The Effect of Bariatric-Metabolic Surgery on Selected Components of Metabolic Syndrome and Visceral Adipose Tissue – The Pilot Study

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Summary

The aim of this study was to monitor changes in the components of the metabolic syndrome defined by Adult Treatment Panel III and the risk of adipose tissue. The study population consisted of 45 patients (30 women, 15 men) who underwent one bariatric procedure – partial jejuno-ileal derivation (n=17), sleeve resection (n=14) or laparoscopic gastric – plication (n=14). Components of metabolic syndrome such as waist circumference, morning glycemia/antihypertension, TAG, HDL cholesterol and blood pressure (BP)/antihypertension were monitored in probands. In addition, Dual Energy X-Ray Absorciometry measurements were performed. Parameters were monitored over the course of one year. The study shows that it is an effective method of weight reduction for the study population with metabolic effects in the risk components of metabolic syndrome – fasting glycemia, increase in HDL cholesterol and reduction in triacylglycerols in the blood, reduction in waist circumference and BP or direct disappearance of metabolic syndrome. Significantly, of the entire cohort, 68.9 % of the probands studied showed signs of metabolic syndrome when measured before the intervention. At the end of follow-up, only 22.2 % of probands showed metabolic syndrome. It was also found that if the amount of visceral fat was reduced, the overall risk of metabolic syndrome was also reduced. The study demonstrates a significant positive effect of bariatric surgery on parameters of metabolic syndrome. The study also showed a positive effect of reduced visceral fat volume on the components of metabolic syndrome.

Key words

Metabolic syndrome • Body composition measurement • Bariatric-metabolic surgery • Visceral fat

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Introduction

The prevalence of overweight and obesity is rising globally [1]. Obesity is one of the major public health problems of the contemporary world. It affects the population at any age and from all kinds of social, economic and cultural backgrounds. Obesity and obesity-related chronic diseases, including cardiovascular disease, diabetes, metabolic syndrome and many cancers, are increasing worldwide [2]. As such, obesity is defined by excess adipose tissue. Increased and inappropriate deposition of this tissue contributes to hyperglycemia, hyperlipidemia, insulin resistance, endothelial

dysfunction, and chronic inflammation [3].

Metabolic syndrome (MS) is a vulnerability factor and a major public health problem. People with MS are 2.5 times more likely to die from cardiovascular disease (CVD) compared to their peers without metabolic syndrome. In addition, these individuals are 5 times more likely to develop type 2 diabetes [4]. A healthy lifestyle is essential to prevent or delay the onset of metabolic syndrome. It is also useful for preventing cardiovascular disease and type 2 diabetes in patients with established MS. Optimal weight or weight loss through reduced energy intake along with increased energy expenditure through physical activity contribute to the prevention and treatment of MS [5]. Several studies have shown that physical activity has a beneficial impact on metabolic syndrome [6,7]. MS has a significant relationship with obesity and also has a high prevalence worldwide [8]. The risk for developing MS is significantly increased by excessive dietary energy intake and reduced physical activity [9]. MS is a collection of several symptom components. The individual components represent a group of metabolic diseases of mass occurrence. It is considered to be one of the very important factors in the development of CVD [10].

There are several definitions for the detection of MS. Our study used the US National Cholesterol Program definition called Adult Treatment Panel III (ATP III) defined by the presence of at least three of criteria, which is listed in the methods of the article [9]. This definition provided by the Adult Treatment Panel appears to be the most widely used definition across the world [11]. Although in 2009 the International Diabetes Federation (IDF) and the American Heart Association/National Heart, Lung, and Blood Institute standardized the criteria for defining MS [12].

There is a consensus of the board of obesitologists, diabetologists, bariatric surgeons and endocrinologists that specifies the position of bariatric-metabolic surgery in the management of type 2 diabetes. It has resulted in recommendations for the surgical treatment of type 2 diabetes that include bariatric-metabolic surgery as an integral part of the treatment of early stages of type 2 diabetes [13]. While obesity rates are rising, the number of bariatric surgeries performed annually is also increasing. In a 2013 survey by the International Federation for the Surgery of Obesity and Metabolic Diseases (IFSO), the total number of bariatric procedures performed worldwide was 468609. The most commonly performed procedure worldwide was Roux-en-Y gastric bypass (RYGB) at 45 %, followed by sleeve gastrectomy at 37 % [14].

Aim of study

The present pilot study addresses potential changes in the amount of visceral adipose tissue (VAT) and its impact on selected components of MS in patients after bariatric-metabolic surgery.

The main aim of this pilot study was to demonstrate the effect of changing VAT on selected components of MS.

The secondary aim was to find out how many probands showed MS at entry and how their individual components of MS changed during the one-year follow-up. Next, we wanted to find out what the success rate of individual bariatric-metabolic surgery tips was and compare them.

Methods

All data were obtained in controls of patients who were divided into three cohorts due to undergoing different bariatric procedures. The research part was conducted at the Obesity Research Center and Human Motion Diagnostic Centre, University of Ostrava. Bariatric procedures were performed at the AGEL Hospital Ostrava-Vítkovice and the University Hospital Ostrava (specific bariatric procedures always at the same department). These studies were conducted in accordance with the ethical standards of the 2013 (7^{th} revision) Declaration of Helsinki and were prospective open-label studies.

