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RESEARCH ARTICLE

The impact of body mass index on lipid profile, blood pressure, and glycemic control in patients with type 2 diabetes mellitus: a comparative study

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Objective: The aim of this study was to highlight the impact of body mass index on the lipid profile, blood pressure, and glycemic control in patients with type 2 diabetes mellitus. **Methods**: We conducted an observational, retrospective study on 294 subjects with type 2 diabetes mellitus, hospitalized between 01.06.2018 - 01.06.2019. Subjects were divided into three groups according to body mass index value: group 1 - normal weight, group 2 - overweight, and group 3 - obesity. **Results**: Out of the 294 subjects, 59.2% were females. There were 41 subjects in group 1, 89 subjects in group 2, and 164 subjects in group 3. The lipid profile was normal in 68.3% of cases in group 1, being abnormal in 49.4% of cases in group 2 and 56.1% of cases in group 3. We found a statistically significant difference between triglycerides levels in the three groups among males (P = <0.001) and females (P = 0.004). Arterial hypertension was found in 91.2% of cases, its prevalence being statistically significant higher in females (94.8%) than in males (85.8%) (P = 0.011). Most subjects had a poor glycemic control (89.1%) without any statistically significant differences among the three groups. **Conclusions**: An increased body mass index in type 2 diabetes mellitus increases the prevalence of various cardiovascular risk factors such as arterial hypertension and dyslipidemia, while glycemic control seems more influenced by the duration of the disease.

Keywords: type 2 diabetes mellitus, body mass index, lipid profile, blood pressure, glucose control

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Introduction

Obesity and overweight have become a public health problem, affecting more than a third of the world's population, with great impact on morbidity, mortality and cost of healthcare [1, 2]. Individual factors such as low physical activity, nutrient-poor food choices, unhealthy lifestyle, genetics, and also socioeconomic factors like poverty and low education have been linked to an increased risk in developing weight problems [1]. Based on the body mass index (BMI), obesity is defined as a BMI equal or greater than 30 kg/m^2, having three grades of severity: grade I (BMI: 30.0-34.9 kg/m^2), grade II (BMI: 35-39.9 kg/m^2), and grade III or extreme obesity (BMI: > 40 kg/m^2) [3]. Metabolic syndrome, cerebrovascular and heart disease, hypertension, dyslipidemia, and diabetes mellitus (DM) are among the morbidities associated with obesity [4]. Abdominal obesity, representing the central distribution of the adipose tissue, is often associated with an increased risk of developing systemic inflammation, dyslipidemia, cardiovascular disease, and insulin resistance [5]. According to the International Diabetes Federation (IDF), central obesity is defined as a waist circumference ≥ 94 cm in Caucasian men and ≥ 80 cm in Caucasian women [6].

DM, like obesity, is a major public health problem, affecting more than 400 million people worldwide, with an expected increase of over 600 million cases by 2040 [7]. It is characterized by high levels of blood glucose due to defects of insulin secretion and/or insulin action, which can lead to damaging of various organs such as eyes, kidneys, heart or nerves [8]. The latest statistics show that there are 1.278.300 of diabetic patients aged between 20-79 years old in Romania, with a prevalence of 8.8% for an adult population of 14.545.800 million [9].

Dyslipidemia is often found in patients with obesity and/or DM, being characterized by increased hepatic production of very-low-density-lipoprotein cholesterol (VLDL-C), decreased triglycerides-rich lipoprotein clearance, high levels of low-density-lipoprotein cholesterol (LDL-C), and low levels of high-density-lipoprotein cholesterol (HDL-C) [10-12]. It is associated with an increased risk of atherosclerosis, cardiovascular diseases, acute myocardial infarction or kidney disease [12].

During pandemics, such as COVID-19, patients suffering from obesity and its complications (especially DM and cardiovascular disease) are at risk of developing more

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severe forms of the infectious disease, therefore, these cases should be included in vulnerable groups and attentive medical care should be applied [13].

The aim of this study was to highlight the impact of BMI on the lipid profile, blood pressure, and glycemic control in patients with type 2 DM.

