Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy
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ORIGINAL RESEARCH

Relationship Between Metabolic Syndrome and the Brazilian Workers' Food Program in Male and Female Manufacturing Workers

This article was published in the following Dove Press journal:
Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy

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Introduction: Several studies have reported increased cardiometabolic risk among workers assisted by food assistance public policies. The aim of this study was to estimate the prevalence of metabolic syndrome (MetS) and its individual components among manufacturing workers and their relationship to the Brazilian Workers' Food Program (WFP).

Methods: It was a prospective, cross-sectional, two-stage survey comparative of manufacturing workers from companies adherent and non-adherent to the WFP stratified by sector of activity and company size. The workers were interviewed in the workplace, and data on waist circumference (WC), blood pressure, and 12-hours fasting blood glucose (FBG), serum triglycerides (TG), and total and HDL-cholesterol were obtained. Mixed effects multilevel regression was used to compare WFP and non-WFP groups separately in each sex. All subjects gave written informed consent.

Results: The survey included 332 workers from 16 WFP companies and 344 workers from 17 non-WFP companies. The general prevalence of MetS, according to IDF/AHA/NHLBI criteria, was high but not statistically different between sexes (39.8% in females versus 28.5% for males, p=0.16). Statistically significant differences were found between sexes in the prevalence of individual components: WC (77.8% in females versus 38.3% in males, p=0.002), TG (27.3% in females versus 40.8% in males, p=0.07), and HDL-C (52.2% in females versus 43.1% in males, p=0.05). Among males, MetS prevalence was significantly higher in the WFP group (33.0% versus 23.9%, p=0.008), and, in the individual components, the WFP group had higher prevalence of increased WC (47.0% versus 29.4%, p<0.001) and elevated FBG (8.9% versus 6.3%, p<0.001), as well as greater average levels of TG, HDL-C and FBG. Among female workers, no statistically significant differences between groups were observed in MetS prevalence and its individual components, but WFP female worker presented lower systolic and diastolic blood pressure.

Conclusion: In a low-income population, male manufacturing workers participating in a food assistance program are at increased risk of MetS, an effect that was not identified among female workers.

Keywords: public policy, workers, cardiovascular risk factors, metabolic syndrome, food insecurity

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Introduction

It is estimated that the Metabolic Syndrome (MetS) affects approximately one quarter of the world population,[1] being three times more prevalent than type 2 diabetes mellitus (T2DM). There has been interest in assessing the prevalence of this syndrome among industry workers, and several studies have presented

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http://doi.org/10.2147/DMSO.S264181

estimates for countries such as India, Korea and Japan.[2–4] Other studies have investigated the relationship of MetS with sex and industry sector. However, the relationship of MetS with food and nutrition public policy programs has not been adequately investigated.

The Workers' Food Program (WFP) is a National Food and Nutrition Security policy for Brazilian workers, created with the objective of securing the provision of healthy and adequate food to low-income workers. The WFP consists of a tax incentive policy for companies that implement food programs, aiming to facilitate the improvement of the nutritional conditions and quality of life of workers, with the ultimate goals of lowering the rate of occupational accidents and increasing worker productivity. The WFP is regulated by Ordinance no. 66 that establishes the nutritional parameters composing the company menus, the requirement for food and nutrition education actions, and the obligation of technical supervision by a qualified dietitian.[5] Currently, there are about 269,000 adherent companies, covering over 21.5 million workers representing 27% of the economically active population.

Due to its relevance and wide reach, the program was the focus of several studies aiming to evaluate the offered food and its impact on the nutritional and health status of workers.[6–9] Some results, however, have pointed to an inadequate nutritional offer, with excesses in energy, protein and lipid supply, in addition to reduced presence of fruits and vegetables on the menus. Comparative studies between companies adherent and non-adherent to the WFP have found greater prevalence of overweight and obesity, in addition to higher values of waist circumference (WC) in workers of WFP-adherent industries.[6–8] A recent longitudinal comparative study among manufacturing workers observed in two waves over a period of four years showed a greater increase in WC in workers from WFP-adherent industries, compared to workers from non-adherent companies.[9] Considering that increased WC is a component of the MetS, that finding raised our interest in whether workers from companies participating in the WFP would present greater prevalence of that syndrome.

Therefore, given the great importance of the WFP as a public policy providing food security for a large population of manufacturing workers, and the deleterious findings of those previous studies evaluating the effectiveness of the WFP, we conducted a population survey with the objective of comparing the prevalence of MetS and its individual components among manufacturing workers from industries adherent and non-adherent to the WFP.