Exclusion criteria for total body weight were BMI>50 or BMI<30, previous gastric surgery, previous technical difficulties in gastric and duodenal endoscopy or inability to perform endoscopy, type 1 diabetes, history of GI diseases (acute gastritis, non-specific intestinal inflammation, pancreatitis, chronic liver disorder, etc.), diagnosed celiac disease, history of malignancy, previous endoscopic and surgical treatment of obesity (intragastric balloons, malabsorptive procedures on GI), specific genetic or hormonal disorders associated with obesity, bleeding and coagulation disorders, psychiatric diseases and other disorders presented as criteria excluding bariatric-metabolic treatment according to IFSO guidelines [15].

ATP III method was chosen for the detection of metabolic syndrome. Definition MS called ATP III defined by the presence of at least three of these criteria: waist circumference ≥102 cm in men/WC≥88 cm in women, BP≥130/85 mm Hg/antihypertensive treatment, morning glucose≥5.6 mmol/l/antidiabetic treatment, AG≥1.7 mmol/l, HDL cholesterol <1.0 mmol/l in men, HDL cholesterol <1.25 mmol/l in women/hypo-lipidemic treatment. The different types of bariatric procedures were:

Non-standard type of bariatric surgery: Partial Jejuno-Ileal Diversion (PJID)

Surgical bariatric procedure with metabolic effect in the lower intestine without gastric restriction. The method consists of surgically performing a partial jejuno-ileal diversion between the jejunum and ileum.

Standard type of bariatric surgery: Laparoscopic Sleeve Gastrectomy (LSG)

Restrictive type of bariatric surgery, when 80-90 % of the patient's stomach volume was resected vertically with a scalpel. The volume of the stomach left to them was then approximately 100-150 ml.

Standard type of bariatric surgery: Laparoscopic Greater Curvature Plication (LGCP)

A restrictive type of bariatric surgery that also results in a reduced ability to take in larger amounts of food and drink at once. During the procedure, a suture is used to plunge the wall of the stomach inward, thereby reducing the overall volume of the stomach.

Laboratory measurements

Body height

Height was measured with a calibrated altimeter and given in centimetres rounded to the nearest whole number.

Body weight

Body weight was measured on a calibrated scale with regular checking and certification. The value was obtained only for subsequent input into the densitometer software. The subsequently obtained value of total body weight from the DXA (Dual Energy X-Ray Absorptiometry; Discovery A instrument; Hologic, Waltham, MA, USA).

Body composition

Body composition measurements were provided by Dual Energy X-ray Absorptiometry/DXA. The densitometer was calibrated according to the manufacturer's recommendations, a daily quality control was performed before each day of measurement, and the minimum error in measurement accuracy was also determined. The visceral fat values were measured according to the DXA manual, i.e. the marking of the measured area at the android part level. Furthermore, the evaluation of the amount of fat in the android and gynoid region was obtained from the automatic calculation of the stance after the correct selection of body segments, which are analyzed automatically after the actual measurement, but it is necessary to check or adjust the selection manually by a laboratory worker if necessary.

Body circumferences

The circumferences at the level of the umbilicus and at the level of the maximum curvature of the buttocks using a tailor's tape measure were used.

The actual anthropometric laboratory measurements were carried out in underwear, without shoes, jewellery, watches or any foreign objects (at most in some cases with a mouthpiece without metal or plastic). Changes in body weights was monitored using TWL ("Total Weight Loss"), EWL ("Excess Weight Loss"), and BMI ("Body Mass Index") and kilograms.

Blood tests

Blood samples were taken in the morning after an overnight fast, mostly on the day of anthropometric measurements, but sometimes at a maximum of seven days apart. Blood samples were processed for analysis within 20 min of collection. Serum glucose, TAG and HDL cholesterol concentrations were assessed. Biochemistry was performed in a routine manner. Analyses of all parameters showed interassay coefficients of variation of less than 5 %.

Statistical evaluation

The data were processed in the EpiData software environment using the double-entry method. All analyses were evaluated using basic descriptive statistical methods. A normality test was performed, namely the Shapiro-Wilk test. Comparison of the results over the course of the one-year follow-up, was performed using linear regression with an equation of the form

$y = \beta 0 + \beta 1 \times x$, and also using a paired *t*-test. The significance of the results was tested at the 5 % level (P=0.05). The R statistical program (The R Project for Statistical Computing) and Microsoft Office Excel were used for the evaluation.

Results

A total of 45 probands who underwent one of the three bariatric surgeries were included in the study and were followed up for one year at regular intervals (baseline-maximum 45 days before bariatric surgery, follow-up-3rd, 6th and 12th month after surgery).

The number of women was higher (n=30) compared to the number of men (n=15). The first cohort consisted of 17 probands (12 females and 5 males) who underwent partial jejuno-ileal diversion (PJID). The next cohort consisted of 14 probands (11 females and 3 males) who underwent laparoscopic sleeve gastrectomy (LSG) and the last cohort consisted of 14 probands (7 females and 7 males) who underwent laparoscopic greater curvature plication (LGCP). The basic characteristics of probands in each cohort are shown in Table 1.

