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Original article

Coronary artery disease and body mass index: What is the relationship?

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S U M M A R Y

Introduction: Nowadays, obesity is considered an independent risk factor for the development of cardiovascular diseases (CVD), which has been presented as an important cause of worldwide morbidity and mortality, especially coronary artery disease (CAD). The objective of the study was to verify the association between body mass index (BMI) and severity of CAD, its risk factors and surgical and percutaneous treatment in patients hospitalized in cardiological units.

Methods: An ambispective, cross-sectional study was performed with patients older than 18 years attended by nutrition in the cardiology units, who underwent coronary angiography. The severity of CAD was categorized into two distinct classifications (CAD Class I and II), considering the presence of CAD as lesions ≥50% and ≥70%. The nutritional status of the patient was established based on BMI according to the World Health Organization (WHO) for the total sample and group of adults, and according to the Pan American Health Organization (PAHO) for the elderly. Age, gender, presence of associated comorbidities, history of smoking, and performed procedures were collected in patients' records. For statistical analysis Kruskal Wallis and Chi-square tests were used, and Hodges-Lehmann estimate was used for the median. Comparisons and associations were considered significant when $p < 0.05$.

Results: A total of 703 patients were included, of which 495 had arterial lesions ≥70% and 513 patients' lesions ≥50%. The average age was 61 years, women were older (63 vs 61; $p = 0.008$), had a higher BMI (28.16 kg/m^2 vs 26.68 kg/m^2, $p = 0.001$) and were more likely to have diabetes mellitus (DM) ($p < 0.001$), dyslipidemia (DSLP) ($p < 0.001$), and hypertension (HTN) ($p = 0.001$). The majority of the sample consisted of men, who more often underwent percutaneous coronary intervention (PCI) (53,9% vs 39%, $p < 0.001$), and were more likely to present more severe CAD ($p < 0.001$ and $p = 0.003$). In patients diagnosed with CAD the increase in BMI was positively associated with the presence of DM ($p < 0.001$), DSLP ($p < 0.001$) and HTN ($p < 0.001$), and negatively with age ($p = 0.007$). Patients with obesity III, were diagnosed with CAD, in average, 11 years earlier than patients with normal BMI ($p = 0.05$). Therefore, the higher the BMI, the lower the age at the moment of the examination in the total sample, and in the group of elderly, and this association was not found in adults. There was no significant association of BMI with the severity of CAD, or with PCI and coronary artery bypass grafting (CABG). The greater severity of CAD was positively associated with the presence of DM ($p = 0.012$ and $p = 0.001$), HTN ($p = 0.033$ and $p = 0.003$) and older age ($p = 0.005$ and $p = 0.015$). Patients who underwent CABG had a higher incidence of and HTN ($p = 0.003$), DM ($p = 0.006$), whereas patients who had PCI had a lower incidence of HTN ($p = 0.021$) and DM ($p = 0.004$).

Abbreviations: CVD, Cardiovascular diseases; CAD, Coronary artery disease; BMI, Body Mass Index; WHO, World Health Organization; PAHO, Pan American Health Organization; DM, Diabetes mellitus; DSLP, Dyslipidemia; HTN, Hypertension; PCI, Percutaneous coronary intervention; CABG, Coronary artery by-pass grafting; IHD, Ischemic health disease; CA, Coronary angiography; VD, Vessel disease; LMCA, Left main coronary artery.

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Conclusion: Obesity was showed to be as an independent risk factor for the early incidence of CAD, which is strongly associated with the presence of comorbidities such as DM, HTN and DSLP. The greater severity of CAD and coronary interventions were associated with the presence of risk factors for CAD.

1. Introduction

Currently, cardiovascular disease (CVD), especially coronary artery disease (CAD), is one of the main causes of morbidity and mortality in the world [1]. The worldwide prevalence of CVD in the year 2015 was over 400 million cases, with 8.92 million deaths due to ischemic heart disease (IHD) [2], values higher than those found in 2010, which estimated 7 million cases, from which 25.6% occurred in people under 65 years [1].

In Brazil, in 2015, CVD caused 28% of the country's total deaths [3,4], accounting for more than 330,000 deaths [3]. In the same year, according to DataSUS data, IHD caused approximately 108 thousand deaths, being acute myocardial infarction responsible for more than 90 thousand deaths, in 2016 deaths for these comorbidities increased to 113 thousand and more than 94 thousand, respectively [5].