Methods

We conducted an observational, retrospective study on a group of 294 subjects hospitalized between 01.06.2018 - 01.06.2019 in the Diabetes, Nutrition and Metabolic Diseases Compartment of Emergency County Hospital of Târgu Mureș. The aim was to highlight the impact of BMI on metabolic parameters such as lipid profile, blood pressure, and glycemic control in subjects with type 2 DM.

Data was collected from medical forms in order to obtain information about reasons for admission, personal and family history, rural/urban background, age, duration of evolution of diabetes mellitus, type of antidiabetic treatment, latest value of glycated hemoglobin (HbA1c), anthropometric measurements (height, weight, abdominal circumference), history of high blood pressure, presence of hepatic steatosis, and lipid profile values (total cholesterol and triglycerides). Inclusion criteria was considered the diagnosis of type 2 DM with or without overt complications. Exclusion criteria were considered the following: subjects under 18 years-old, subjects with type 1 DM, pregnant subjects, subjects lacking certain data such as anthropometric measurements (height, weight, abdominal circumference), glycosylated hemoglobin value, blood pressure value, abdominal ultrasound, and/or serum cholesterol and triglycerides values. Also, subjects lacking information about the evolution and duration of DM or with multiple admissions during the study period, were excluded.

Subsequently, the 294 selected cases were divided into three groups according to the value of BMI: group 1 - normal-weight subjects (BMI: 18.5-24.9 kg/m^2), group 2 - overweight subjects (BMI: 25.0-29.9 kg/m^2), and group 3 - obese subjects (BMI: > 30.0 kg/m^2).

Abdominal obesity was defined according to IDF as waist circumference ≥ 94 cm in males and ≥ 80 cm in females. A good glycemic control was considered a level of HbA1c below 7%, respectively below 7.5% in cases with a long evolution (> 20 years) of DM. Cut-off values for cholesterol and triglycerides levels were considered 200 mg/dL, respectively 150 mg/dL. We evaluated the presence of hepatic steatosis based on abdominal ultrasound. Metabolic syndrome was defined as the concomitant presence of the following factors: abdominal obesity, dyslipidemia (hypercholesterolemia, hypertriglyceridemia or mixed dyslipidemia), high blood pressure (grade I: 140-159/90-99 mmHg; grade II: 160-179/100-109 mmHg; grade III: >180/>110 mmHg), and DM type 2.

The access to medical data was done with the approval of the Diabetes, Nutrition and Metabolic Diseases Compartment of Emergency County Hospital of Târgu Mureș. The study was conducted respecting the ethical principles stated in the Declaration of Helsinki for medical research involving human subjects.

The data were collected and statistically processed in Microsoft Excel software and GraphPad Prism 8. Discrete quantitative variables and binary qualitative variables were used. The quantitative variables were expressed as mean ± standard deviation or medians; qualitative variables were expressed as frequency or percentages. To assess the normality, D'Agostino & Pearson test was used, Fisher exact test was used to compare differences in proportions of qualitative variables, and Kruskal Wallis non-parametric test for the comparison of characteristics among the three groups for each sex. A P value of less than 0.05 was considered significant.

Results

After applying the inclusion/exclusion criteria, we found 294 eligible subjects. Most of the subjects were females (F) (59.2%, n = 174), and 40.8% (n = 120) were males (M). Rural background was predominant (63.6%, n= 187). The mean age was 60.9 ± 12.5, and median age was 63. Group 1 consisted of 41 normal-weight subjects (23 F and 18 M), group 2 of 89 overweight subjects (52 F and 37 M), and group 3 of 164 obese subjects (99 F and 65 M) (Table I). 86.1% of subjects (n = 253) were from group 2 and 3. Most of these subjects had a rural background (67.2% vs 32.8%). Subjects aged between 60-69 years old were the most affected in group 2 and 3 (Figure 1).

