Original paper

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The impact of bariatric surgery on nutritional status of patients

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Abstract

Introduction: *Currently, surgical treatment is considered to be the most efficient method of dealing with morbid obesity.*
Aim: *To evaluate changes in nutritional status after surgical treatment of obesity in the early postoperative period.*
Material and methods: *The study included 50 patients (30 women and 20 men) treated surgically due to morbid obesity. During the preliminary visit and during control visits measurements of body mass, height, and waist and hip circumference were conducted. Also, analysis of body content was performed and blood was taken for biochemical analysis. Statistical analysis was conducted using the program Statistica 10.*
Results: *Six months after the surgery, in the group of women, significant reduction of average body mass, average waist circumference, average hip circumference and average body mass index (BMI) was observed. Also, significant reduction of the percentage of body fat and an increase in the percentage of fat-free body mass were observed. A significant decrease in muscle mass was also noted. Both in women and in men, 6 months after the surgery, a significant decrease in fasting glucose concentration, fasting insulin and triglycerides in blood serum was observed.*
Conclusions: *Bariatric procedures lead to significant body mass, BMI, waist and hip circumference reduction. Loss of body mass is caused mainly by the reduction of fat tissue. Application of surgical procedures in morbid obesity treatment also allowed us to achieve improvement in insulin, glucose and lipid metabolism.*

Key words: *morbid obesity, nutritional status, body composition, obesity surgery.*

Introduction

According to World Health Organization data from 2012, over half of the European Union population is overweight and 17% is obese [1]. According to the results of WOBASZ, a study conducted in Poland between 2003 and 2005, the percentage of obese men was 21.2% and that of obese women was 22.4%; among them morbid obesity (body mass index (BMI) > 40 kg/m^2) was respectively 0.6% and 2.2% [2]. Conservative treatment of patients with morbid obesity is inefficient, which is why surgical treatment is necessary. Surgical treatment is recommended for patients between 18 and 60 years old with BMI ≥ 40 kg/m^2 or BMI ≥ 35 kg/m^2 with co-morbidities connected with obesity, in which a surgically induced effect of body mass reduction would lead to their recovery. According to available data from 2011, 340 768 bariatric procedures have been performed worldwide. The most frequently performed procedures were Roux-en-Y gastric bypass (RYGB) (46.6%), sleeve gastrectomy (SG) (27.8%), adjustable gastric banding (AGB) (17.8%) and biliopancreatic diversion/duodenal switch (BPD/DS) (2.2%) [3]. It is estimated that in Poland 1200 bariatric operations are performed per year [3]. Although bariat-

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ric treatment is associated with the occurrence of complications resulting from the procedure or from nutritional insufficiencies, it leads to significant body mass reduction and metabolic improvement of obese patients.

Aim

The aim of the study was to evaluate changes in nutritional status and selected biochemical parameters of blood of patients after surgical treatment of obesity in the early postoperative period – the first 6 months after the surgery.

Material and methods

The study included 50 patients – 30 women (average age 38.8 ±8.9) and 20 men (average age 47.6 ±12.1) after surgical treatment of obesity. Sixty-five percent of patients underwent laparoscopic sleeve gastrectomy (LSG) and 35% underwent RYGB.

All bariatric procedures (SG and gastric bypass) were performed laparoscopically by one panel of surgeons including one operator and two assistants. Both operations were performed with the patient in Fowler's position at approximately 30° by using 5 trocars: 2 × 13 mm, 2 × 10 mm, 1 × 5 mm.

Laparoscopic sleeve gastrectomy lasted approximately 64 min. This procedure particularly included cutting of the gastrocolic omentum near the wall of the stomach 4–6 cm from the pylorus to the left diaphragmatic branch. The size of the stomach was limited to the tube with diameter of 34–36 Fr and next 4–5 linear staplers of different colors (Echelon, EndoGIA) were applied.

The gastric bypass procedure lasted approximately 78 min and involved creating a 20 ml pouch from the upper part of the stomach using linear staplers. Furthermore, a nutritional loop of approximately 120–150 cm was created and connected with the stomach using a 45 mm linear stapler, and next the enzymatic loop of 60 cm was connected with the nutritional loop using a 45 mm linear stapler.