Changes in weight loss

If we were to evaluate the success rate of bariatric treatment, all bariatric procedures were successful. Although the patients had the highest BMI (43.1 kg/m^2) on average before the LSG procedure, one year after the procedure they had the most successful reduction of the three procedures studied. They reached an average of 29.4 kg/m^2, thus at the overweight cutoff. During the year, they had a BMI of 35.0 kg/m^2 in the 3rd month after the procedure and 31.4 kg/m^2 in the 6th month. In contrast, the cohort of patients after PJID had a mean value at entry of 41.6 kg/m^2 and the reduction after the procedure led to 37.7 kg/m^2 at month 3 and 35.9 kg/m^2 at month 6. The baseline data was then a BMI of 33.6 kg/m^2. Very similar values were found for the LGCP procedure, where patients had an average of 42.2 kg/m^2 at entry, then at 3rd month 36.3 kg/m^2, the follow-up at 6th month 4.8 kg/m^2, and the subsequent exit data gave them 33.4 kg/m^2, which was defined as firtst level of obesity as in the PJID patients.

The cohort of patients following LSG surgery demonstrated the greatest EWL, with an average of 76 % in all of its patients at one year post-procedure. This is in contrast to LGSP which reached 51 % and PJID with 48 %. Already within a year, LSG showed signs of the most successful reduction, this was already the case at the 3rd month after the procedure with a value of 45 % against LGSP which had a value of 34 % or PJID with 24 %. After another 3 months, the value for LSG became even more successful and also reached the highest rung, with a 65 % success rate, while for LGCP it was 43 % and PJID 34 % EWL. These changes in weight loss are shown in Table 2.

Changes in Metabolic Syndrome

Of the total sample of 45 probands, metabolic syndrome was demonstrated in 68.9 % (31 probands) at baseline measurement, decreased to 51.1 % (23 probands) at month 3 follow-up, 35.5 % (16 probands) at month 6 follow-up, and was demonstrated in 22.2 % (10 probands) at 1-year follow-up. The conclusiveness of MS was evaluated according to ATP version III. Thus, if a given proband fulfilled 3 or more risk components of MS, metabolic syndrome was confirmed.

Within the studied components of MS according to the specified version of the definition, after one year of weight reduction after bariatric surgery, there were positive or no differences in the values of these components, see Table 3 for an overview of the studied components and their changes. The most successful reduced components (largest difference from baseline and 12th month post-procedure measurements) of the metabolic syndrome were TAG and HDL cholesterol values, which were found in all cohorts.

Table 4 shows the individual frequencies of MSitself and its risk components. Thus, in what number of probands the values of the monitored MS components were not in the normal range. According to the evaluation, it cannot be said that those who were diagnosed with MS at entry struggled with it throughout the year and vice versa. Sometimes there were cases that, for example, at the second follow-up measurement, i.e. month 3, the patient was still proven to have MS, then at the measurement of month 6 they was not, but then again at month 12 they was. This resulted in the expected high number of confirmed probands with MS, despite the fact that unfortunately all five risk components were not monitored in each study. In fact, all five components were measured only in the PJID procedure, with BP measurements omitted in the other two procedures. Thus, it can be assumed that if BP had been monitored in all, there might have been more confirmed probands with MS.

Table 1. Parameters from anthropometric measurements and biochemical analysis.