Out of all 294 subjects, 111 (37.8%) cases were having type 2 DM for 11-20 years, 49 (16.7%) cases for 1-5 years, 44 (14.9%) cases for 6-10 years, 43 (14.6%) cases for > 20 years, 9 (3.1%) cases for less than 1 year, while 38 (12.9%) subjects presented new-onset type 2 DM.

Regarding abdominal obesity, we found that the overall prevalence was 92.5% (n = 272). 97.7% of females (n = 170) and 85.0% of males (n = 102) had positive criteria for central obesity. All subjects from the 3rd group had abdom-

Table I. Description of demographic data and comorbidities in the three groups

Analyzed parameter	Group 1 (n = 41)	Group 2 (n = 89)	Group 3 (n = 164)
Mean age (± SD)	65.3 ± 12.5	63.6 ± 12.1	62.8 ± 9.4
Gender distribution (F/M)	23 (56.1%)/18 (43.9%)	52 (58.4%)/37 (41.6%)	99 (60.4%)/65 (39.6%)
Central obesity	23 (56.1%)	85 (95.5%)	165 (100%)
Abnormal lipid profile	13 (31.7%)	44 (49.4%)	92 (56.1%)
Hepatic steatosis	11 (26.8%)	39 (43.8%)	109 (66.5%)
Arterial hypertension	30 (73.2%)	77 (86.5%)	161 (98.2%)

Abbreviations: SD, standard deviation; F, females; M, males

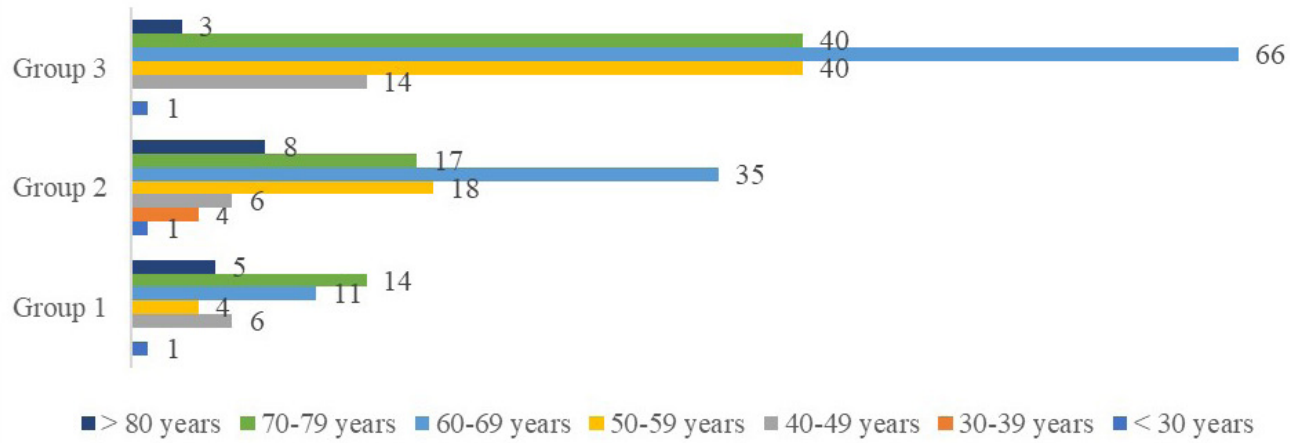

Fig. 1. Age distribution in the three groups

Table II. Prevalence of abnormal lipid profile, hepatic steatosis, arterial hypertension, abdominal obesity, and metabolic syndrome in males and females with type 2 DM