Materials and Methods

Study Design

This study was conducted by the Nutrition Department of the Federal University of Rio Grande do Norte (UFRN) between September 2017 and July 2018 in the state of Rio Grande do Norte (RN), with a population of 3.5 million and located in Northeastern Brazil. It was an observational, cross-sectional, prospective study, based on a probability sample, comparative between manufacturing workers from industries adherent and non-adherent to the WFP.

The survey was limited to three industrial subsectors, which are the ones with the greatest economic and social importance to the State: food and beverages, non-metallic minerals, and textiles. The sampling plan consisted of a combined, stratified proportional and two-stage sampling, obtained separately in each comparative group (WFP and non-WFP). The stratification factors were the size of the industry, categorized as small (20 to 99 workers), medium (100 to 499) and large (500 or more), and the three subsectors of industrial activity. In the first stage, companies were selected by simple randomization in proportion to the total number of companies active in the State in each stratum. The sampling frames for the selection of companies were created from a list of all industries operating in the State provided from the State Industry Federation (FIERN). The second stage consisted of workers selected by simple randomization from a roster with the identification of all workers, which was provided by the companies selected in the first stage.

The inclusion criteria were: male and female workers over 18 years old who had been employed for more than a year. Trainees and workers on probation were excluded because they usually do not have a full-time work schedule or are employed on a temporary basis, as well as pregnant women because in such persons the WC does not reflect the amount of visceral fat.

Data Collection

To guarantee the quality of anthropometric measurements, the interviewers underwent training at the beginning and in the middle of the data collection period. Data collection was carried out for two consecutive days in each company. On the first day, data collection included demographic data, life style, medication history and job description. Arterial blood pressure was measured by the average of two measurements taken 5 minutes apart in the right brachial artery with an aneroid sphygmomanometer Tycos (Welch Allyn, Miami, USA) and with the subject in the sitting position. Body weight and height were measured with a digital scale (Inner Scan, Tanita Corp., Tokyo, Japan) and with a stadiometer (Sanny, São Bernardo do Campo, SP, Brazil), respectively. WC was measured at the midpoint between the last rib and the iliac crest.[10] The level of physical activity in MET.min/week, a potentially confounding variable in the comparison between groups, was assessed with the short version of the International Physical Activity Questionnaire.[11]

On the second day, 12-hours fasting venous blood samples (5 mL) were collected and sent to the Laboratory of Clinical and Toxicological Analysis of our department, where they went through the centrifugation process at 3500 RPM for 15 minutes at room temperature to obtain the serum to be used in biochemical analyzes. Serum levels of glucose, triglycerides (TG), HDL cholesterol (HDL-C), and total cholesterol were measured using colorimetry and enzymatic colorimetric assays in the biochemical analyzer Labmax Plenno (Labtest, Minas Gerais, Brazil).

The diagnosis of MetS adopted the IDF/AHA/NHLBI criteria, which define MetS by the presence of three of the five individual components:[12] WC $\geq$ 94 cm in men and $\geq$80 cm in women, TG $\geq$150mg/dL or receiving drug therapy for hypertriglyceridemia, HDL-C $<$40mg/dL for men and $<$50mg/dL for women or receiving drug therapy for reduced HDL-C, systolic blood pressure (SBP) $\geq$130 mmHg and/or diastolic blood pressure (DBP) $\geq$85mmHg or use of antihypertensive drugs with a clinical history of arterial hypertension, fasting blood glucose $\geq$100mg/dL or administration of oral antidiabetics or insulin. For the WC cutoff point, the recommendation for the Caucasian population was used. To enable comparison of the results with other studies, MetS was also defined according to other often used criteria proposed by the International Diabetes Federation (IDF)[13] and NCEP's Adult Treatment Panel III (NCEP-ATP III).[14]

The 10-year risk of heart disease or stroke was estimated with the pooled cohort ASCVD equations[15] as well as with the Framingham Heart Study equations[16] from the following components: age, sex, total cholesterol, HDL-C, TG, smoking, systolic blood pressure, antihypertensive use, and T2DM.

Statistical Analysis

Formal methods for the calculation of sample sizes when multilevel models are used for the analysis of complex survey plans have not yet been developed, and sample size calculations are commonly based on suggested guidelines. One often used method recommends that 30 clusters with a cluster size of 30 are probably adequate to obtain unbiased estimates of effect sizes.[17] Accordingly, we defined a target sample size of 30 companies with 30 workers from each company.

Statistical analysis was performed for each sex separately. Population estimates of bio-demographic characteristics in each sex and group were obtained according to the combined stratified and multistage survey plan, using survey weights and finite population corrections for companies using information provided by FIERN. Survey weights were computed for each sex as the inverse of the probability of being selected to the sample within each stratum.