Cases of acute myocardial infarction treated with percutaneous coronary intervention (PCI) have increased in recent years, with more than 75,000 hospitalizations for PCI in 2015, much higher than the hospitalizations in 2010, which were almost 56 million [3].

Obesity has been shown to be a major risk factor for the development of CVD [4] and is considered to be an independent risk factor for CAD [6,7], and also related to the risk of acute myocardial infarction, as demonstrated by the Interheart study [8]. Likewise, obesity is also related to the increased prevalence of comorbidities associated with the development of CAD, such as diabetes mellitus (DM), systemic arterial hypertension (HTN), dyslipidemia (DSLP) [7], and higher rates of PCI [9].

In 2016, 13% of the world population over 18 years had some degree of obesity, evaluated as a body mass index (BMI) of 30 kg/m^2 or more, 1.9 billion people were overweight and 22% of the Brazilian adult population was obese [4].

The objective of the study was to verify the association between Body Mass Index (BMI) and severity of CAD, as well as to evaluate the presence of risk factors for the development of CAD, the treatment of coronary artery bypass grafting (CABG), and PCI in hospitalized patients in a tertiary hospital, attended by the nutrition team.

2. Materials and methods

Ambispective, cross-sectional study using the database from a nutritional care in the cardiology units of a university hospital from January 2011 to March 2017.

The present research consists of a sub study of “Epidemiological and Nutritional Profile of Cardiopathy Patients” research, approved by the research ethics committee of Federal University of Paraná.

All patients older than 18 years, who had coronary angiography (CA) and nutritional assessment were included in the study. Patients who had previously performed prior hospitalization to CABG and PCI were excluded.

The nutritional status of the patient was established according to the BMI, using the current or estimated weight [10] and measured or estimated height [11,12]. The BMI was classified according to the World Health Organization (WHO) (1997) [13] for analysis of the total sample, and in a second analysis we used WHO (1997) [13] for adults and the classification proposed by the Pan American Health Organization (PAHO) (2001) [14] for elderly patients (age ≥60 years).

The extent of CAD was categorized into two distinct classifications. Classification I stratified the patients according to the number of arterial territories with obstructions ≥50%, classifying them in 1, 2 or 3 vessel disease (VD) or Left Main Coronary Artery (LMCA). The second classification was similar to the first, but only lesions ≥70% (CAD classification II) were considered. CA reports that did not contain numerical value of the percentage of the lesion were included in the study considering moderate lesion as lesion of 50–69%, critical lesion of 70–94%, and sub occlusive lesion as above or equal to 95%.

Data on age, sex, medical diagnoses, associated comorbidities, smoking history, cardiac coronary angiography records, and PCI and CABG procedures were collected from patients' records.

2.1. Statistical analysis

Numerical variables were described as average and standard deviation, while categorical variables were expressed in number and percentage. Statistical analyzes were performed using SPSS v.24 program. The Kruskal Wallis test was used to compare the numerical variables. For categorical variables, an association with the Chi-square test was used, but in the violation of the assumptions of this test Fisher's, with estimated p-value through Monte Carlo simulations. The Hodges-Lehmann test was used to estimate the age difference between groups of risk factors and BMI, together with a 95% confidence interval for the parameter. Comparisons and associations were considered significant when $p < 0.05$. Omitted cases were not counted in the analyzes.

3. Results

3.1. Of the total sample

From the 1941 patients hospitalized in the cardiological units from January 2011 to March 2017 attended by nutrition, 975 were excluded since they did not undergo CA, 263 had previous PCI or CABG, so they were also excluded, 703 patients met the criteria and were included in this study. As demonstrated in Table 1, CAD presenting lesions ≥50% (Classification I) was present in 72.9% of the patients (n = 513). From these, 495 patients (70.4%) also had CAD lesions ≥70% (Class II).

The average age was 61 years, the majority of patients were males (59.9% vs 40.1%), who most frequently had PCI (53.9% vs 39%, $p < 0.001$) and were more likely to develop CAD, with 3 VD obstructive pattern with lesions ≥50% (26,1% vs 18,4%, p < 0,001) e ≥ 70% (18,1% vs 13,5%, p = 0.003). Women were older (average age 63 years, p = 0.008), and they presented a higher BMI average (28.16 kg/m^2 vs 26.68 kg/m^2, p = 0.001), and more likely to have DM (44,7% vs 25,4%, p < 0.001), DSLP (47.2% vs 33.3%, p < 0.001) and HTN (80.1% vs 68.4%, p = 0.001) compared to men. Only smoking and CABG did not present significant differences between genders.