		Baseline	12. month	*P*
		Median ± SD (Minimum-Maximum)	**Median ± SD (Minimum-Maximum)**	
PJID (n=17)	**Age (years)**	**47.3** ± 7.90 (28.9-60.7)	**48.4** ± 7.83 (30.1-61.8)	<0.001
	BMI (kg/cm^2)	**42.2** ± 5.60 (32.9-50.4)	**32.8** ± 5.40 (25.68-43)	<0.001
	Hip circumference (cm)	**125.0** ± 11.68 (114-158)	**112** ± 11.76 (91-133)	<0.001
	WHR index	**0.94** ± 0.10 (0.80-1.17)	**0.94** ± 0.08 (0.83-1.01)	<0.001
	Fat mass (kg)	**49.4** ± 10.20 (36.0-71.4)	**34.62** ± 10.66 (23.4-62.90)	<0.001
	Fat mass (%)	**45.7** ± 4.10 (37.8-51.0)	**39.6** ± 6.13 (30.5-49.8)	0.067
	Fat-free mass (kg)	**62.96** ± 12.50 (42.71-86.2)	**55.87** ± 12.31 (40.62-81.4)	<0.001
	% fat in the android area	**48.20** ± 2.64 (44.10-52.0)	**41.1** ± 6.93 (28.6-35.4)	0.038
	Active mass (kg)	**60.4** ± 12.30 (40.7-83.2)	**53.19** ± 12.06 (38.91-78.49)	<0.001
	VAT (g)	**960** ± 286,00 (608-1685)	**759** ± 246.91 (252-1366)	<0.001
	Android/gynoid ratio	**1.06** ± 0.09 (0.94-1.25)	**1.04** ± 0.11 (0.79-1.18)	0.010
	Body weight (kg)	**118.7** ± 20.40 (78.7-154.3)	**91.66** ± 19.58 (69.75-144.25)	0.000
	Total cholesterol (mmol/l)	**3.35** ± 0.81 (3.67-6.62)	**3.66** ± 0.71 (2.2-5.1)	0.0872
	LDL cholesterol (mmol/l)	**3.48** ± 0.91 (1.81-4.83)	**2.12** ± 0.48 (1.33-3.07)	0.1919
LSG (n=14)	**Age (years)**	**46** ±7.70 (30.4-58.0)	**47.85** ± 7.76 (31.4-59.3)	<0.001
	BMI (kg/cm^2)	**40** ± 6.80 (37.0-59.6)	**27.35** ± 5.29 (21.64-39.18)	<0.001
	Hip circumference (cm)	**125.5** ± 13.79 (106-151)	**105.5** ± 11.58 (89-124)	<0.001
	WHR index	**0.96** ± 0.08 (0.87-1.14)	**1.05** ± 0.10 (0.96-1.31)	0.3150
	Fat mass (kg)	**51.4** ± 14.90 (37.1-91.0)	**28.89** ± 9.80 (15.84-46.03)	<0.001
	Fat mass (%)	**46.5** ± 6.10 (31.1-54.1)	**37.35** ± 7.28 (22-48.4)	<0.001
	Fat-free mass (kg)	**62.3** ± 11.10 (49.6-85.7)	**49.21** ± 10.61 (40.64-76.24)	<0.001
	% fat in the android area	**48.93** ± 5.57 (41.05-58.64)	**38.74** ± 13.52 (21.63-80.7)	0.0272
	Active mass (kg)	**59.6** ± 10.80 (47.5-81.9)	**46.89** ± 10.30 (38.49-72.87	<0.001
	VAT (g)	**1170** ± 344.00 (540-2031)	**568.5** ± 254.17 (276-1150)	<0.001
	Android/gynoid ratio	**1.16** ± 0.18 (0.86-1.61)	**1.04** ± 0.18 (0.65-1.35)	<0.001
	Body weight (kg)	**121.4** ± 20.60 (91.3-176.6)	**81.01** ± 16.57 (58.47-121.35)	<0.001
	Total cholesterol (mmol/l)	**5.15** ± 0.87 (3.7-6.54)	**5.52** ± 0.81 (3.94-6.96)	0.1819
	LDL cholesterol (mmol/l)	**36** ± 1.00 (1.48-4.7)	**3.34** ± 0.65 (2.49-5.05)	0.2951
LGCP (n=14)	**Age (years)**	**45.1** ± 8.50 (33.3-65.1)	**46.15** ± 8.60 (33.6-66.1)	<0.001
	BMI (kg/cm^2)	**41.7** ± 4.10 (35.0-49.8	**33.86** ± 5.41 (26.35-45.06)	0.0011
	Hip circumference (cm)	**131** ± 8.50 (121-148)	**113.0** ± 9.24 (102-136)	0.0269
	WHR index	**1** ± 0.10 (0.89-1.2)	**1.02** ± 0.06 (0.95-1.17)	0.0578
	Fat mass (kg)	**51.9** ±7.60 (44.8-71.7)	**35.05** ± 9.92 (24.15-60.04)	0.0316
	Fat mass (%)	**42.8** ± 6.20 (34-53.5)	**36.9** ± 7.83 (25.3-49.7)	0.0002
	Fat-free mass (kg)	**70.7** ± 14.50 (48.84-91.7)	**63.95** ± 11.13 (45.34-80.84)	<0.001
	% fat in the android area	**47.8** ± 4.80 (38.50-55.80)	**39.45** ± 7.89 (26.1-52.4)	0.0016
	Active mass (kg)	**67.9** ± 14.20 (46.47-88.6)	**61.26** ± 10.79 (42.82-77.18)	<0.001
	VAT (g)	**1010** ± 233.00 (768-1601)	**734.5** ± 210.17 (329-1170)	0.0594
	Android/gynoid ratio	**1.16** ± 0.14 (0.98-1.38)	**1.05** ± 0.15 (0.87-1.38)	<0.001
	Body weight (kg)	**128.4** ± 16.10 (97.6-148.0)	**97.95** ± 13.33 (73.57-121.21)	0.0122
	Total cholesterol (mmol/l)	**4.66** ± 1.32 (3.18-6.92)	**4.98** ± 0.92 (2.62-5.84)	0.0036
	LDL cholesterol (mmol/l)	**2.94** ± 0.94 (1.44-4.3)	**3.15** ± 0.79 (1.33-3.98)	0.0058

SD ("Standard Deviation"), BMI ("Body Mass Index"), WHR index ("Waist Hip Ratio"), VAT ("Visceral Adipose Tissue"), LDL cholesterol "Low Density Lipoprotein Cholesterol"), PJID ("Partial Jejuno-Ileal Diversion"), LSG ("Laparoscopic Sleeve Gastrectomy"), LGCP ("Laparoscopic Greater Curvature Plication").

