $\pm$ SD	Adequate	
		%	n
Trans fat (g/day)	1 $\pm$ 1	27	12
Polyunsaturated fat(g/dia)	12 $\pm$ 5	48	21
Monounsaturated fat (g/day)	16 $\pm$ 11	41	18
Fiber (g/day)	13 $\pm$ 6	7	3
The energetic adequation follow the recommendation of DRI's (59). Adequate: Values in accordance to describe in methods for each category. BMI: body mass index; HbA1c: glycated hemoglobin; Homa (IR): <i>Homeostatic Model Assessment</i> – Insulin resistance; HDL-c: High-density lipoprotein; LDL-c: Low-density lipoprotein; TGL: Triglycerides. Values expressed as mean and standard deviation			

Regarding food consumption, 82% (n = 36), 52% (n = 23) and 59% (n = 26) presented high/inadequate consumption of saturated, polyunsaturated, and monounsaturated fats, respectively (Table 1); 66% (n = 29) of women did not consume adequate levels of protein. The consumption of carbohydrates was adequate for only 34% (n = 29) of the participants, and only 7% (n = 3) consumed adequate levels of fibers.

The prevalence (%) of disorders related to MetS among the participants is shown in Figure 1. WC was high (>88 cm) in 98% (n = 43), 91% (n = 40) had low HDL-C or used drug treatment for reduced HDL-c, 84% (n = 37) had hypertension or used antihypertensives, and 86% (n = 39) had high concentration of TG or used medication for dyslipidemia.

Table 2 shows the relationship between food consumption and biochemical variables. The relationship between the consumption of monounsaturated fats and the glycemic values was significant (β : 7.27; $P < 0.05$). The consumption of other macronutrients, on the other hand, did not show a significant relationship with the biochemical variables.

Table 2

– Relationship between dietary intake and biochemical markers of women with metabolic syndrome.

	Kcal	Protein	Lipids	CHO	Fat		Fiber
	total				Poli	Mono	
HbA1c	0.001 (0.01)	0.001 (0.03)	-0.05 (0.06)	-0.001 (0.02)	0.02 (0.04)	0.11 (0.07)	0.01 (0.03)
Glycaemia	0.13 (0.29)	-0.24 (1.29)	-3.85 (2.85)	-0.48 (1.11)	0.62 (2.2)	7.27 (3.31)	-0.46 (1.33)
Insulin	0.002 (0.05)	0.041 (0.23)	-0.063 (0.52)	0.02 (0.20)	0.5 (0.39)	0.14 (0.6)	0.07 (0.24)
Homa RI	-0.001 (0.02)	0.02 (0.08)	-0.10 (0.18)	0.01 (0.07)	0.16 (0.14)	0.3 (0.21)	-0.02 (0.08)
Uric acid	0.003 (0.01)	0.01 (0.04)	0.001 (0.08)	-0.01 (0.03)	-0.07 (0.06)	-0.09 (0.1)	0.05 (0.04)
CT	0.19 (0.23)	1.01 (1.02)	1.59 (2.27)	0.76 (0.88)	-1.39 (1.72)	-1.08 (2.63)	-1.4 (1.06)
HDL	-0.03 (0.06)	0.08 (0.25)	0.31 (0.55)	0.14 (0.22)	0.09 (0.42)	-0.21 (0.64)	-0.24 (0.6)
TGL	-0.14 (0.54)	1.39 (2.41)	1.6 (5.33)	0.14 (2.08)	-1.31 (4.05)	-1.7 (6.17)	2.24 (2.5)
CRP	0.003 (0.03)	0.02 (0.12)	-0.16 (2.63)	0.002 (0.10)	0.11 (0.2)	0.29 (0.31)	-0.004 (0.1)
The values were expressed in Beta coefficient and standard error (SE). HbA1c: glycated hemoglobin; Homa (IR): <i>Homeostatic Model Assessment</i> – Insulin resistance; CT: Total cholesterol; HDL-c: High-density lipoprotein; LDL-c: Low-density lipoprotein; TGL: Triglycerides; CRP: C-reactive protein; CHO: Carbohydrates. Bold letter: P<0.05.							

Table 3 shows the relationship between food consumption and anthropometric variables. There was an inverse relationship between fiber consumption and body mass (β : -0.71; P<0.05) and waist circumference (β : -0.56; P<0.05).

Table 3

Relationship between the dietary intake and the anthropometric measurements of women with metabolic syndrome.

	Kcal total	Protein	Lipids	CHO	Fat		Fiber
					Poly	Mono	
Body mass (kg)	-0.04 (0.06)	0.26 (0.3)	-0.01 (0.61)	0.24 (0.26)	0.08 (0.50)	0.82 (0.78)	-0.71 (0.32)
BMI (kg/m ²)	-0.02 (0.03)	0.12 (0.12)	0.11 (0.10)	-0.05 (0.24)	0.49 (0.31)	0.13 (0.2)	-0.14 (0.12)
WC (cm)	-0.04 (0.07)	0.3 (0.30)	0.3 (0.26)	-0.04 (0.62)	0.78 (0.79)	0.30 (0.51)	-0.56 (0.32)
The values were expressed in Beta coefficient and standard error (SE). WC: Waist circumference; CHO: Carbohydrates. Bold letter: P<0.05.							

Discussion

This research aimed to assess the relationship between food consumption, biochemical markers, and anthropometric values in women with MetS. There was a significant relationship between the consumption of monounsaturated fat and fast glycaemia, and an inverse relationship between fiber consumption, body mass and waist circumference.