Regarding to BMI classification, when WHO classification [13] was used for all patients, 2.9% was under weight, 32.5% normal

Table 1
Characterization of the total sample.

	Total
Age $\bar{x}$ ± SD	61 ± 12.73
BMI $\bar{x}$ ± SD	27.28 ± 5.19
Male - n (%)	421 (59.9%)
Diabetes - n (%)	233 (33.1%)
Hypertensive - n (%)	514 (73.1%)
Dyslipidemics - n (%)	273 (38.8%)
Current smoker - n (%)	182 (25.9%)
BMI Classification - n (%)[a]	
Underweight	20 (2.9%)
Normal weight	225 (32.5%)
Overweight	245 (35.4%)
Obesity I	152 (21.9%)
Obesity II	42 (6.1%)
Obesity III	9 (1.3%)
Total	693 (100%)
CAD Classification I (lesions ≥50%) - n (%)	
No CAD (lesions < 50%)	190 (27%)
1 VD	167 (23.8%)
2 VD	149 (21.2%)
3 VD	162 (23%)
LMCA	35 (5%)
Total	703 (100%)
CAD Classification II (lesions ≥70%) - n (%)	
No CAD (lesions < 70%)	208 (29.6%)
1 VD	210 (29.9%)
2 VD	136 (19.3%)
3 VD	114 (16.2%
LMCA	35 (5%)
Total	703 (100%)
Coronary Interventions Performed - n (%)	
PCI Performed	337 (47.9%)
MRS performed	81 (11.5%)

$\bar{x}$: Average; SD: Standard deviation; BMI: Muscle mass index; n: Number; CAD: Coronary artery disease; VD: Vessel disease; LMCA: Left main coronary artery; PCI: Percutaneous coronary intervention; CABG: Coronary artery bypass grafting.
[a] Omitted Cases: 10.
Source: Authors, 2019.

weight, 35.4% overweight and 29.3% were obese. The increase in BMI was positively associated with the presence of DM ($p < 0.001$), DSLP ($p < 0.001$) and HTN ($p < 0.001$), and negatively with age ($p = 0.021$). However, there was no significant association of BMI with smoking, severity of CAD, CABG and PCI.

Similar results were found, for adults and elderly, when BMI was separated. Adult and elderly patients also had increased BMI significantly associated with DM ($p = 0.001$ for adults and $p < 0.001$ in elderly), HTN ($p < 0.001$ and $p = 0.004$, respectively), DSLP ($p < 0.001$ for both) and lower age for elderly ($p = 0.004$).

3.2. From the sample of patients with CAD

Patients with CAD, 513 with lesions ≥50% and 495 with lesions ≥70%, presented significantly lower age and higher percentages of DM, DSLP and HTN associated with an increase in BMI classification, when the analysis was performed using the same classification for adults and elderly according to WHO (1997) (Table 2).

Similar results were observed in the elderly group for both CAD ratings, when we used BMI classification according to PAHO (2001), there was an association with higher BMI and the presence of HTN ($p = 0.016$ for CAD ≥50% and $p = 0.019$ for CAD ≥70%), DM ($p < 0.001$ for both CAD scores), DSLP ($p = 0.002$ and $p = 0.005$) and lower age ($p = 0.046$ and $p = 0.004$). In the adults group with CAD, BMI according to WHO [13], a significant association was found with higher BMI and DSLP presence ($p = 0.005$ for CAD ≥50% and $p = 0.001$ for CAD ≥70%), and HTN ($p = 0.001$ for both CAD scores).

No significant association with BMI was found for all BMI classifications, with severity of CAD, CABG or PCI (Table 2). However, it was verified that patients with higher BMI (WHO for adults and elderly) were younger at the time of CA in both patients classified as having CAD with lesions ≥50% ($p = 0.007$) (Graph 1) and in patients with CAD lesions ≥70% ($p = 0.004$) (Graph 2), the same association was significant using BMI for elderly (PAHO, 2001) [14]. In adults' cases there was no significant association with higher BMI and earlier age.