Potential confounders were searched among the bio-demographic, life style and job description variables. Because of the non-normal distribution of those variables, with the exception of age, they were dichotomized at their median value. Physical exercise was dichotomized at 700 MET.min/week, a cut-off corresponding to the recommended weekly exercise activity according to the 2019 ACC/AHA guidelines[18] (approximately 150 minutes per week of moderate-intensity, or 75 minutes per week of vigorous-intensity, physical exercise). Those variables were compared between the two groups (WFP or non-WFP) with mixed effects multilevel linear or logistic regression, as appropriate, stratified by company size, with group as fixed factor, and with sector of activity, company nested within sector of activity and workers nested within companies as random factors, including survey weights for companies, and for workers conditional on the selection of the respective company. The variables statistically different between groups at the $p<0.10$ significance level were included as co-variables in subsequent analyses.

For the comparison of the prevalence of MetS and its individual components between sexes, the bio-demographic, life style and job description variables were first compared between sexes with the same logistic model, including the group as covariate. Then, the prevalence of MetS and its individual components were compared between sexes using the same model, with sex as independent variable, WFP group as co-variate, and adjustment by the variables that were statistically different between sexes at the $p<0.10$ significance level.

For the comparison of the prevalence of MetS and its individual components between groups, each sex was analyzed separately using the same model with WFP group as independent variable and adjustment by the confounding variables identified in the previous analyses. In all analyses, an independent covariance structure and robust standard errors using the sandwich estimator were assumed.

Differences with a two-tailed significance level of 5% were considered statistically significant. Stata 15 (Stata Corporation, College Station, TX, USA) was used in all analyses. The full study dataset is provided in the Supplementary File.

Results

On a universe of 100 companies, 10 companies randomized in the first stage (6 WFP and 4 non-WFP) declined participation in the study and were replaced. Thirty-three companies were randomly selected in proportion to the total number of companies in each combination of levels of activity sector and company size (Table 1). Among the 930 workers invited to the study, 254 (27.3%, 113 WFP and 141 non-WFP) did not show on the second day for blood sample collection. With the exception of a difference in the highest education degree achieved, which was somewhat higher among excluded workers (66.1% versus 54.1% with high-school and above, p=0.001), there were no statistically significant differences in demographic variables (age p=0.29, sex p=0.31, married, p=0.77, income p=0.98, in-house formation p=0.33 and physical activity>700 MET.min/week, p=0.24). Therefore, the analysis set for this study consisted of 676 workers (387 males and 289 females). This sample was distributed as 332 workers and 16 companies in the WFP group, and 344 workers and 17 companies in the non-WFP group. The sample distribution by industries and participants in each group is shown in Table 1.

Table 2 shows, in each sex, the frequency of the biodemographic, lifestyle and job variables in WFP and non-WFP groups. The differences between groups were, in male workers, greater proportion in industries adherent to the WFP with high school or higher education (67.2% versus 52.2%, p<0.001), with in-house formation (31.0% versus 12.7%, p= 0.002) and married (74.2% versus 62.0%, p= 0.06); in female workers, greater proportion of white collar workers (p <0.001), workers with high school or higher education (65.3% versus 49.3%, p= 0.08), and with yearly income above 1 minimum wage, corresponding to 12,402 BRL or about 2300 USD (43.7% versus 21.8%). Those variables were included as co-variables in the subsequent analyses.

The population estimate of the prevalence of MetS among manufacturing workers, regardless of the comparative groups, is shown in Table 3. The estimated prevalence of MetS was higher in female workers (39.8% versus 28.5%, p=0.09) but the difference was not statistically significant after covariates adjustment (p=0.16). A similar result was observed when MetS was defined according to the IDF criteria and the NCEP-ATP III criteria.

Regarding the individual components of the MetS (Table 3), the most prevalent component among male workers was arterial hypertension, while in women was increased WC. In the comparison between sexes, men had a higher prevalence of elevated triglycerides, although the difference did not reach statistical significance after covariates adjustment (covariates-adjusted odds ratio (AOR) 1.53, p=0.07). Women had higher prevalence of increased

Table 1 Distribution of the Sampled Industries and Workers in the WFP and Non-WFP Groups, According to the Sector of Economic Activity and the Size of the Industry, Rio Grande do Norte, Brazil, 2017

Characteristics of the Surveyed Industries	Workers' Food Program			Non-Workers' Food Program		
	Number of Companies	Selected Workers	Analyzed Workers	Number of Companies	Selected Workers	Analyzed Workers
Sector of activity						
Food and beverages	7	189	146	7	200	118
Non-metallic minerals	3	86	71	3	93	72
Textiles	6	170	115	7	192	154
Company size						
Small	6	133	123	7	168	135
Medium	7	177	156	7	168	143
Large	3	135	53	3	149	66

Table 2 Sex-Specific Population Estimates of Bio-Demographic Characteristics of Manufacturing Workers from Industries Adherent and Non-Adherent to the Workers' Food Program, Rio Grande do Norte, Brazil, 2017