Parameter	Males (n = 120)	Females (n = 174)	P value
Lipid profile			
Abnormal	60 (50%)	89 (51.1%)	0.905
Normal	60 (50%)	85 (48.9%)	
Hepatic steatosis			
Present	62 (51.7%)	97 (55.8%)	0.551
Absent	58 (48.3%)	77 (44.2%	
Arterial hypertension			
Present	103 (85.8%)	165 (94.8%)	0.011
Absent	17 (14.2%)	9 (5.2%)	
Abdominal obesity			
Present	102 (85.0%)	170 (97.7%)	<0.001
Absent	18 (15.0%)	4 (2.3%)	
Metabolic syndrome			
Present	49 (40.8%)	82 (47.1%)	0.339
Absent	71 (59.2%)	92 (52.9%)	

inal obesity. In the 2nd group, all the females had abdominal obesity (n = 52), as well as 33 out of 37 males, meaning that 95.5% (n = 85) of 2nd group had central obesity. In the 1st group, we found abdominal obesity in 19 out of 23 females and 4 out of 18 males, meaning that 56.1% (n = 23) of cases in group 1 had central obesity. The prevalence of abdominal obesity was significantly higher in females (97.7%) than in males (85.0%) (P = < 0.001) (Table II).

The lipid profile was normal in 49.3% of cases (n = 145), while 50.7% (n = 149) of subjects had an abnormal lipid profile. In group 1, 68.3% of cases (n = 28) had a normal lipid profile. In group 2 and group 3, 50.6% (n = 45), respectively 43.9% (n = 72) of cases had a normal lipid profile. Hypercholesterolemia was found in 7.3 % (n = 3) of cases in group 1, in 11.2 % (n = 11) of cases in group 2 and in 5.5% (n = 9) in group 3. Hypertriglyceridemia was found in 9.8% (n = 4) of cases in group 1, in 16.9% (n = 15) of cases in group 2 and in 27.4% (n = 45) of cases in group 3. We found mixed dyslipidemia in 14.6% (n = 6) of cases in group 1, in 21.3% (n = 19) of cases in group 2 and in 23.2% (n = 38) of cases in group 3. Triglycerides levels among males (P = <0.001) and females (P = 0.004) were significantly different in the three groups. No significant differences were found when assessing the cholesterol levels or HbA1c (Table III).

When analyzing the antidiabetic treatment, 61.2% (n = 180) of subjects used a combined treatment with insulin and oral antidiabetic drugs (OAD), 23.1% (n = 68) used only insulin and 15.7% (n = 46) used only OAD. In group 1, almost half of the subjects (48.8%, n = 20) used only insulin, while in the 2nd and 3rd group, most subjects used a combined treatment with OAD and insulin (57.3%, n = 51, respectively 71.3%, n = 117). Insulin alone was used in 20.2% (n = 18) of cases in group 2 and in 18.3% (n = 30) in group 3. The use of only OAD had the lowest prevalence in all three groups with 22.0% (n = 9), 22.5% (n = 20), and 10.4% (n = 17) of cases in group 1, group 2, respectively group 3.

Most subjects had a poor glycemic control in each of the three groups (Table IV).

Hepatic steatosis was found in 54.1% (n = 159) of cases. In the 3rd group, 66.5% (n = 109) of subjects had hepatic

Table III. Serum lipid profile parameters and HbA1c comparison between the three groups

Males	Group 1 (n = 18)			Group 2 (n = 37)			Group 3 (n = 65)			
Parameter	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	P value
TG(mg/dL)	98.2	51.6	88.2	160.5	130.5	120.8	221.6	167.6	153.4	< 0.001
TC(mg/dL)	157.9	55.8	144.3	166.7	49.0	152.0	198.0	213.0	159.5	0.490
HbA1c (%)	8.8	1.7	8.6	10.3	3.1	9.2	9.0	1.9	8.9	0.215
Females	**Group 1 (n = 23)**			**Group 2 (n = 52)**			**Group 3 (n = 99)**			
Parameter	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**P value**
TG(mg/dL)	130.2	85.0	96.4	156.4	104.4	126.2	189.3	118.5	146.1	0.004
TC(mg/dL)	176.9	48.6	156.4	189.2	85.1	173.6	189.6	73.5	180.8	0.702
HbA1c (%)	8.7	1.6	8.3	9.1	2.3	8.5	9.0	1.8	8.7	0.952

Abbreviations: TG, triglyceride; TC, total cholesterol; HbA1c, hemoglobin A1c; SD, standard deviation