At the end of both procedures the tightness was checked with the methylene blue test and a drain was placed in the peritoneal cavity.

After surgery (SG and gastric bypass) on the second or third day patients were discharged home and remained under the control of a clinical dietician and out-patient clinic. A low-calorie diet was the main recommendation. However, in the first 2 weeks after the procedure a low-sodium, semi-liquid diet was recommended, followed by a low-fat and low-carbohydrate diet.

The criteria to include patients in the study were: age 18–64 years, BMI ≥ 40 kg/m^2 or BMI ≥ 35 kg/m^2 with co-morbidities connected with obesity. The exclusion criteria were: cardio-respiratory failure, gastrointestinal tract neoplasms and pregnancy. During the preliminary visit (1 day before the surgery) and during control visits (1, 3 and 6 months after the surgery) the evaluation of nutritional status (body mass, BMI, waist and hip circumference, body content) and selected biochemical blood parameters was conducted.

Body mass (with an accuracy of 0.1 kg) and body height (with an accuracy of 0.1 cm) were determined using a medical weighing scale with a RADWAG WPT 100/200 OW stadiometer (patients dressed in light outerwear, without shoes). Waist circumference (at the height of the navel) and hip circumference were measured using a tape measure. Using the Lorentz formula, ideal body weight was established for each patient (women's ideal body weight = height in cm – 100 – (height in cm – 150)/2; men: ideal body weight = height in cm – 100 – (height in cm – 150/4)). Furthermore, the percentage of excess weight loss (%EWL) was determined %EWL = ((preoperative weight – current weight)/(preoperative weight – ideal weight) × 100) in every examined period (1, 3 and 6 months after the surgery) [4].

Assessment of body content was conducted using the method of bioelectrical impedance. The content of fat tissue (kg and % of body mass), fat-free body mass (kg and % of body mass) and water (liters and % of body mass), muscle mass (kg) and value of resting metabolic rate (kcal/day) were estimated using the analyzer of body content BioScan 920, Maltron International Ltd.

Biochemical blood assays, such as complete blood count (erythrocytes, leucocytes, hemoglobin, blood platelets), lipids (total, low-density lipoprotein (LDL) and high-density lipoprotein (HDL) cholesterol, triglycerides), uric acid, fasting glucose, insulin and C-reactive protein (CRP), were conducted in diagnostic laboratories of the University Hospital in Bialystok. As norms, standard ranges of referential values were adopted.

The study obtained the consent of the Bioethical Committee of the Medical University of Bialystok no.

R-I-002/525/2010. Each patient signed voluntarily consent to participate in the study.

Statistical analysis

Statistical analysis of data (mean values, standard deviation, minimum and maximum values) was conducted using Statistica 10. Results of examinations performed before the surgery were compared with results obtained 1, 3 and 6 months after the surgery. To compare results in particular periods, Student's *t*-test for independent samples was used. Results where $p \leq 0.05$ were assumed to be statistically significant.

Results

The study included 50 obese patients – 30 women (average age 38.8 ±8.9 years) and 20 men (average age 47.6 ±12.1 years) treated surgically. Body mass in women before the surgery was between 82 kg and 169.9 kg (average 120.66 ±21.24 kg) and BMI between 36.7 kg/m^2 and 72.6 kg/m^2 (average 44.55 ±9.73 kg/m^2). In the group of men, body mass before the surgery was between 130 kg and 175 kg (average 142.83 ±28.41 kg) and BMI was 38.3–60.5 kg/m^2 (average 47.75 ±9.78 kg/m^2). Average waist circumference of examined women was 130.96 ±20.48 cm and examined men 146.33 ±17.96 cm. In women, average hip circumference before the surgery was 137.46 ±14.53 cm and in men it was 137.08 ±17.90 cm. Average body mass, average waist and hip circumference and average BMI in women decreased significantly 3 and 6 months after the surgery. Results are presented in Table I. In the case of men, mean values of aforementioned parameters also decreased but differences were statistically insignificant (Table II).