Variables	Male Workers			Female Workers		
	WFP	Non-WFP	p	WFP	Non-WFP	p
Age, years (mean)	39.3	34.3	0.21	39.8	42.1	0.57
Married (%)	74.2	62.0	0.06	54.1	55.7	0.79
With children (%)	74.8	57.6	0.25	75.4	80.5	0.46
Education[a] (%)	67.2	52.2	<0.001	65.3	49.3	0.08
Income[b] (%)	81.1	64.5	0.30	43.7	21.8	0.06
In-house formation (%)	31.0	12.7	0.002	26.4	13.2	0.16
Smoker (%)	7.1	9.6	0.82	2.0	3.9	0.88
Physical activity[c] (%)	67.6	43.9	0.29	89.8	86.6	0.78
Job type (%)			0.63			<0.001
Plant manager	14.1	13.1		12.3	11.7	
Manufacturing technician	18.8	12.2		4.5	0.0	
Administrative assistant	26.4	3.4		18.6	8.8	
Production worker	18.9	33.5		48.8	65.9	
Machine operator	20.4	33.9		11.0	9.6	
Food processing worker	1.5	4.9		4.8	4.0	

Notes: [a]High-school and above; [b]Above 1 minimum wage (954 BRL or about 240 EUR); [c]>700 MET.min/week.

Table 3 Sex-Specific Estimates of Population Prevalence of the Metabolic Syndrome and Its Individual Components in Manufacturing Workers from Industries Adherent and Non-Adherent to the Workers' Food Program, Rio Grande do Norte, Brazil, 2017

Variables	Male Workers % (95% CI)	Female Workers % (95% CI)	p* (Unadjusted)	Adjusted OR* (95% CI)	p** (Adjusted)
Metabolic syndrome					
AHA	28.5 (21.8–36.3)	39.8 (31.9–48.3)	0.09	0.51 (0.20–1.30)	0.16
IDF	25.3 (19.0–32.9)	38.8 (30.9–47.3)	0.08	0.47 (0.18–1.28)	0.14
NCEP	21.4 (15.6–28.7)	33.9 (26.1–42.6)	0.36	0.47 (0.13–1.79)	0.27
Individual components					
WC	38.3 (30.7–46.5)	77.8 (68.0–85.2)	0.001	0.19 (0.06–0.55)	0.002
TG	40.8 (33.3–48.7)	27.3 (19.9–36.2)	0.05	1.53 (0.96–2.43)	0.07
HDL-C	43.1 (35.1–51.3)	52.2 (43.2–61.0)	0.004	0.47 (0.22–0.99)	0.05
AHT	43.9 (35.7–52.5)	40.5 (31.8–49.9)	0.39	1.17 (0.52–2.65)	0.71
FBG	7.6 (4.7–12.1)	13.6 (8.5–21.1)	0.76	0.79 (0.11–5.73)	0.82

Notes: WC: Waist circumference ≥94 cm in men and ≥80 cm in women; TG: Triglycerides ≥150mg/dL or use of drug therapy for hypertriglyceridemia; HDL-C: High-Density Lipoprotein Cholesterol <40mg/dL for men and <50mg/dL for women or use of drug therapy for reduced HDL-C; AHT: Arterial hypertension defined as systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85mmHg or use of antihypertensive agents with a clinical history of AHT; FBG: Fasting blood glucose ≥100mg/dL or administration of oral antidiabetic or insulin. Analysis by mixed effects multilevel logistic regression. *Stratified by group; **Stratified by group and adjusted by income>1 minimum wage, married, smoker, and physical activity >700 MET.min/week.
Abbreviations: CI, confidence interval; OR, odds ratio.

WC (AOR 5.26 p=0.002) and low HDL-cholesterol (AOR 2.13, p= 0.05).

Table 4 shows the results of the comparative analysis of the prevalence of MetS and its individual components between WFP and non-WFP workers, separately in each sex. Among male workers, those in the WFP group have higher prevalence of MetS (AOR 1.73, p= 0.008) and, in the individual components of MetS, have increased prevalence of high WC (AOR 1.71, p< 0.001), and elevated fasting blood glucose or administration of oral antidiabetic or insulin (AOR 4.01, p< 0.001). Among female workers, when adjusted by education, income and job type (blue versus white collar worker), no statistically significant results were observed in the prevalence of metabolic syndrome and the individual components.