The relationship between age and risk factors was analyzed, as well as between age and BMI categories. As demonstrated in Table 3, female CAD patients, patients with diabetes, hypertension and dyslipidemia and those underweight were older at the time of the diagnostic test, whereas patients with a higher BMI were younger than patients in the normal BMI range. For example, at the time of CA, patients with Obesity I were 5 years younger than patients with normal BMI compared to average age in each group.

It was verified that the highest severity of CAD, in classifications I and II, was positively associated with the presence of DM ($p = 0.012$ and $p = 0.001$), HTN ($p = 0.033$ and $p = 0.003$) (Graph 3) and greater age ($p = 0.005$ and $p = 0.015$), with no significant association with DSLP, smoking, gender and BMI. Moreover, it is possible to observe that patients with 3 VD CAD generally had a higher frequency of associated comorbidities in relation to patients with 1 ou 2 VD obstructive pattern (Graph 3).

In both CAD classifications, it was found that patients with 1 and 2 VD obstructive patterns were more likely to have PCI ($p < 0.001$ for both CAD classifications), whereas among patients with 3 VD CAD or lesions in LMCA, CABG was more frequent ($p < 0.001$ for both CAD classifications) (Graph 4).

When analyzing the presence or absence of CABG in patients with CAD classification I (Graph 5), it is possible to observe that patients who performed CABG had a higher incidence of other pathologies such as HTN (86% vs 70%, $p = 0.003$) and DM (48% vs 32%, $p = 0,006$), in relation to patients who did not performed CABG, no significant association was found with DSLP ($p = 0.053$), smoking ($p = 0.097$) and BMI ($p = 0.303$). However, the result was inverse in the patients who underwent PCI (Graph 6), there was a lower frequency of patients with HTN (69% vs 79%, $p = 0.021$), DM (31% vs 43%, $p = 0.004$) and higher frequency of smokers (34% vs 19%, $p = 0.003$), with no association with DSLP ($p = 0.09$) and BMI ($p = 0.818$).

The same significant associations were also verified in patients with CAD classification II. Patients who underwent CABG had a higher incidence of HTN ($p = 0.002$) and DM ($p = 0.008$), whereas patients who underwent PCI had a lower prevalence of HTN ($p = 0.024$), DM ($p = 0.003$), and a higher number of smokers ($p = 0.005$).

4. Discussion

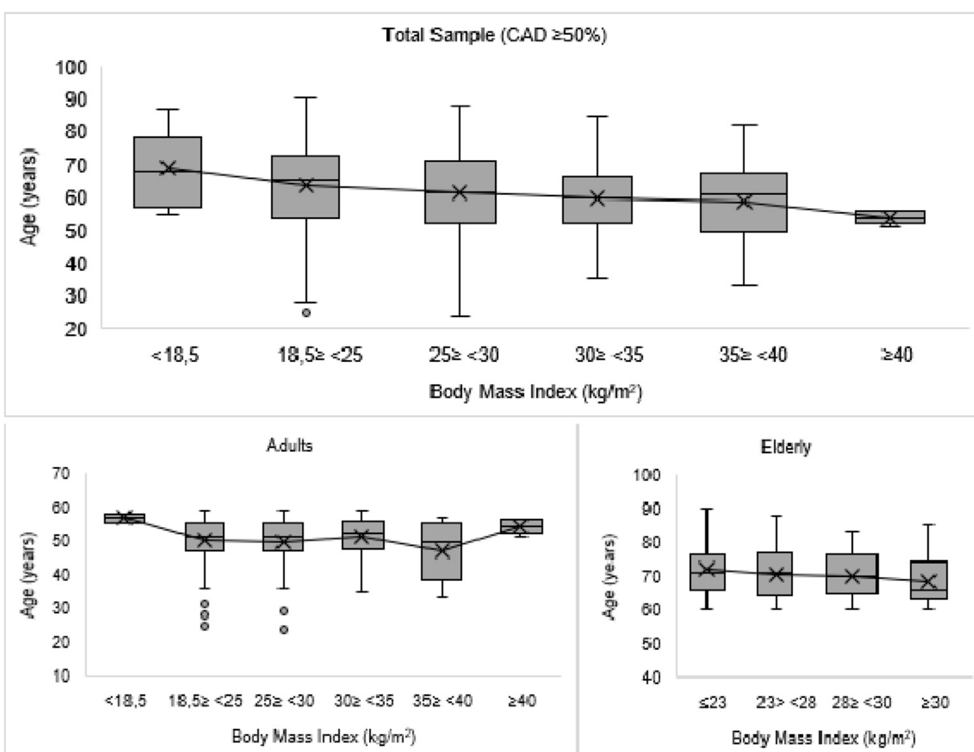
In this study, a significant negative association was found between BMI and the age of patients at the time of CA, where it was demonstrated that the increase in BMI is inversely related to the lower age at the time of CAD diagnostic examination, which matches with other publications [6,9,15], contrary to the presence of DM, DSLP, HTN, female and underweight that were associated with older age, an association also described in the literature [6].