In this study, percentage of excess weight loss (%EWL) in patients 1, 3 and 6 months after the surgery was determined. In women %EWL was 19.74 ±6.98% 1 month after the surgery, 33.97 ±12.47% 3 months after the surgery and 47.43 ±16.67% 6 months after the surgery, and in men it was 22.38 ±6.65% 1 month after the surgery, 34.49 ±10.69% 3 months after the surgery and 45.53 ±16.83% 6 months after the surgery. Analysis of body content of patients before the surgery revealed a high percentage of fat tissue (women average 50.79 ±5.24%, men average 41.28 ±7.93%), which in women was significantly reduced 3 months after the surgery (44.37 ±6.39%), and after 6 months (41.93 ±8.31%). In the case of men the reduction of fat tissue was respectively 36.01 ±7.66% and 35.30 ±11.20%. In both examined groups, the percentage of fat-free body mass increased. In women fat-free body mass before the surgery was 49.20 ±5.24%; 3 months (55.62 ±4.60%) and 6 months (57.51 ±16.55%) after the surgery a statistically significant ($p \leq 0.05$) increase of fat-free body mass was observed. In men an increase of fat-free body mass was also observed from 58.72 ±7.93% before the surgery to 66.55 ±9.41% 6 months after the surgery. Despite a beneficial proportion of fat-free mass (FFM) in comparison to fat mass (FM), a statistically significant loss of fat-free mass was observed in women, from 58.44 ±5.73 kg before the surgery to 53.68 ±5.07 kg 6 months after the surgery. An adverse effect was observed in both groups concerning loss of muscle mass. In women muscle mass was reduced 3 months after the surgery (23.54 ±2.36 kg), and after 6 months (22.79 ±2.45 kg). In men average muscle mass before the surgery was 39.20 ±8.00 kg and after 6 months it decreased to 35.69 ± 5.11 kg. What is more, 6 months after the surgery, an increase of total content of water in the body was observed – in women from 40.94 ±3.87% to 45.29 ±4.19% ($p \leq 0.05$) and in men from 47.23 ±5.69% to 51.75 ±7.14%. Results are presented in Tables I and II.

In the present study, both groups revealed a significant decrease in average fasting glucose concentration, average fasting insulin concentration 3 and 6 months after the surgery and average triglycerides concentration 6 months after the surgery (Figure 1). Results of remaining biochemical blood parameters (excluding HDL cholesterol), such as LDL cholesterol (Figure 2), concentration of erythrocytes and leukocytes, blood platelets and hemoglobin, also showed decreases during 6 months after the surgery, but the differences were statistically insignificant. Average concentration of total cholesterol in serum periodically fluctuated (Figure 3). In the first month after the surgery, concentration of cholesterol in women decreased from 197.64 ±21.20 mg/dl to 164.69 ±37.01 mg/dl, and in men from 192.67 ±28.63 mg/dl to 169.67 ±31.19 mg/dl, and 3 months after the surgery it reached 184.07 ±28.30 mg/dl in women and 180.67 ±31.38 mg/dl in men. However, average values of evaluated parameters 1, 3, and 6 months after the surgery were within the standard. Evaluation of HDL cholesterol concentration in se-

Table I. Anthropometric measurements and body composition of women prior to the surgery, 1 month, 3 and 6 months after the surgery