Table 4 Prevalence of Metabolic Syndrome and Its Individual Components in Manufacturing Workers from Industries Adherent and Non-Adherent to the Workers' Food Program, Rio Grande do Norte, Brazil, 2017

Variables	WFP % (95% CI)	Non-WFP % (95% CI)	Adjusted OR (95% CI)	p (Adjusted)
Male workers*				
Metabolic syndrome				
AHA	33.0 (22.7–45.3)	23.9 (15.8–34.5)	1.73 (1.16–2.60)	0.008
IDF	29.0 (19.3–41.0)	21.6 (13.9–32.0)	1.62 (1.59–1.65)	<0.001
NCEP	29.2 (19.6–41.1)	13.4 (7.7–22.5)	1.42 (0.31–6.54)	0.66
Individual components				
WC	47.0 (34.9–59.4)	29.4 (20.3–40.4)	2.07 (1.71–2.50)	<0.001
TG	44.8 (34.1–55.9)	36.7 (26.3–48.4)	1.26 (0.89–1.78)	0.19
HDL-C	46.5 (35.5–57.8)	39.5 (28.6–51.6)	1.49 (0.48–4.62)	0.49
AHT	42.7 (30.0–56.4)	45.2 (34.7–56.2)	0.81 (0.30–2.19)	0.67
FBG	8.9 (4.5–16.8)	6.3 (3.2–12.1)	4.01 (2.12–7.57)	<0.001
Female workers**				
Metabolic syndrome				
AHA	40.0 (31.1–49.6)	39.7 (28.9–51.5)	0.69 (0.35–1.38)	0.30
IDF	38.0 (29.1–47.7)	39.4 (28.6–51.3)	0.70 (0.33–1.48)	0.35
NCEP	33.0 (23.8–43.7)	34.6 (24.3–46.4)	0.72 (0.48–1.02)	0.06
Individual components				
WC	76.9 (60.9–87.7)	78.5 (65.8–87.4)	1.04 (0.31–3.51)	0.95
TG	29.6 (21.3–39.5)	25.5 (14.9–40.0)	0.82 (0.38–1.80)	0.63
HDL-C	52.7 (42.3–63.0)	51.8 (38.8–64.5)	0.76 (0.34–1.70)	0.50
AHT	34.4 (23.9–46.7)	45.3 (33.3–57.7)	0.60 (0.24–1.49)	0.27
FBG	12.7 (6.2–24.3)	14.3 (7.3–25.9)	0.72 (0.32–1.63)	0.44

Notes: WC: Waist circumference ≥94 cm in men and ≥80 cm in women; TG: Triglycerides ≥150mg/dL; HDL-C: High-Density Lipoprotein Cholesterol <40mg/dL for men and <50mg/dL for women; AHT: Arterial hypertension defined as systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85mmHg or use of antihypertensive agents with a clinical history of AHT; FBG: Fasting blood glucose ≥100mg/dL or administration of oral antidiabetic or insulin. Analysis by mixed effects multilevel logistic regression, *OR and p-values adjusted by marital status, education and in-house formation. **p-values adjusted by education, income and job type (blue collar/white collar).
Abbreviations: OR, odds ratio; CI, confidence interval.

Table 5 shows sex-specific estimates in the WFP and non-WFP groups, of the population means of body mass index (BMI), computed as weight in kg divided by squared height in meters, individual components of the MetS, and 10-year risk of heart disease or stroke. Male workers in the WFP group had WC in average 4.38 cm larger (p=0.009), TG in average greater by 16.9 mg/dL (p=0.05), HDL-cholesterol lower by 3.55 mg/dL (p=0.08), fasting blood glucose greater in average by 3.38 mg/dL (p= 0.002). Female workers in the WFP group had lower systolic and diastolic blood pressures (in average 5.75 mmHg, p<0.001, and 4.37 mmHg, p=0.05, respectively). In the remaining components, the estimated mean values were fairly similar in the two groups and no statistically significant differences were found.

There was no statistical difference between WFP and non-WFP groups in the mean values of BMI and 10-year cardiovascular risk.

Discussion

The present study in a representative sample of manufacturing workers found that over one-quarter of men and over one-third of women have MetS, with women more often than men having increased WC and lower HDL-C, and men elevated TG. Compared to workers not covered by a food assistance program, male workers from companies that are beneficiary of the WFP had greater prevalence of MetS, while no significant difference was observed among female workers after adjustment by covariates. Regarding the individual components of MetS, males from WFP-adherent companies had greater prevalence of increased WC and fasting blood glucose, while among female workers there were no statistically significant differences between WFP and non-WFP workers.