Table 2. Reduction in body weight after individual bariatric surgeries.

	PJID	LSG	LGCP
Body weight (kg)	21.5	37.6	26.6
TWL (%)	18.5	31.2	20.9
EWL (%)	48	76	51
BMI (kg/cm^2)	8	13.7	8.8

PJID ("Partial Jejuno-Ileal Diversion"), L LSG ("Laparoscopic Sleeve Gastrectomy"), LGCP ("Laparoscopic Greater Curvature Plication"), BMI ("Body Mass Index"), TWL ("Total Weight Loss"), EWL ("Excess Weight Loss").

Table 3. Status of Metabolic Syndrome components.

		Baseline	12. month	*P*	Percentage difference
		Median ± SD (Minimum-Maximum)	Median ± SD (Minimum-Maximum)		
PJID (n=17)	**Waist (cm)**	**126** ± 14.10 **(99-146)**	**106** ± 13.46 **(79-131)**	<0.001	-16 %
	Systolic BP (mm Hg)	**130** ± 150 **(100-150)**	**120** ± 12.45 **(100-150)**	0.0213	-8 %
	Diastolic BP (mm Hg)	**80** ± 8.60 **(60-100)**	**80** ± 9.83 **(65-95)**	0.0088	
	Glycemia (mmol/l)	**6.50** ± 1.78 **(5.1-12.00)**	**5.4** ± 0.81 **(4.4-7.3)**	0.0002	-17 %
	HDL cholesterol (mmol/l)	**1.11** ± 0.41 **(0.62-2.18)**	**1.11** ± 0.31 **(0.6-1.77)**	0.0002	0 %
	Triacylglycerols (mmol/l)	**1.85** ± 1.04 **(0.80-4.64)**	**1.27** ± 0.65 **(0.71-2.63)**	0.0010	-31 %
LSG (n=14)	**Waist (cm)**	**128.5** ± 15.00 **(110-165)**	**93.0** ± 14.76 **(76-128)**	<0.001	-28 %
	Glycemia (mmol/l)	**5.85** ± 1.90 **(5.10-11.20)**	**5** ± 0.55 **(4.5-6.6)**	0.0178	-15 %
	HDL cholesterol (mmol/l)	**1.14** ± 0.14 **(0.86-1.49)**	**1.45** ± 0.27 **(1.14-2.04)**	0.0298	27 %
	Triacylglycerols (mmol/l)	**2.26** ± 0.90 **(0.96-4.17)**	**1.2** ± 0.43 **(0.54-2.0)**	0.0475	-47 %
LGCP (n=14)	**Waist (cm)**	**129.5** ± 8.3 **(113-140)**	**112.5** ± 16.68 **(89-128)**	0.1715	-13 %
	Glycemia (mmol/l)	**5.66** ± 1.71 **(4.70-10.5)**	**4.95** ± 0.81 **(4.1-7)**	0.0225	-13 %
	HDL cholesterol (mmol/l)	**1.05** ± 0.21 **(0.72-1.47)**	**1.54** ± 0.25 **(0.93-1.81)**	0.2171	47 %
	Triacylglycerols (mmol/l)	**1.78** ± 1.72 **(0.70-5.73)**	**0.99** ± 0.35 **(0.41-1.52)**	0.0126	-44 %

PJID ("Partial Jejuno-Ileal Diversion"), LSG ("Laparoscopic Sleeve Gastrectomy"), LGCP ("Laparoscopic Greater Curvature Plication"), HDL ("High Density Lipoprotein Cholesterol"), SD ("Standard Deviation"), BP ("Body Pressure").

Table 4. Frequency of MS and its risk components in individual interventions.

Frequency of MS and its risk components in individual interventions												
	PJID				LSG				LGCP			
	Number of probands				Number of probands				Number of probands			
	Baseline	3rd month	6th month	12th month	Baseline	3rd month	6th month	12th month	Baseline	3rd month	6th month	12th month
Probands in total	17	17	17	17	14	14	14	14	14	14	14	14
Higher WC	17	17	17	15	14	13	10	9	14	14	13	13
Higher BP	8	2	4	3	x	x	x	x	x	x	x	x
Higher TAG	11	8	5	3	11	6	2	3	8	1	2	0
Lower HDL cholesterol	10	12	13	10	12	12	8	1	9	7	4	1
Higher glycemia	14	8	9	8	10	4	3	2	7	6	2	3
Proven MS	13	12	11	8	12	7	4	1	6	4	1	1

PJID ("Partial Jejuno-Ileal Diversion"), LSG ("Laparoscopic Sleeve Gastrectomy"), LGCP ("Laparoscopic Greater Curvature Plication"), WC ("Waist Circumferences"), BP ("Blood Pressure"), TAG ("Triacylglycerols"), HDL ("High Density Lipoprotein Cholesterol"), MS ("Metabolic Syndrome").