Parameter	Women				
	Prior to surgery	1 month after surgery	3 months after surgery	6 months after surgery	%
	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	
Body weight [kg]	120.66 ±21.24 (82–169.9)	109.17 ±19.66 (71.8–153)	102.30* ±20.71 (65.5–148.6)	92.89* ±19.70 (59–141.5)	–23.29 ±5.48
Waist circumference [cm]	130.96 ±20.48 (104–181)	123.25 ±21.59 (94–174)	117.53* ±23.07 (89–169)	110.53* ±23.04 (82–163)	–15.89 ±16.11
Hip circumference [cm]	137.46 ±14.53 (111–154)	130.74 ±14.70 (102.5–150)	125.50* ±12.88 (103.5–148)	120.26* ±13.09 (97–144)	–12.72 ±12.01
BMI [kg/m^2]	44.55 ±9.73 (32.8–72.6)	40.41 ±9.14 (28.7–66.6)	37.90* ±9.37 (26.2–63.47)	34.92* ±9.21 (23.63–60.4)	–22.47 ±16.28
% EWL	–	19.74 ±6.98	33.97 ±12.47	47.43 ±16.67	
Fat mass (%)	50.79 ±5.24 (43.59–62.49)	48.44 ±6.44 (39.26–62.05)	44.37* ±6.39 (34.17–54.23)	41.93* ±8.31 (28.61–58.28)	–17.30 ±4.77
Fat mass [kg]	62.18 ±17.27 (36.18–106.17)	54.03 ±16.80 (28.19–96.74)	45.98* ±12.77 (22.38–61.27)	40.80* ±16.55 (16.88–82.46)	–33.07 ±22.01
Fat-free mass (%)	49.20 ±5.24 (37.51–56.41)	51.55 ±6.44 (37.95–60.74)	55.62* ±6.4 (45.77–65.83)	57.51* ±8.76 (41.72–71.39)	+18.63 ±17.97
Fat-free mass [kg]	58.44 ±5.73 (45.82–67.05)	55.35 ±5.60 (43.61–64.65)	56.29 ±11.08 (43.12–89.48)	53.68* ±5.07 (42.14–60.31)	–9.42 ±10.48
Muscle mass [kg]	26.14 ±3.82 (19.94–36.15)	24.13 ±2.48 (18.94–28.16)	23.54* ±2.36 (18.5–26.99)	22.79* ±2.45 (17.93–26.31)	–13.37 ±12.00
Protein mass [kg]	6.9 ±2.06 (2.45–9.78)	7.40 ±1.97 (3.29–10.22)	7.52 ±2.11 (3.14–10.44)	7.63 ±2.36 (2.95–10.82)	13.57 ±22.45
Mineral mass [kg]	2.81 ±0.84 (1.00–3.99)	3.02 ±0.80 (1.34–4.17)	3.07* ±0.86 (1.28–4.26)	3.12 ±0.94 (1.2–4.42)	39.00 ±21.59
Total body water (%)	40.94 ±3.87 (35.2–48.6)	41.68 ±3.5 (34.97–47.03)	43.25 ±3.98 (36.76–49.63)	45.29* ±4.19 (38.78–52.43)	11.93 ±12.91
Total body water [l]	48.25 ±6.44 (36.2–60.2)	45.02 ±5.84 (32.84–54.52)	42.23 ±4.51 (37.33–54.63)	41.90* ±6.02 (30.93–54.88)	–14.09 ±13.34
Resting metabolic rate [kcal/day]	1660.64 ±120.52 (1472–1882)	1624.71 ±111.86 (1441–1848)	1606.30* ±106.04 (1434–1811)	1587.78 ±102.0 (1412–1787)	–5.02 ±5.91

**Statistical significance $p < 0.05$ in comparison to initial values (before the surgery).*

rum revealed a decrease 1 month after the surgery (women average from 51.14 ±11.01 mg/dl to 42.46 ±11.79 mg/dl; men average from 40.83 ±8.20 mg/dl to 35.33 ±6.68 mg/dl) and then a gradual increase 3 months (women average 47.14 ±8.91 mg/dl, men average 39.83 ±8.06 mg/dl) and 6 months after the surgery (women average 54.07 ±12.42 mg/dl; men average 43.17 ±7.49 mg/dl) (Figure 4). In both groups, an increase of serum uric acid concentration was observed 1 month after the surgery and a decrease 3 and 6 months after the surgery. In the case of CRP, a decrease of its average concentration to normal values was observed 6 months after the surgery (in women average concentration 3.11 ±6.25 mg/l, in men average concentration 3.7 ±3.06 mg/l). Results of laboratory tests are presented in Tables III and IV.