The prevalence of MetS that was found among manufacturing workers in this study was similar to the results reported from population-based surveys aimed at

Table 5 Sex-Specific Estimates of Mean Values of the Individual Components of the MetS, Body Mass Index and 10-Year Cardiovascular Risk in Manufacturing Workers from Industries Adherent and Non-Adherent to the Workers' Food Program, Rio Grande do Norte, Brazil, 2017

Variables	WFP	Non-WFP	Difference (Adjusted)	p (Adjusted)
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	
Male workers*				
WC (cm)	94.3 (91.6–97.1)	88.8 (86.2–91.3)	4.38 (1.11; 7.65)	0.009
BMI (kg/m2)	27.8 (26.8–28.8)	26.1 (25.1–27.1)	1.19 (−0.30; 2.68)	0.12
SBP (mmHg)	121.9 (118.3–125.6)	122.5 (119.3–125.7)	−1.10 (−5.31; −3.12)	0.61
DBP (mmHg)	81.3 (77.8–84.8)	80.6 (78.0–83.1)	0.14 (−5.25; 5.54)	0.96
TG (mg/dL)	157.4 (139.3–175.5)	141.4 (120.3–162.6)	16.9 (−0.02; 33.8)	0.05
HDL-C (mg/dL)	41.4 (37.8–45.0)	44.6 (41.7–47.6)	−3.55 (−7.57; 0.47)	0.08
FBG (mg/dL)	86.8 (78.7–94.8)	85.5 (82.7–88.2)	3.38 (1.27; 5.49)	0.002
AHA 10-yr CV risk (%)	6.8 (4.8–8.8)	4.6 (3.2–6.0)	1.97 (−0.29; 4.24)	0.09
ASCVD 10-yr CV risk (%)	8.6 (3.9–13.3)	10.6 (3.3–17.9)	−2.20 (−9.66; 5.25)	0.56
Female workers**				
WC (cm)	89.0 (86.1–91.9)	90.6 (87.0–94.1)	−2.98 (−8.17; 2.20)	0.26
BMI (kg/m2)	28.2 (26.9–29.4)	28.7 (27.3–30.1)	−1.28 (−3.66; 1.09)	0.29
SBP (mmHg)	114.8 (111.1–118.5)	118.8 (114.0–123.6)	−5.75 (−7.10; −4.39)	<0.001
DBP (mmHg)	74.9 (72.6–77.1)	79.5 (76.0–83.0)	−4.37 (−8.85; 0.12)	0.05
TG (mg/dL)	121.0 (106.2–135.7)	131.5 (107.4–155.7)	−19.5 (−50.98; 12.04)	0.23
HDL-C (mg/dL)	49.3 (46.8–51.8)	49.2 (46.3–52.0)	0.53 (−3.40; 4.47)	0.79
FBG (mg/dL)	86.5 (79.7–93.3)	93.4 (83.8–103.1)	−7.63 (−23.07; 7.80)	0.33
AHA 10-yr CV risk (%)	3.2 (2.3–4.6)	3.8 (2.9–4.6)	0.14 (−1.58; 1.87)	0.87
ASCVD 10-yr CV risk (%)	1.2 (0.8–1.6)	1.4 (1.0–1.9)	0.18 (−0.87; 1.24)	0.73

Notes: WC: Waist circumference; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; TG: Triglycerides; HDL-C: High-density lipoprotein cholesterol; FBG: Fasting blood glucose; Analysis by multilevel mixed effects linear regression, *p-values adjusted by marital status, education and in-house formation. **p-values adjusted by education, income and job type (blue collar/white collar).
Abbreviations: CV, cardiovascular; CI, confidence interval.

estimating the prevalence of MetS in Brazil, which estimated the overall prevalence of MetS at about 30%, with no sex differences.[19,20] As was reported in those studies, and in many others, we have found that the most common MetS component was arterial hypertension in men and increased WC in women.

Worldwide, the prevalence of MetS in manufacturing workers was investigated in several countries. Some of the reported differences in prevalence estimates may be accounted for by the MetS criteria adopted in the studies. While the IDF/AHA/NHLBI defined MetS by the presence of any three of the five factors, the IDF criteria requires the presence of increased WC, and the National Cholesterol Education Program (NCEP) ATP-III defines higher cutoff points for fasting blood glucose and does not consider treatment-controlled blood pressure or FBG levels as MetS criteria. Therefore, NCEP ATP-III criteria result in prevalence estimates that are quite lower than IDF-based estimates which, in turn, are a little lower than IDF/AHA/NHLBI estimates. Thus, a US study based on data from NHANES using the NCEP ATP-III criteria,[14] estimated the prevalence if MetS at about 30% in industrial workers.[21] A prospective study conducted in India in 2287 industrial workers estimated the prevalence at 27% (30% in men and 21% in women),[22] while another study also in India with 1077 men estimated the prevalence at 51.4%.[23] On the other hand, in a study in a German automobile industry in 27,359 workers, the prevalence was only 11.7% (12.7% in men and 7.4% in women).[24] However, we have found no other published studies, based on probability samples, that have provided unbiased prevalence estimates of MetS for the entire population of manufacturing workers.