Differently from other clinical findings [7,16] this study found no significant association of BMI with the severity of CAD and with surgical or percutaneous treatment of CAD. However, the association between BMI increase and the presence of risk factors for CAD, such as DM, HTN and DSLP, was also significant, as was also observed in other studies [6,17].

Table 2
Comparisons between BMI with categorical and numerical variables of patients with CAD Classification I.

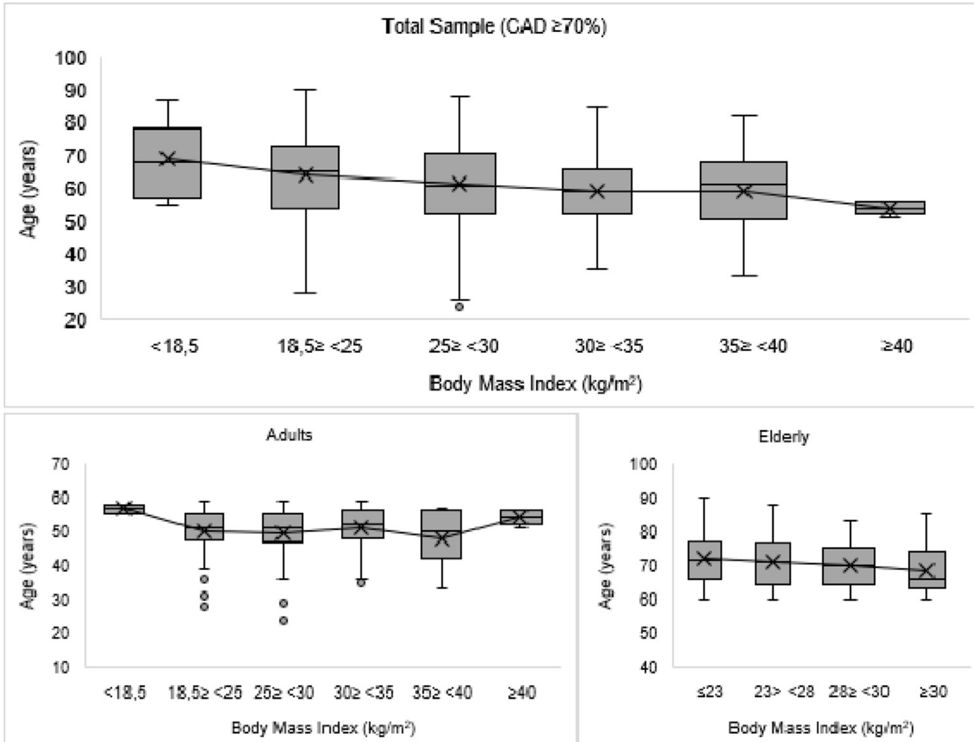
Variable	BMI Classification (n)						
	Underweight	Normal	Overweight	Obese I	Obese II	Obese III	P value
Age - $\bar{x}$ ±SD	69 ± 12	64 ± 13	61 ± 12	60 ± 11	58 ± 13	54 ± 2	0.007*
Diabetics – n (%)	4 (36.4%)	43 (25.7%)	60 (32.3%)	50 (43.9%)	18 (72%)	3 (60%)	<0.001*
Hypertensive - n (%)	7 (63.6%)	102 (61.1%)	136 (73.9%)	95 (83.3%)	23 (92%)	5 (100%)	<0.001*
Dyslipidemics - n (%)	3 (27.3%)	57 (34.1%)	64 (34.8%)	66 (57.9%)	17 (68%)	1 (20%)	<0.001*
Smokers - n (%)	4 (36.4%)	54 (32.3%)	47 (25.5%)	34 (29.8%)	5 (20%)	1 (20%)	0.683
Gender - n (%)							
Female - n (%)	8 (72.7%)	47 (28.1%)	56 (30.4%)	50 (43.9%)	15 (60%)	3 (60%)	<0.001*
Male - n (%)	3 (27.3%)	120 (71.9%)	128 (69.6%)	64 (56.1%)	10 (40%)	2 (40%)	
CAD Classification I (lesion ≥ 50%) - n (%)							
1 VD	3 (27.3%)	51 (30.5%)	60 (32.6%)	41 (36%)	10 (40%)	1 (20%)	0.325
2 VD	2 (18.5%)	50 (29.9%)	52 (28.3%)	34 (29.8%)	6 (24%)	3 (60%)	
3 VD	6 (54.5%)	46 (27.5%)	65 (35.3%)	33 (28.9%)	7 (28%)	1 (20%)	
LMCA	0 (0%)	20 (12%)	7 (3.8%)	6 (5.3%)	2 (8%)	0 (0%)	
Total	11 (100%)	167 (100%)	184 (100%)	114 (100%)	25 (100%)	5 (100%)	
CAD Classification II (lesion ≥ 70%) - n (%)							
No CAD (<70%)	0 (0%)	5 (3%)	7 (3.8%)	5 (4.4%)	1 (4%)	0 (0%)	0.698
1 VD	5 (45.5%)	69 (41.3%)	74 (40.2%)	47 (41.2%)	11 (44%)	3 (60%)	
2 VD	2 (18.2%)	42 (25.1%)	49 (26.6%)	34 (29.8%)	5 (20%)	1 (20%)	
3 VD	4 (36.4%)	31 (18.6%)	47 (25.5%)	22 (19.3%)	6 (24%)	1 (20%)	
LMCA	0 (0%)	20 (12%)	7 (3.8%)	6 (5.3%)	2 (8%)	0 (0%)	
Total	11 (100%)	167 (100%)	184 (100%)	114 (100%)	25 (100%)	5 (100%)	
Coronary Interventions- n (%)							
PCI	7 (63.6%)	133 (62%)	114 (62%)	77 (67.5%)	15 (60%)	4 (80%)	0.815
CABG	3 (27.3%)	22 (13.2%)	32 (17.4%)	17 (14.9%)	7 (28%)	0 (0%)	0.308