Table IV. The glycemic control in the three groups

	Duration of diabetes			
	< 20 years		> 20 years	
HbA1c level	< 7%	> 7%	< 7.5%	> 7.5%
Group 1 (n = 41)	2 (4.9%)	32 (78.1%)	1 (2.4%)	6 (14.6%)
Group 2 (n = 89)	6 (6.7%)	68 (76.4%)	3 (3.4%)	12 (13.5%)
Group 3 (n = 164)	16 (9.8%)	127 (77.4%)	4 (2.4%)	17 (10.4%)
Total (n = 294)	24 (8.2%)	227 (77.2%)	8 (2.7%)	35 (11.9%)

Abbreviations: HbA1c, hemoglobin A1c

steatosis, 43.8% (n = 39) in the 2nd group, and 26.9% (n = 11) in the 1st group. Out of the 159 cases with hepatic steatosis, 55.3% (n = 88) had an abnormal lipid profile.

We found that 91.2% (n = 268) of the analyzed cases had high blood pressure: 30 cases in the 1st group, 77 cases in the 2nd group, and 161 cases in the 3rd group (table I). Most subjects had grade II arterial hypertension in all groups, with 20 out of 30 cases (66.7%) in 1st group, 56 out of 77 cases (72.7%) in 2nd group, and 122 out of 161 cases (75.8%) in the 3rd group. Grade III arterial hypertension was found in 3 out of 30 cases (10.0%) in group 1, 9 out of 77 cases (11.7%) in 2nd group, and 22 out of 161 cases (13.7%) in the 3rd group. Only 3 subjects from the 3rd group presented normal values of blood pressure (1.8%). The 1st group had the highest percentage of cases with normal blood pressure (26.8%, n = 11), while in the 2nd group, 13.5% (n = 12) of subjects had normal blood pressure. The prevalence of arterial hypertension was significantly higher in females (94.8%) than in males (85.8%) (P = 0.011) (table II).

Overall, metabolic syndrome affected 47.1% of females (n = 82) and 40.8% of males (n = 49), without any statistically significant difference between males and females (P = 0.339) (table II). The highest prevalence was found in the 3rd group (54.3%, n = 89). In the 2nd group, 41.6% (n = 37) of cases presented metabolic syndrome, while in the 1st group, we found the lowest prevalence, with only 12.2% (n = 5) of cases being affected (Figure 2).

Discussion

This study aimed to emphasize the influence of the BMI on metabolic parameters such as lipid profile, blood pressure, and glycemic control in subjects with type 2 DM. The global age-standardized prevalence of DM is 9.0% in males compared to 7.9% in females [14]. In Romania, according to a study from 2013, the prevalence of DM was