Recent studies emphasize the impact of macronutrient intake on the energetic biomarkers related to metabolic health; genetic effects are more powerful when healthy diets are consumed (31). The interactions gene/macronutrient modulates the risk of obesity and metabolic diseases (32). In the present study, high ingestion of fats and low ingesting of fibers was noted. There was a direct relationship between monounsaturated fat intake and high fast glycaemia. Monounsaturated fat intake was from a high amount of red meat and dairy products; distinct cardiometabolic effects are related to intake of mono or polyunsaturated fats (33). Jiao *et al.* (34) found a positive association between monounsaturated fat and mortality.

Consumption of red meat, especially processed meat, was related to an increase in diabetes. In contrast, the intake of milk, cheese, and yogurt showed a neutral effect over cardiometabolic effects. Vegetables that provide monounsaturated fat had positive cardiometabolic effects (33, 35, 36). The 24-h dietary recalls confirmed the choice of unhealthy sources of monounsaturated fat such as processed meats and cheese, which have a high amount of saturated fat that have postprandial effects, promote the store of fat (lipogenesis), increase inflammatory processes and glycaemia (37, 38).

Another important factor for metabolic homeostasis is the intestinal microbiota which is dependent on alimentary residues, as fiber, for its surveillance and metabolism (39). Moreover, the intestinal microbiota

gives high rates of butyrogenesis, exercising epigenetics and immunomodulators effects on other organs of the body (40). This information could help understand the relationship between high ingest of fiber and the reduction in many pathologies, including metabolic diseases (41–45). It is important to highlight the low fiber intake found in the present study (13 g/day), which was 50% less than the recommended 26 g/day (30).

The analysis of dietary intake and anthropometrics measurements revealed an inverse relationship between the fiber intake and waist circumference. This result agrees with other studies. Liu *et al.* (46) evaluated 74,091 nurses over 12 years and observed that the nurses with high fiber intake gain less weight than their counterparts. Furthermore, overweight and obese women have lower intake of fruits and vegetables (47). Dietary fiber intake is inversely related to body mass, BMI and WC (48–50). The consumption of fiber is a critical to promote weight loss in subjects with obesity or overweight (49, 50). The most prevalent MetS factor in the present study was high WC (98% > 88 cm). Fibers prevent obesity by supporting the intestinal microbiota, decreasing the absorption of nutrients (51), inhibiting appetite (52, 53), and regulating homeostasis (54, 55).

This study demonstrates that small changes in eating habits, as the decrease in monounsaturated fat intake and an increase in fiber intake, could reduce the risk factors for women with MetS. Once the monounsaturated fat has a relationship with glycaemia, fibers have an inverse relationship with body mass and WC. The data found in the study enhance the importance of dietary fiber intake since it could promote beneficial effects on the anthropometric profile.

The present study has some limitations such as the small sample size, only one dietary intake assessment, and lack of data on physical activity levels. The 24-h dietary recall is subject to errors in the representation of actual dietary intake. However, there is no gold standard method available for researchers to evaluate dietary intake (56, 57). Even applied only once, this recall search estimates the absolute intake instead of relative through its open structure (58).

Conclusion

The intake of monounsaturated fats and fiber were associated to higher blood sugar levels and with lower body mass and waist circumference, respectively. These relationships highlight the importance of dietary intake in MetS management in women.

The present study increases the understanding of the relationship between dietary habits, biochemical and anthropometric markers in women with MetS. The findings indicate that the consumption of fibers is important to the control of visceral obesity in women with MetS. Further longitudinal studies are necessary to evaluate the cause-effect relationship between dietary intake and its effects on physiological and anthropometrical markers in people with MetS.

Abbreviations

BMI
Body Mass index
BP
systolic blood pressure
CRP
C-reactive protein
CT
total cholesterol
FVG
Fasting venous glycaemia
HbA1c
glycated hemoglobin
HDL-c
high-density lipoprotein
LDL-c
low-density lipoprotein
MetS
Metabolic syndrome
SD
standard deviations
SE
standard errors
TG
Triglycerides
WC
waist circumference
 β
regression coefficients

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The local ethics committee Ethics Committee in Research with Human Beings of the State University of Londrina approved the research (protocol # 2,837,313). The patients received information about the study's objectives and procedures and signed an informed consent form.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request

COMPETING INTERESTS

The authors declare that they have no competing interests.

FUNDING

Not applicable.

AUTHORS' CONTRIBUTIONS

KM: Conception and Design, methodology, data collection, analysis and interpretation of data, drafting the article, final approval.

VW: Conception and Design, analysis and interpretation of data, drafting the article, final approval.

MQ: Revising it critically, interpretation of data, final approval.

DF: Conception and Design, analysis of data, final approval.

CC: Revising it critically, supervision, final approval.

EV: Revising it critically, interpretation of data, final approval

DV: Conception and Design, methodology, drafting the article, supervision, final approval.

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Figures

Figure 1

Prevalence of components of metabolic syndrome of women.

The values were expressed in percentual; WC: Waist Circumference ≥ 88 cm; TG: Triglycerides ≥ 150 mg/dl or using medication for dyslipidemia; HDL-c: High Density Lipoproteins < 50 mg/dL o or using antilipemic; Glycaemia: Fasting venous glycaemia (FVG) ≥ 100 mg/dl or when using a hypoglycemic agent; Blood Pressure: systolic blood pressure (BP) ≥ 130 and diastolic ≥ 85 mm / Hg or when using antihypertensive drugs.

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