Omitted Cases: 7.
*Significant p-value at of 5% significance.
$\bar{x}$: Average; SD: Standard deviation; BMI: Muscle mass index; n: Number; CAD: Coronary artery disease; VD: Vessel disease; LMCA: Left main coronary artery; PCI: Percutaneous coronary intervention; CABG: Coronary artery bypass grafting.
Source: Authors, 2019.



Graph 1. Comparison between BMI and Age in patients with CAD (lesions ≥50%). Source: Authors, 2019. CAD: Coronary artery disease. Single fitting image.

Approximately 65% of the sample with CAD (lesion ≥50%) were overweight or obese according to WHO classification [13], without distinguishing adults and elderly, similar to the results described by Simone et al. [17] with patients who underwent PCI, to that found in Australian patients, where 75% of the sample was overweight [6].



Graph 2. Comparison between BMI and Age in patients with CAD (lesions ≥70%). Source: Authors, 2019. CAD: Coronary artery disease. Single fitting image.

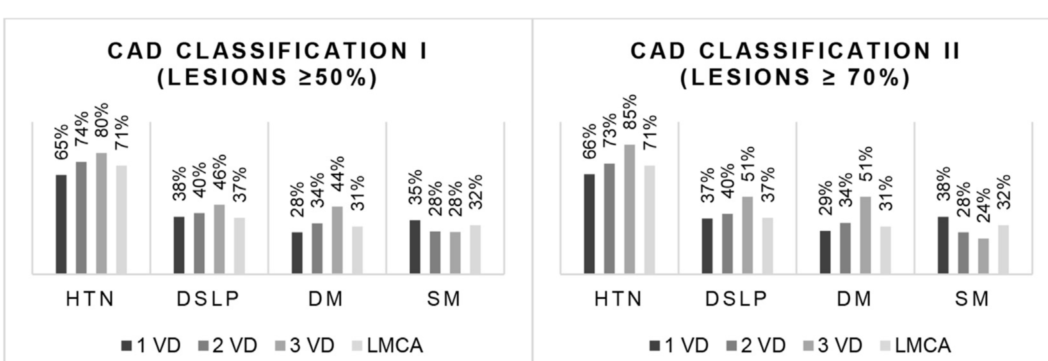
Table 3
Hodges-Lehmann average age difference among risk factors of patients with CAD with lesions ≥50%.