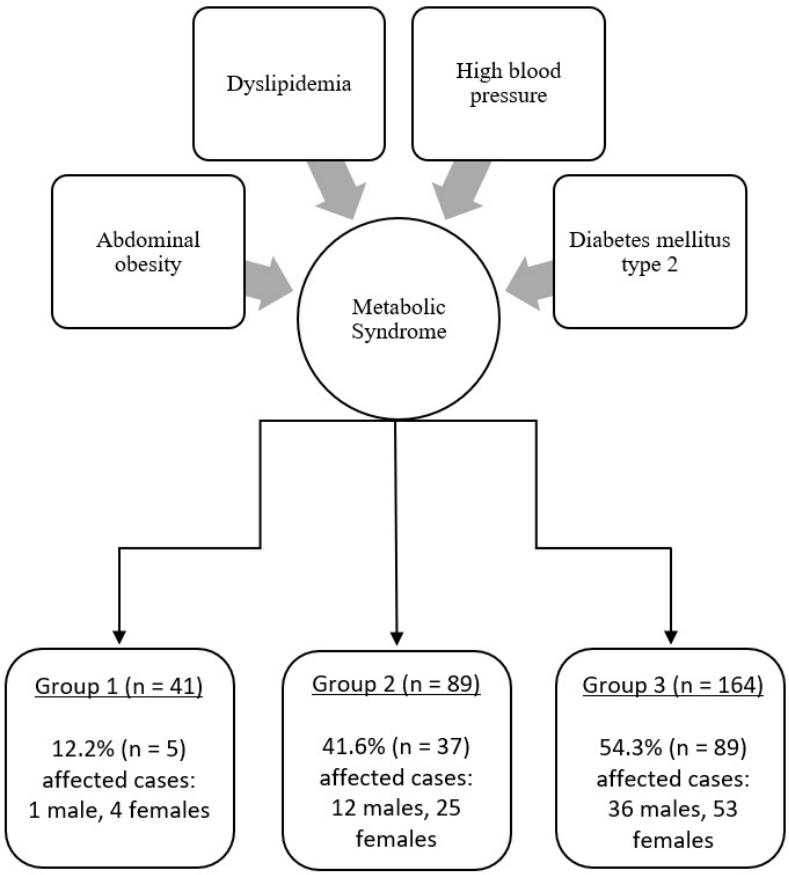

Fig. 2. The prevalence of metabolic syndrome (defined as the concomitant presence of abdominal obesity, dyslipidemia, high blood pressure, and diabetes mellitus type 2) among the three groups

higher in females (52.4%) than in males (47.6%) [15]. Our results were similar, females (59.2%) having a higher prevalence than males (40.8%).

In our study, 253 subjects had weight problems (86.1%). In each of the three groups, there were more females than males. Overweight and obesity are usually more common in females; moreover, overweight/obesity increases the risk of insulin resistance that may eventually lead to type 2 DM [16, 17]. Therefore, this could be one explanation for the higher proportion of females in this study; it may also explain why the 3rd group had the greatest number of subjects. We found that 63.6 % of subjects had a rural background. Urban areas are thought to have a higher incidence of overweight/obesity due to greater access to food services, processed foods, and lower physical activity than rural areas. However, more than 55% of the global rise in the BMI in the past decades was due to increase in BMI in people with rural background [18].

Several studies have shown that in older adults, overweight and obesity are associated with increased risk of metabolic complications, like in young adults. In our study, most of our subjects were aged between 60-69. Therefore, we expected metabolic comorbidities to be highly prevalent. Furthermore, in older adults, obesity is far more concerning regarding adverse mortality outcomes compared to overweight; moreover, in some studies, overweight was associated with a lower mortality when compared to normal BMI [19-21].

The prevalence of abdominal obesity in our study was 92.5%, with females having a significantly higher prevalence than males (97.7% vs. 85.0%) (P = < 0.001). One possible explanation for this result could be that in our study, the proportion of females was higher in each group. Other studies have also shown higher prevalence of central obesity in females than in males [22]. However, ethnic variances must be taken into consideration, and central obesity prevalence among genders might differ depending on the studied population [23]. In our study, the prevalence of central obesity increased as the BMI increased (56.1% vs. 95.5% vs. 100%). Excess visceral fat is associated with cardiovascular disease, dyslipidemia, and insulin resistance, even in normal-weight patients; this association is even stronger than general obesity [24]. Therefore, thoughtful management is advised in normal-weight patients if they present central obesity.

Dyslipidemia contributes greatly to increasing the atherosclerotic risk in type 2 DM [25]. In our study, almost half of the subjects (49.3%) had a normal lipid profile. However, we must take into consideration that most likely, the majority of subjects were under treatment with lipid-lowering agents, therefore the proportion of abnormal lipid profile may be higher. Furthermore, all subjects were under antidiabetic treatment, which may improve the lipid profile [26, 27]. Nevertheless, half of the subjects (50.7%) presented an abnormal lipid profile. This could be explained by type 2 DM and overweight/obesity on one hand, and by low compliance to lipid-lowering treatment on the other hand. As expected, group 1 had the highest prevalence of subjects with normal lipid profile (68.3%), while group 3 had the highest prevalence of subjects with abnormal lipid profile (56.1%). The prevalence of dyslipidemia increases with increasing BMI according to several studies, this statement being confirmed as well in our study [28, 29]. Triglycerides levels among males (P = <0.001) and females (P = 0.004) were significantly different in the three groups. One explanation for this result could be the increased secretion and decreased clearance of triglyceride-rich VLDL, a combination that may explain the hypertriglyceridemia found in people with overweight/obesity. Also, hypertriglyceridemia is more often found in type 2 DM than hypercholesterolemia [30, 31]. Duration of type 2 DM could also influence the lipid metabolism. A longer evolution of DM can affect the lipid metabolism, resulting in dyslipidemia [32]. In our study, most cases had type 2 DM for 11-20 years (37.8%).