Discussion

In the literature, there is a constantly increasing amount of data regarding high and long-term

Table II. Anthropometric measurements and body composition of men prior to the surgery, 1 month, 3 and 6 months after the surgery

Parameter	Men				
	Prior to surgery	1 month after surgery	3 months after surgery	6 months after surgery	%
	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	
Body weight [kg]	142.83 ±28.41 (130–175)	126.92 ±25.25 (94–160.5)	118.13 ±23.92 (88–152.2)	111.43 ±27.44 (81.5–156.1)	–19.41 ±5.10
Waist circumference [cm]	146.33 ±17.96 (125–175)	134.33 ±13.35 (119–155)	128.42 ±14.63 (112–149)	122.67 ±19.51 (102–152)	–16.43 ±4.13
Hip circumference [cm]	137.08 ±17.90 (121–164)	128.17 ±16.19 (109–156)	125.5 ±17.02 (104–150)	120.67 ±19.33 (99–151)	–12.22 ±3.41
BMI [kg/m^2]	47.75 ±9.78 (38.3–60.5)	41.76 ±8.57 (33.67–55.5)	38.85 ±8.12 (31.8–52.60)	36.7 ±9.48 (28.7–53.97)	–23.25 ±8.75
% EWL	–	22.38 ±6.65	34.49 ±10.69	45.53 ±16.83	
Fat mass (%)	41.28 ±7.93 (28.07–48.92)	39.36 ±6.45 (28.13–48.92)	36.01 ±7.66 (24.12–44.76)	35.3 ±11.20 (17.31–48.23)	–15.69 ±17.75
Fat mass [kg]	60.22 ±20.02 (33.68–79.72)	54.06 ±17.32 (29.68–75.08)	43.86 ±17.35 (24.02–68.12)	37.12 ±19.07 (15.58–72.12)	–39.51 ±17.03
Fat-free mass (%)	58.72 ±7.93 (51.08–71.93)	60.01 ±6.41 (53.22–71.87)	63.99 ±7.66 (55.24–75.88)	66.55 ±9.41 (55.63–83.86)	13.68 ±10.96
Fat-free mass [kg]	82.62 ±12.33 (66.6–95.28)	76.48 ±8.14 (62.6–85.42)	74.27 ±8.12 (59.7–84.07)	72.44 ±10.25 (55.63–83.86)	–11.68 ±10.81
Muscle mass [kg]	39.20 ±8.00 (28.6–46.63)	37.84 ±4.43 (30.29–42.74)	37.82 ±4.89 (29.46–43.73)	35.69 ±5.11 (27.42–41.70)	–7.08 ±14.95
Protein mass [kg]	10.74 ±2.31 (7.75–12.75)	11.60 ±2.50 (7.42–13.45)	11.78 ±2.32 (7.41–13.67)	12.02 ±1.71 (8.65–13.26)	15.47 ±27.61
Mineral mass [kg]	3.96 ±0.53 (3.16–4.47)	4.07 ±0.87 (2.61–4.72)	4.3 ±0.53 (3.41–4.80)	4.23 ±0.60 (3.04–4.66)	8.14 ±20.33
Total body water (%)	47.23 ±5.69 (42.99–58.39)	48.09 ±4.96 (42.13–55.63)	50.24 ±4.69 (45.18–58.19)	51.75 ±7.14 (43.54–64.68)	9.54 ±6.75
Total body water [l]	66.81 ±11.51 (48.8–78.05)	60.17 ±7.62 (48.8–68.30)	55.58 ±8.59 (46.14–68.76)	56.47 ±8.86 (43.93–67.93)	–14.92 ±10.12
Resting metabolic rate [kcal/day]	2173.67 ±404.46 (1614–2595)	2112.45 ±269.80 (1628–2408)	2078.67 ±242.75 (1645–2382)	2043.33 ±268.86 (1567–2364)	–4.74 ±11.13