Corelation between VAT and glycemia

The added value of our study may be to monitor visceral fat with DXA and to observe correlation and regression. All interventions showed an increasing trend of VAT versus morning blood glucose level. The *P-value* for patients after the PJID procedure <0.001, for LSG<0.001, and for LSGC<0.001. The Pearson Correlation Coefficient (*r*) was 0.488 and 0.731 for the PJID procedure and 0.572 for the LGCP procedure. These strong correlations were always found for each intervention for both sexes together. All are included in one graph in Figure 1. However, it is important to note here the fact that some patients may have been on antidiabetic treatment, so it is possible that the results would have been even more conclusive if they were not on this treatment.

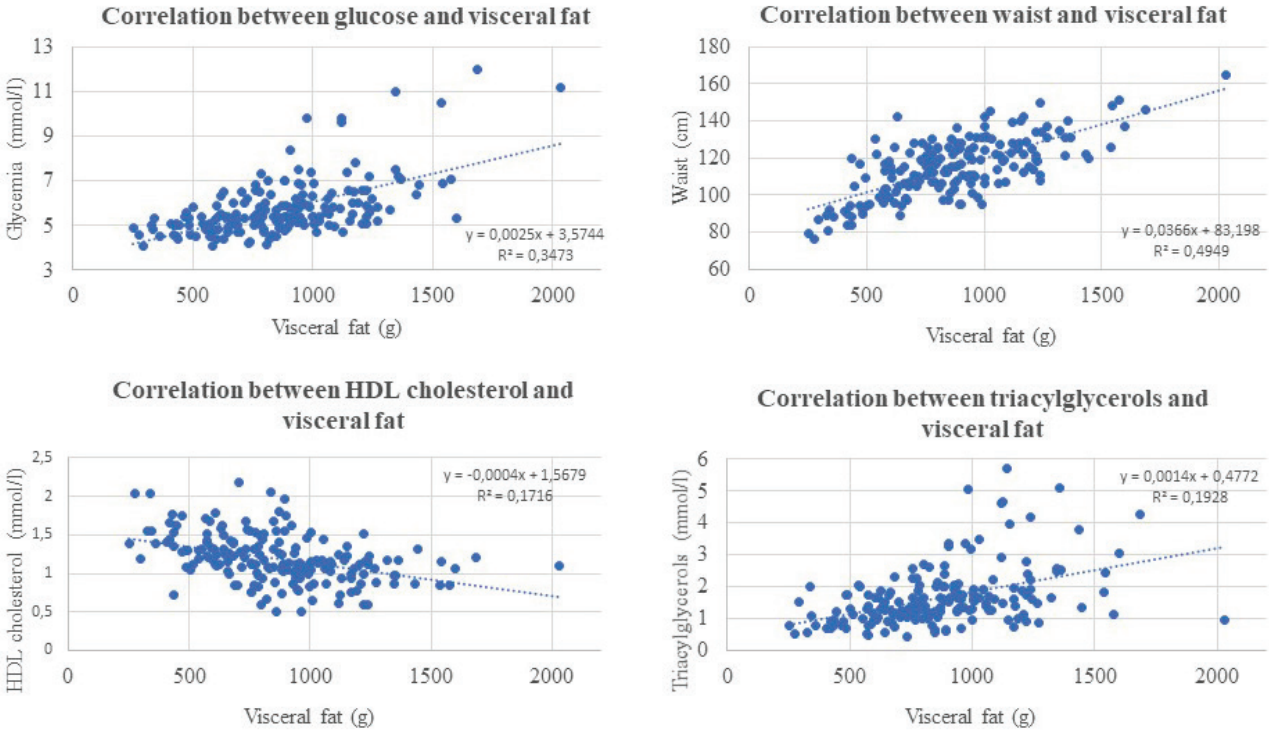

Fig. 1. Correlation between VAT on components of MS. HDL ("High Density Lipoprotein Cholesterol"), VAT ("Visceral Fat"), MS ("Metabolic Syndrome").

Corelation between VAT and waist circumference

Regarding the dependence of VAT on waist circumference, the outcome of the PJID intervention shows statistical significance for both variables, which were gender and VAT. There was a dependence even without the effect of gender, thus gender played a significant role in this case, but VAT itself had some effect on waist circumference. Men were found to have overall higher waist circumferences (WC) than women (android type of obesity). R for the PJID procedure for males came out to be 0.49, with a significant dependence according to the *P*=0.028. For females, the *r* came out to be 0.286, with a *P*=0.049, while it is still closer to 0.05, so the dependence is there, but not completely clear (this may be due to the small sample size in the group). Thus, the results show a stronger dependence of males than females. From the calculation of both LSG and LGCP, the outputs of the regression models are that VAT is significant but gender is no longer, i.e. waist circumference has an effect on VAT regardless of gender and, moreover, in this case, waist circumference is not even affected by gender. The LSG assessment yielded an overall *r* of 0.859 and a *P*<0.001, thus a highly significant correlation. And overall for the LGCP, the *r* came out to be 0.642 and the *P*<0.001. Thus, this shows that in general, patients with higher VAT have higher WC here. These results are included in one graph in Figure 1.