Variables	Age difference (in years)	95% CI	P Value
Female vs Male	2	0,00 a 5,00	0,061
DM vs No DM	3	0,00 a 5,00	0,023*
HTN vs No HTN	6	3,00 a 8,00	<0,001*
DSLP vs No DSLP	3	0,00 a 5,00	0,023*
BMI			
Underweight	5	−4,00 a 13,00	0,265
Overweight	−3	−5,00 a 0,00	0,058
Obesity I	−5	−8,00 a −2,00	0,003*
Obesity II	−5	−11,00 a 1,00	0,073
Obesity III	−11	−20,00 a 0,00	0,050

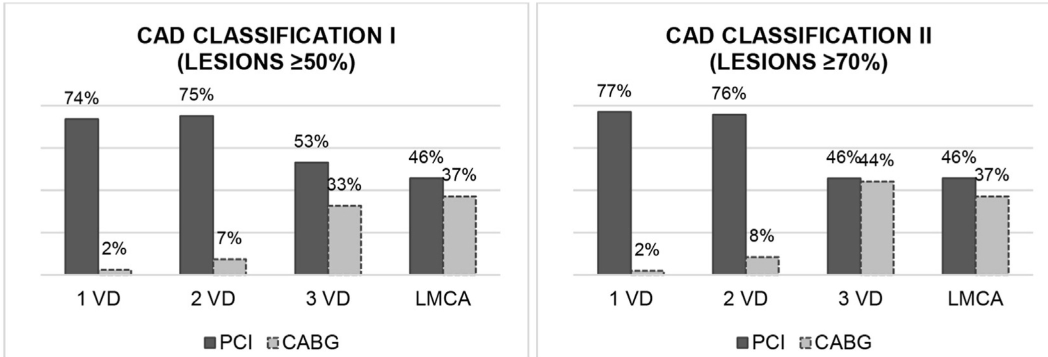
*Significant p-value at 5% significance; DM: Diabetes mellitus; HTN: Hypertension; DSLP: Dyslipidemia; BMI: Body mass index; CI: Hodges-Lehmann confidence interval; BMI average was compared to the median of the normal BMI group (18.5 ≥ <25 kg/m^2).
Source: Authors, 2019.

As well as it was observed by Mahalle et al. [16], the presence of DM and HTN was more common in patients with 3 VD CAD. The data presented in our study indicated that patients with greater number of obstructed vessels had older age, lower percentage of PCI and higher percentage of CABG in relation to patients with fewer diseased vessels, with no significant difference between the performance of interventions and BMI. In the study by Terrada et al., a significant relationship was found between the levels of overweight and obesity with the intervention performed [9].

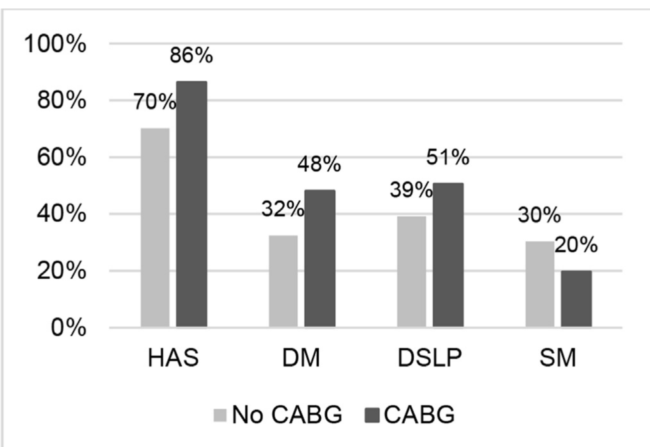
Although obesity is an important risk factor for CVD, there are still controversies regarding to the effects of high BMI on the severity of CAD [15]. Overweight and obesity are associated with increased risk of developing CAD [18], however, in patients with comorbidities already established, it is well known that levels of overweight and moderate obesity have been shown to be a protective factor for mortality in cardiovascular disease, including CAD, but it is not applicable to more severe levels of obesity [19].