The risk of MetS has been associated with several factors, among them the occupational status. For example, Davila et al, when evaluating a sample of 8498 individuals representative of the US population identified a higher prevalence of MetS among workers in the primary and secondary sectors, than among those in the tertiary sector.[21] However, to the best of our knowledge, the association between MetS and the food offered by companies has never been the subject of previous studies. For that reason, the main aim of this study was to evaluate the prevalence of MetS in workers who receive food assistance from industries adhering to a public food policy, the WFP, comparing it with the prevalence among workers of non-adherent industries.

As the only policy of its kind in Brazil, the WFP was created over 40 years ago, when the nation's social context was marked by nutritional deficiencies and malnutrition. The provision of adequate and healthy food to low-income workers thus emerged as a solution to increase their physical capacity, and resistance to fatigue and diseases, in order to reduce occupational accidents and increase the productive force. Over the years, with the progressive improvement in wealth and social conditions in Brazil, the nutritional parameters defined by the WFP suffered several reformulations in order to maintain its commitment to the food and nutritional security of workers. However, several studies that have assessed the relationship between the WFP and the nutritional status of workers have consistently shown a high prevalence of overweight and obesity among workers from companies that adhere to the program,[6–9] which goes against the main objective of the program. The results of the present study corroborate those found in the literature since, after adjustment for co-variates, it was observed that the prevalence of MetS was higher among manufacturing workers from companies adherent to the WFP.

Among the individual components of the MetS, this study showed increased levels of FBG and TG, and decreased HDL-C among male workers, all of them being biochemical changes related to overweight and obesity, and to dietary inadequacies with increased consumption of simple carbohydrates. Among female workers, those in WFP companies have lower levels of systolic and diastolic blood pressure, most likely related to lower sodium consumption as was reported in a previous study in the same workers population.[8]

An interesting finding of this study was that exposure to the WFP appears to have a different effect in either sex. While among males the prevalence of MetS was clearly much higher among workers from companies adherent to the WFP, the same was not observed among females, with similar frequency in workers from both WFP and non-WFP industries. Although this study was not able to show a difference between sexes in the relationship between a food assistance program and the MetS and its individual components, the overall results strongly suggest such a difference is likely to exist.

We believe this contrast may be explained in conformity with the results of studies conducted in other countries that investigated the influence of food assistance programs on BMI. A large number of studies carried out in the last 20 years or so, most of them in the US but also in other countries with similar results, have repeatedly shown an association between food assistance programs and overweight/obesity in low-income populations.[25–28] The combined results of those studies and ours are consistent with the existence of a qualitative interaction between food assistance by public programs and sex on the risk of overweight and obesity, which is influenced by low income and by food insecurity, and is closely associated with metabolic syndrome and cardiovascular morbidity/mortality.[29]

Food insecurity (FI) is said to exist when an individual does not have access to safe food in sufficient quantity and with adequate nutritional quality to meet their biological needs.[30] Several studies have presented evidence of an association between FI and higher values of BMI among women with little financial resources and lower educational level, when compared to individuals living in food security situations, which is related to diets with high calorie intake, higher prevalence of arterial hypertension and hyperlipidemia.[31–34] However, in those studies, such relationship between food insecurity and overweight has not been found among males.

The results of our study suggest that the same relationships between food assistance programs, recipient sex, income and food insecurity may exist regarding the MetS. While in male workers we have found a clear association between the food assistance program and the prevalence of metabolic syndrome and several of its components, among females this association was not apparent and no marked differences were seen between groups in MetS components. Therefore, it is possible that the increased prevalence of MetS in male workers in WFP-adherent companies may be related to a weight-increasing effect of the food assistance program on low-income individuals, while in female workers the weight-increasing effect is reduced, or even reversed, by the reduction in food insecurity experienced by women participants of a food assistance program.

This rationale is supported by evidence from other studies that MetS is related to socioeconomic level in women but not in men. For example, a study evaluating the association between MetS and socioeconomic position using data from NHANES III found that in women, but not in men, MetS was associated with low education (OR 1.77; CI 1.39–2.24) and lower income (OR, 1.81; CI, 1.37–2.40).[35] Several factors may contribute to this sex disparity, including high parity and a number of psychosocial stressors that are more common in women from lower socioeconomic classes, such as poverty, unemployment, single parenting, which ultimately lead to poor lifestyle choices and consequent development of metabolic abnormalities.[36]