Corelation between VAT and HDL cholesterol

The PJID intervention that higher VAT values are associated with lower HDL values. There is a large effect of gender (women have lower values than men). The value of the *r* for both sexes is -0.399 and the

P=0.001, so clearly a significant relationship. The LSG intervention, the dependence also came out significant negative, with a *r* of -0.544 and a *P*<0.001 for both genders. The LGCP intervention, it can be seen from the graph that the common points also tend to decrease, but are quite far apart. According to the correlation, there is again a negative dependence and closely comes out as significant as the *r* is -0.375 and the *P*=0.004. So all the interventions show similar evaluations and that VAT has an effect on HDL cholesterol values, such that the more VAT, the less HDL cholesterol. These results are included in one graph in Figure 1.

Corelation between VAT and TAG

The PJID intervention to assess the relationship between VAT and TAG shows a positive linear relationship even without the influence of gender. The Pearson *r (r)* 0.542, the *P*<0.001, thus a significant dependence that clearly holds for both sexes. The LCP intervention, gender also does not play a significant role, hence the following dependence is also without gender influence. The correlation came out significant and positive with a *r*=0.397 and a *P*=0.002. The LGCP intervention, 5 outliers were deleted for statistical evaluation for better efficiency of the result. Subsequently, a more or less significant trend was found with a *P*<0.001 and a *r* 0.46. Thus, all three interventions agree that triacylglycerols and VAT have a significant positive relationship with each other, thus the more VAT in the body, the more TAG in the blood. These results are included in one graph in Figure 1.

Corelation between VAT and android/gynoid ratio

We also evaluated the correlations of visceral fat and android/gynoid ratio; in one graph in Figure 2, the values are sex-specific and there is a clear dependence. The *r* came out to be 0.66 for PJID for both sexes together, and the *P*<0.001, indicating a highly significant dependence. According to the LSG results, the *r* across gender was 0.5 and the *P*<0.001. According to the LGCP plot, there is again a clear positive dependence, and here again gender plays a role, with males having a higher android/gynoid ratio than females in the densitometric measurements (indicating android type obesity early in males). The correlation of all LGCP probands together again came out highly significant, with a *r*=0.67 and a *P*<0.001. According to the graphs and the correlations, this is true for both sexes separately. Hence, it shows that gender acts as a significant factor which is different in males and females. Thus, men are at greater risk of higher visceral fat.

In the following graph in Figure 2, the data of all 45 probands are included for clarity, but only from the output body composition measurements. At a glance, it is already evident that there is a direct relationship between the amount of adipose tissue in the android region of the body and VAT. According to the regression model, it can be argued that gender is significant for the resulting relationship with VAT, as women have on average 310 g less VAT than men with the same percentage of adipose tissue in the android region. It is further hypothesized that if the android fat representation is increased by one percent, an increase in visceral fat of 16.5 g can be expected. In the case of males, the *r* comes out to be 0.8 and the *P*<0.001. Females also confirm this relationship with a *r* of 0.613 and a *P* also <0.001. This suggests that probands with a greater proportion of fat in the android region, have a higher VAT.

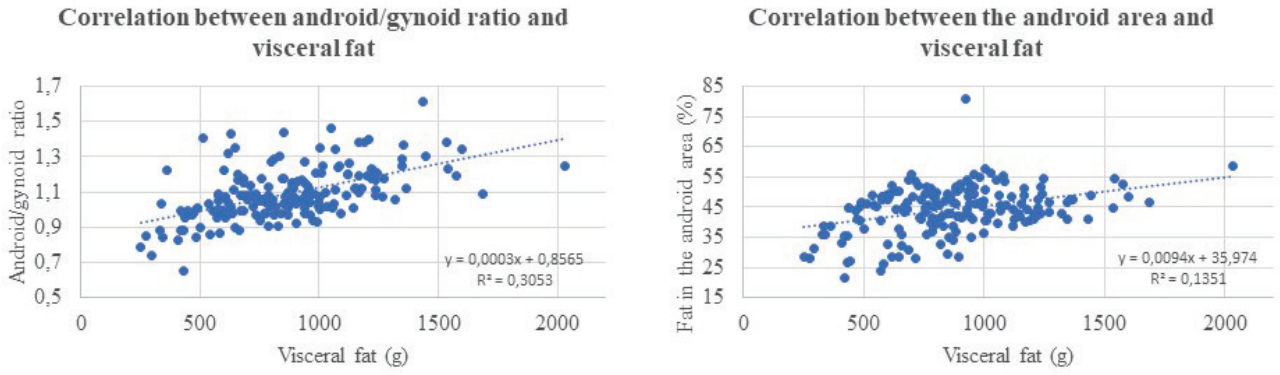

Fig. 2. Correlation of VAT on anthropometric parameters.