Out of all analyzed subjects, 61.2% used a combined treatment with OAD and insulin, this type of treatment being used in 57.3% of cases in group 2 and in 71.3% of cases in group 3. This can be explained by the insulin resistance that is seen in subjects with overweight/obesity, meaning that a higher insulin dose is needed in order to have a good glycemic control [17, 33]. However, only 8.2% of cases with duration of DM < 20 years and 2.7% of cases with duration of > 20 years had a good glycemic control. This could mean that the longer the duration of DM, the harder to achieve a good glycemic control. This finding was consistent with other studies [34]. Also, poor glycemic control has been linked to higher risk of dyslipidemia, suggesting that HbA1c could have a role in predicting the risk of dyslipidemia in type 2 DM [35].

Type 2 DM, overweight, central/general obesity and dyslipidemia are all risk factors for developing atherosclerotic events and complications such as hepatic steatosis and arterial hypertension. The incidence of such events it's even greater when all of these risk factors are found together [24, 28, 29]. In our study, we found hepatic steatosis in 54.1% of cases. Also, 55.3% of subjects with hepatic steatosis presented dyslipidemia. The prevalence of hepatic steatosis got higher as the BMI increased; if in group 1 there were only 26.9% cases with hepatic steatosis, in group 3, 66.5% of cases had this complication. We also found arterial hypertension in 91.2% of cases. High prevalence of hepatic steatosis and arterial hypertension in type 2 DM and overweight/obesity is often found in the literature [36, 37]. In our study, arterial hypertension had a significant higher prevalence in females than in males (P = 0.011). This could be explained by the high proportions of females in each of the three groups. Group 1 had the most subjects without arterial hypertension (26.8%) compared with group 3 in which only 1.8% of cases had a normal blood pressure. This result suggests that having a normal-weight, even with type 2 DM or central obesity, may be more beneficial for

the blood pressure as opposed to being overweight/obese.

In our study, females had a higher prevalence of metabolic syndrome compared to males (47.1% vs. 40.8%), even though it was not significantly higher (P = 0.339). Other studies showed higher prevalence of metabolic syndrome in females than in males [38, 39]. Cut-off criteria for waist circumference or lipid profile can influence the prevalence of metabolic syndrome. Also, these findings may suggest that females tend to associate more metabolic comorbidities than males.

Our study had several limitations. This was an observational, retrospective study in which the analyzed data reproduced the information from medical forms, without having the possibility to evaluate other parameters, such as LDL/HDL-cholesterol. There was no information regarding the compliance of the subjects, nor about the lipid-lowering therapy.

Conclusions

Most patients with type 2 DM associate obesity of varying degrees, as well as central obesity. An increased BMI in type 2 DM increases the prevalence of various cardiovascular risk factors such as arterial hypertension, dyslipidemia, hepatic steatosis, and metabolic syndrome. Therefore, losing weight can contribute in reducing the incidence of these risk factors in patients with type 2 DM, moreover reducing the risk of atherosclerosis and cardiovascular complications. Glycemic control seems more influenced by the duration of the disease rather than the body weight, but further studies are needed in order to evaluate the impact of BMI on this parameter in type 2 DM.

Conflict of interest

None to declare.

Authors' contribution

AER - Conceptualization, investigation, acquisition of data, writing - original draft; RAT - Acquisition of data, interpretation of data, writing - revision, editing; ADTM - Acquisition of data, interpretation of data; MCT - Conceptualization, investigation, supervision, writing - revision, final approval.

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