**Statistical significance $p < 0.05$ in comparison to initial values (before the surgery).*

efficiency of bariatric surgery in treatment of morbid obesity [5, 6]. Efficiency of surgical treatment of obesity is evaluated mainly by percentage of excess weight loss (%EWL) and changes in BMI. The surgical procedure is considered to be successful when after 5 years the loss of ≥ 50% of excess body mass is obtained [7]. Available publications indicate that weight loss as %EWL during 3–6 years after the surgery is 25–65% after laparoscopic adjustable gastric banding (LAGB), 66–68% after SG and 53–77% after RYGB [5, 6]. In this study, percentage of excess weight loss in the early postoperative period (first 6 months) was determined. In women the average was 47.43 ±16.67% and in men it was 45.53 ±16.83%. As the available data suggest, in patients after SG %EWL was 35–49% 6 months after the surgery [8–12]. Six months after RYGB, %EWL was higher and amounted to 56–64% [13, 14]. Higher %EWL was connected with the fact that RYGB, unlike gastrectomy, is a mixed procedure. It means that despite the considerable limitation of consumed food, it also limits the absorption of nu-

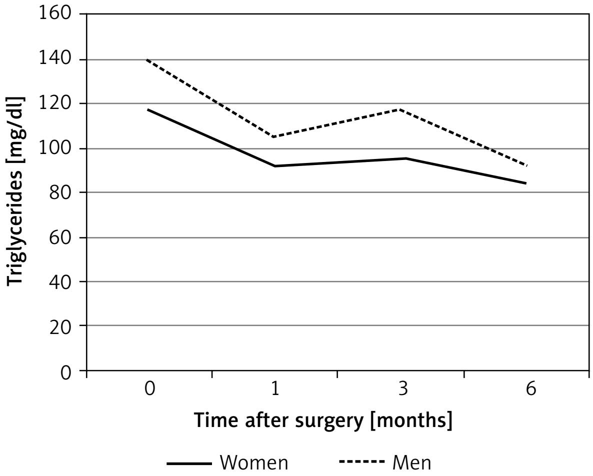

Figure 1. Comparison of average concentration of triglycerides in serum in women and men prior to the surgery, 1 month and 3 and 6 months after the surgery

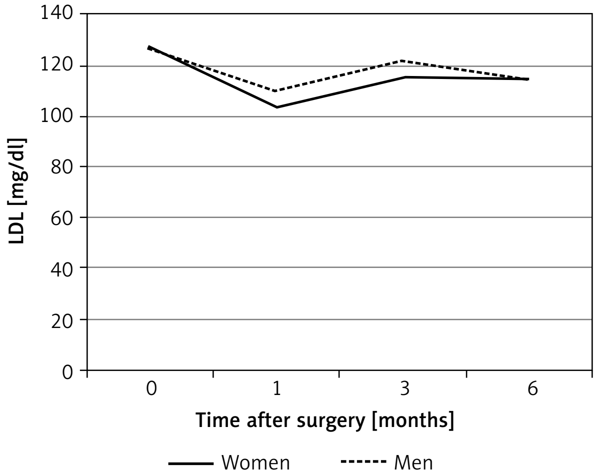

Figure 2. Comparison of average concentration of LDL cholesterol in serum in women and men prior to the surgery, 1 month and 3 and 6 months after the surgery

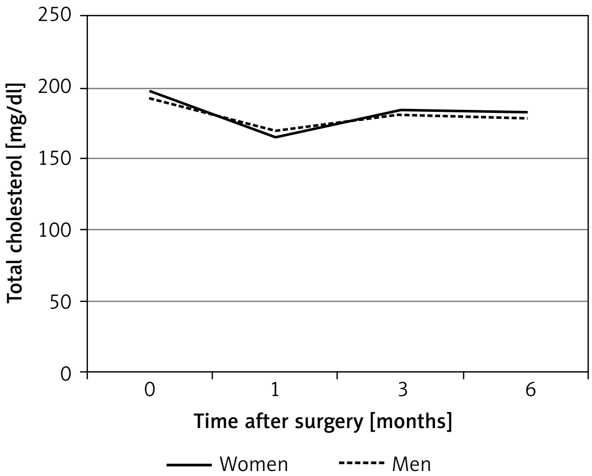

Figure 3. Comparison of average concentration of total cholesterol in serum in women and men prior to the surgery, 1 month and 3 and 6 months after the surgery