Discussion

Obesity is associated with reduced life expectancy and linked to MS [16]. From the above publication assessing the impact of overweight and obesity in 195 countries, it is clear that in 2015, a total of 603.7 million adults were obese. There were an alarming 107.7 million obese children. The prevalence of obesity has doubled in more than 70 countries. This assessment is taken in comparison to 1990. In most countries it is on an increasing trend. Obesity is associated with high BMI. The BMI causes higher mortality rates. It deaths that are associated with high BMI attributed to the incidence of cardiovascular disease [8]. It is with evidence of MS that we speak of the presence of several risk factors for the development of cardiovascular disease and type 2 diabetes [4,9]. For example, the main trigger for dyslipidaemia is insulin resistance/hyperinsulinaemia. In recent years, the form of dyslipidemia arising when insulin resistance and obesity act together has been recognized as “metabolic dyslipidemia”. Its main characteristic is high TAG concentrations accompanied by reduced HDL cholesterol concentrations. HDL cholesterol concentrations may be optimal or slightly elevated, although the number of LDL particles may be increased. Dyslipidaemia is an important link between obesity and the development of type 2 diabetes, cardiovascular disease and some cancers [17]. The ratio between elevated TAG and reduced HDL values, also known as the atherogenic index, has been established as a predictor of major cardiovascular events, insulin resistance and metabolic syndrome. It can be readily obtained by routine biochemical analysis and can be used as a prognostic and predictive factor of peripheral arterial disease and cardiovascular risk [18].

When evaluating the results of DXA measurement of visceral fat and its correlation with android/gynoid ratio and percentage of fat in the android region, it was confirmed that there is a strong relationship between them, and their higher values are at risk for the development of CVD and MS. Our work confirms that the greater the amount of visceral fat in the body, the greater the percentage of fat in the android region, and thus the higher the android/gynoid ratio, indicating the android type of obesity [19]. Our study monitored VAT based on DXA, which is the gold standard for measuring body composition. However, the most effective measurement is by CT or MRI. Some studies have compared the concordance between BIA and CT, the results are not positive for BIA. On the other hand, there is consensus on the use of DXA to evaulate VATS, which is close to CT and MRI results [19,20].

Recently, there has been increasing interest in monitoring the correlation between VAT and components of the metabolic syndrome [21]. Since the possibility of quantifying VAT directly by DXA with significantly lower radiation than CT has recently become well established [21-24]. Therefore, we used this method in our study. According to our study, the amount of VAT has a major influence in the pathogenesis of MS, because when total body weight, adipose tissue and VAT were successfully reduced, probands improved their health status and with it the number of MS risk components. In terms of the frequency of risk components, there were no probands with at least one confirmed MS component at baseline measurement, and at the end of the follow-up period there were only six such probands. An important note, however, is that only the results from the measurements were included in this part of the study, not data from the patient's medical records, which could also help to increase the risk or directly confirm MS (e.g. compensated type 2 diabetes = antidiabetic treatment, antihypertensive treatment, etc.). Therefore, it is possible that even though some patients had normal monitored parameters, it may not mean that they were not at risk because their levels were normal through medical treatment, not through weight reduction or lifestyle changes. We think it is worth mentioning the important fact that some of the patients who entered the study had pharmacological treatment for some components of MS. However, they were certainly not newly prescribed during follow-up. On the contrary, in some of them, after the results improved to normal, it was discontinued.

VAT was found to correlate very well with all the observed components of metabolic syndrome. When visceral fat was compared with morning fasting glycemia, a strong correlation was found, indicating that patients with higher glycemia had a greater representation of VAT. Furthermore, a strong correlation was confirmed that patients with higher VAT had higher WC. While waist circumference measurements correlated very highly with visceral fat mass using DXA, which is confirmed by other studies [25]. It was also found that with decreasing HDL cholesterol, a greater amount of VAT appears in the body. In the case of TAG and VAT assessment, it has been revealed that when TAG levels increase, a greater amount of VAT appears in the body. In the case of comparing total body fat percentage with HDL and TAG

blood levels, the correlations were not found to be as high as expected. This confirmed to us that directly VAT and with it android fat deposition are stronger predictors for CVD and associated MS. Our findings support those of other studies dealing with bariatric patients [26-29].

Other research shows that, compared to more advanced methods, comparing BMI and waist circumference can more accurately predict the amount of VAT [30]. Also, the combination of BMI and waist-to-height ratio identify increased CVD risk better than BMI alone, which we take as a limitation that we did not analyze [31].

Limitations

We are knowlege, that we have lower number of patients in all cohorts. Another limitation of our study may be the absence of BP measurements in all cohorts. We do not have a comparison of DXA with another method. CT could not be used due to ethical standards. We also included only measurement data and not pharmacological data of MS in the study.

Conclusions

Bariatric metabolic surgery is an effective treatment for obesity with a metabolic effect. Bariatric surgery is a successful treatment for obesity in terms of dramatic reduction of overall body weight. We evaluate significant weight reduction in adipose tissue, which has a positive impact on metabolic syndrome risk in all types of bariatric surgery studied. Another positive outcome is the reduction of visceral fat. Overall, we assess that bariatric-metabolic surgery has a high impact on glycemic control, adipose tissue (subcutaneous fat and visceral fat), and all studied components of MS. From the results of our pilot study, it can be argued that bariatric surgery had a significant positive impact on these values: WC, BP, morning glucose, TAG, HDL cholesterol. On the basis of this study, further studies may be conducted, e.g. with probands who are not on pharmacological treatment.

Conflict of Interest

There is no conflict of interest.

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