To the best of our knowledge, only a single retrospective study has investigated the relationship of a food assistance program with the metabolic syndrome. Leung et al[37] using data from NHANES, reported a statistically significant association between participation in the US Supplemental Nutrition Assistance Program (SNAP) and the prevalence of MetS defined according to the NCEP-ATP III guidelines,[14] with 26.2% of SNAP participants with MetS criteria, versus 18.7% of non-participants (age-adjusted prevalence ratio 1.51, 95% confidence interval 1.09–2.10). Among the individual components, they found a positive association of participation in the SNAP with increased WC and TG, and low HDL-C. Those changes in glucose and lipid profile coincide with the findings in our study for the male population in relation to the WFP. The authors of that paper did not find sex differences in the prevalence of MetS and its components, which might have been because the analyses were adjusted by household food insecurity. Regrettably, in our study, we did not collect data about food security and therefore we were not able to formally confirm the hypothesis of interaction of food assistance program participation with sex and food insecurity on the prevalence of MetS. However, it seems reasonable to assume that female workers who are assisted by the WFP and therefore have the guarantee of a lunch in the worksite are less likely to experience food insecurity.

With the development of T2DM and cardiovascular diseases as main outcomes, the MetS causes great public health concerns in several countries, especially those in the low- and middle-income range, which have high percentages of deaths from cardiovascular diseases.[38] The World Health Organization, aware of this global health trend, had launched the Global Action Plan for the Prevention and Control of non-communicable diseases 2013–2020,[39] with the objective of decreasing premature mortality by 25% from those comorbidities. Among the action strategies, the plan recommends the implementation of actions at the national level, involving other sectors in addition to the health sector, that improve people's quality of life, and mentions the strengthening of food and nutrition policies as a key point for the creation of environments that encourage the adoption of healthier eating habits and lifestyles.

The present study has several strengths. It was based on representative sample of the population of manufacturing workers, the design was of a comparative study, adopted a complex survey strategy with a combined stratified and two-stage design to ensure adequate representativeness of all kinds of companies, data collection was prospective and performed by qualified and trained personnel, and statistical analysis was design-based tailored to the sampling plan by including stratification, clustering and survey weights, adjustment by co-variates, and robust standard errors. In addition, participation in the WFP, because it was not self-reported, was measured without error, blood samples were analyzed in the same central laboratory and always by the same technician, and anthropometric measurements were taken according to a standard protocol.

MetS has several causes that are widely recognized, some endogenous such as age, ethnicity, insulin resistance and family history, and some exogenous such as dietary habits, smoking, and physical inactivity. In order to isolate the impact of dietary habits on the prevalence of MetS, we collected data and tested for differences between groups in age, smoking and physical activity, measured with a validated instrument, between WFP and non-WFP groups, in each sex, and found the groups to be balanced in the distribution of those variables.

The study has some limitations to generalizability of the findings. The survey, although covering an entire State, was limited to the companies operating in that State and to only three sectors of activity representing the major contrition to the State economy. The cross-sectional study design does not allow the establishment of causality, although it seems unlikely that some form of selection bias has influenced men with MetS to find work in WFP-adherent companies. Some companies declined participation in the study but that was not in any way related to the objectives of the research. There was significant attrition among workers, who failed to show in the second day of the interview when blood samples would be collected, which reduced the statistical power of the study to find differences between groups but, again, a relationship to the research objectives can safely be discarded. Mixed effects multilevel models are gaining popularity for the analysis of complex survey data but they rely on a large number of assumptions, which may somehow compromise their robustness. For that reason, we conducted several analyses while changing some model parameters to ensure that the presented results are robust and reliable.

Finally, we recognize the relevance of developing public policy assessment studies, especially when these studies describe policy outcomes on the target population. Additionally, these results can serve as an alert for the competent bodies to take appropriate measures, such as changes in the program recommendations, changes in its execution and, also, to develop means of monitoring the food and nutrition programs, in addition to encouraging the adoption of measures for the early detection of disorders such as MetS.

Conclusion

This was one of the first studies reporting an association between a food assistance program and the prevalence of the MetS in manufacturing workers and the first prospective study investigating such association. The association is positive and relevant for males, but probably null or negative for females, suggesting an influence of food insecurity in the effects of food assistance programs in low-income populations. Because of this, we recommend that future research on the effects of food assistance programs on the nutritional status should analyze each sex separately and include an assessment of food insecurity.

Data Sharing Statement

Study data were made available as Supplementary File.

Ethics Approval and Informed Consent

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University Hospital Onofre Lopes with the authorization code 2.198.545/2017. All study participants agreed to participate in the research by signing an informed consent form before any procedure had been conducted.

Acknowledgments

The authors wish to thank the dieticians who participated in the research, Andréa A. Medeiros, Daionara B. Sousa and Rafaella B. D. Bezerra, as well as to the graduate students who gave a significant contribution to data collection, Nathanael J. Araujo, Roberta C. Santos and Jeferson M. R. Silva.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001.

Disclosure

The authors declare no conflicts of interest.

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