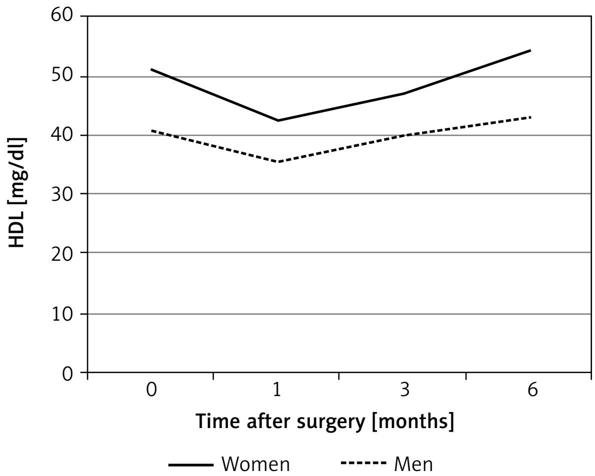

Figure 4. Comparison of average concentration of HDL cholesterol in serum in women and men prior to the surgery, 1 month and 3 and 6 months after the surgery

trients, mainly carbohydrates, which are the main source of energy.

It would be the most beneficial if the loss of excess body weight was caused only by the reduction of fat tissue. According to Christensen, maximum content of fat tissue in the body of healthy women should be 35% of body mass and in the case of men 22% [15]. In the present study, in the group of women statistically significant reduction of fat tissue was observed 3 and 6 months after the surgery. Similar results were obtained by Bavaresco *et al.*, but they examined only patients after RYGB [16]. In our own study, in women average content of fat tissue 6 months after the surgery was 41.93 ±8.31% and in men it was 35.3 ±11.20%. In the study by de Freitas Junior, the percentage of fat tissue in the body was 38.67 ±7.86 [17]. Significant reduction of body mass and fat tissue after bariatric procedures suggests the efficiency of the applied procedure. It should be noted that in the period of intensive body mass loss,

Table III. Selected biochemical parameters of blood in obese women prior to the surgery and 1 month, 3 and 6 months after the surgery

Parameter	Women				
	Prior to surgery	1 month after surgery	3 months after surgery	6 months after surgery	Norm
	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	
Fasting glucose [mg/dl]	119.21 ±30.07 (97–189)	98.83 ±10.32 (81–117)	97.38* ±8.94 (85–113)	95.28* ±7.85 (86–108)	65–105
Fasting insulin [µIU/ml]	17.28 ±13.08 (5.7–43.5)	12.42 ±11.38 (3.8–36.9)	8.37* ±4.60 (3.3–20)	7.02* ±4.14 (3.8–18.3)	7–15.6
CRP [mg/l]	9.36 ±8.59 (0.6–31.2)	7.88 ±7.69 (0.8–23.6)	6.7 ±10.84 (1.2–31.4)	4.11 ±6.25 (0.6–18.4)	0.0–5.0
Total cholesterol [mg/dl]	197.64 ±21.20 (155–230)	164.69 ±37.01 (105–231)	184.07 ±28.30 (129–228)	182.57 ±27.25 (129–228)	130–200
LDL [mg/dl]	127.57 ±21.31 (76–161)	104 ±34.82 (34–170)	115.07 ±25.35 (72–164)	114.42 ±22.18 (77–166)	100–159
HDL [mg/dl]	51.14 ±11.01 (35–80)	42.46 ±11.79 (27–74)	47.14 ±8.91 (35–68)	54.07 ±12.42 (36–84)	45–65
Triglycerides [mg/dl]	117.28 ±35.20 (71–191)	92.41 ±22.10 (69–146)	95.64 ±25.36 (62–166)	84.21* ±27.94 (50–167)	40–200
Uric acid [mg/dl]	4.95 ±0.91 (3.18–6.62)	6.34 ±1.73 (3.76–9.42)	4.95 ±0.89 (3.69–7.11)	4.92 ±1.12 (2.98–7.26)	2.4–5.7
RBC [10^6/µl]	4.50 ±0.32 (4.0–5.04)	4.56 ±0.28 (4.05–5.02)	4.49 ±0.31 (4.12–5.3)	4.49 ±0.30 (4.12–5.16)	4–5.5
Hgb [g/dl]	13.16 ±0.74 (12.1–14.2)	13.24 ±0.47 (12.2–14.1)	13.06 ±0.59 (12–14.1)	12.96 ±0.49 (12.3–13.6)	12–16
WBC [10^3/µl]	8.34 ±1.83 (4.99–11.44)	7.36 ±1.63 (4.96–11.3)	8.15 ±1.63 (4.95–11.1)	7.69 ±1.62 (5.01–10.9)	4–10
PLT [10^3/µl]	313.28 ±50.5 (235–415)	278.07 ±76.34 (207–497)	284.42 ±47.83 (205–362)	284.46 ±47.43 (215–388)	130–350