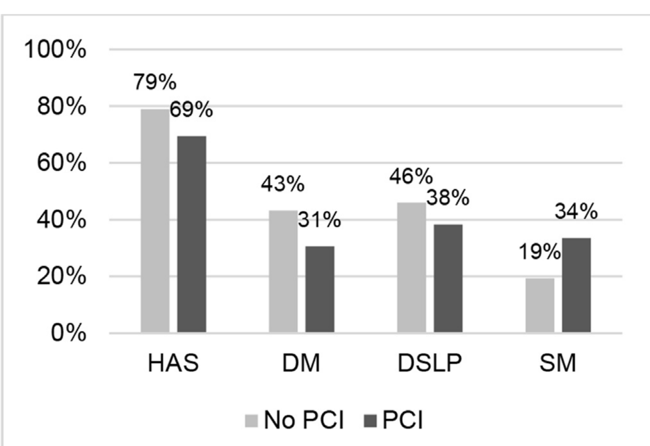
Graph 3. Association between risk factors and classification of coronary artery disease. Source: Authors, 2019. CAD: Coronary artery disease; VD: Vessel disease; LMCA: Left main coronary artery; HTN: Hypertension; DM: Diabetes mellitus; DSLP: Dyslipidemia; SM:Smoking. Single fitting image.



Graph 4. Correlation between CAD Classification and Interventions Carried Out. Source: Authors, 2019. CAD: Coronary Artery Disease; VD: Vessel disease; LMCA: Left main coronary artery; PCI: Percutaneous Coronary Intervention; CABG: Coronary artery bypass grafting. Single fitting image.



Graph 5. Risk factors in patients with CAD lesions ≥50% who underwent CABG. Source: Authors, 2019. HTN: Hypertension; DM: Diabetes Mellitus; DSLP: Dyslipidemia; SM: Smoking; CABG: Coronary artery bypass grafting. Single fitting image.



Graph 6. Risk factors in patients with CAD lesions ≥50% who underwent PCI. Source: Authors, 2019. HTN: Hypertension; DM: Diabetes mellitus; DSLP: Dyslipidemia; SM: Smoking; PCI: Percutaneous coronary intervention. Single fitting image.

In the study by Engel et al. [20] it was demonstrated that underweight BMI patients had a higher number of complications and mortality after CABG compared to obese patients, but obese patients underwent surgery at a younger age. A study with Japanese has also shown that underweight and obese patients are at increased risk of CVD mortality [21]. In our study, 7.4% (n = 51) of severe obese patients (obesity II and III) and 2.9% (n = 20) of underweight patients were found, therefore 10% of the population presented a higher risk for mortality, according to the IMC, and should receive greater attention from the multi professional team to improve nutritional status.

Due to criticism to the literature regarding the classification proposed by WHO [13], which does not consider changes in the aging process, where elderly individuals present an increase and redistribution of body fat [22], using the same standard for adults and elderly individuals, this article classified adults according to WHO [13] and elderly according to WHO [13] and PAHO [14], finding differences in the results of the analyzes of the groups regarding to the association of BMI with age and risk factors. Therefore, the importance of using a classification adapted for the elderly, even in patients with CAD, is suggested.

5. Conclusion

The PCI was the most frequent treatment in the population studied.

The present article found no direct association between obesity and the severity of cardiovascular disease. However, when analyzing the age at which the exam was performed, we found that patients with higher BMI were younger at the time of diagnosis of CAD, indicating a direct association of obesity with early incidence of CAD.

Also the obesity was strongly associated with the presence of risk factors such as DM, HTN and DSLP, and these comorbidities are correlated with the greater severity of CAD and with the treatments performed.

Consequently the prevention and treatment of obesity deserve special attention from health team.

Declaration of authorship

Franciane Silvana Formentini: Conception, design of the study, acquisition, analysis and interpretation of data, manuscript drafting and final approval of the version to be submitted.

Francisca Eugenia Zaina Nagano: design of the study, acquisition of data, critical review of the manuscript content and final approval of the version to be submitted.

Francisco Diego Negrão Lopes Neto: analysis and interpretation of data and critical review of the manuscript content.

Eduardo Leal Adam: design of the study and critical review of the manuscript content.

Fernanda Santos Fortes: acquisition of data and critical review of the manuscript content.

Lannay Ferreira da Silva: acquisition of data and critical review of the manuscript content.

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