**Statistical significance p < 0.05 in comparison to initial values (before the surgery).*

also fat-free body mass is reduced, including muscles (approximately 50%), soft tissues, bones and collagen [17]. Fat-free body mass is an important component of lost body mass after a bariatric procedure, especially during the first 6 months after the surgery [18]. In our study, average loss of fat-free body mass in women was 9.42 ±1.48%, and in men it was 11.68 ±10.81%. In the examination conducted among 36 obese patients after open gastric bypass, significant, over 19%, loss of fat-free body mass was observed 6 months after the surgery [17]. As Chaston *et al.* suggest in their review article, fat-free body mass may be even 31.3% of lost body mass in patients after RYGB [19]. In order to prevent excessive loss of fat-free body mass, optimal supply of protein and regular physical activity should be ensured [20, 21]. According to Heber *et al.* and Moize *et al.*, protein supply 1.5 g/kg of ideal body weight may help to maintain a positive nitrogen balance and thus prevent loss of fat-free body mass [22, 23].

An indisputable advantage of bariatric surgery is the possibility of improvement of metabolic balance in obese patients (improved metabolism of insulin, glucose and lipids). Only 3 months after the surgery, concentration of glucose and triglycerides in serum significantly decreases [24]. In our study, 3 months after the surgery a significant decrease in fasting glucose and insulin concentration was seen in both groups. The level of triglycerides did not decrease substantially until 6 months after the surgery. Similar results were obtained by other authors [16, 25–28]. In a prospective cohort study including

Table IV. Selected biochemical parameters of blood in obese men prior to the surgery and 1 month, 3 and 6 months after the surgery

Parameter	Men				
	Prior to surgery	1 month after surgery	3 months after surgery	6 months after surgery	Norm
	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	
Fasting glucose [mg/dl]	130.83 ±13.01 (107–146)	106.17 ±17.01 (85–132)	107.17* ±9.68 (91–119)	98.83* ±7.33 (86–106)	65–105
Fasting insulin [µIU/ml]	30.42 ±0.49 (15.7–40.2)	11.08 ±3.45 (7.4–17.5)	12.22* ±8.07 (4.6–26.3)	7.78* ±3.69 (5.2–15.2)	7–15.6
CRP [mg/l]	7.8 ±3.37 (3.8–12.2)	6.22 ±4.62 (0.9–13.4)	5.42 ±3.77 (5.42–11.6)	3.7 ±3.06 (0.9–9.6)	0.0–5.0
Total cholesterol [mg/dl]	192.67 ±28.63 (153–222)	169.67 ±31.19 (118–205)	180.67 ±31.38 (146–218)	178.85 ±31.13 (152–230)	130–200
LDL [mg/dl]	126.33 ±26.84 (88–157)	109.67 ±26.88 (63–144)	121.67 ±28.04 (85–155)	114.17 ±24.45 (87–159)	100–159
HDL [mg/dl]	40.83 ±8.20 (25–47)	35.33 ±6.68 (27–42)	39.83 ±8.06 (28–49)	43.17 ±7.49 (32–52)	35–55
Triglycerides [mg/dl]	138.83 ±35.76 (79–172)	105.0 ±18.15 (77–128)	117.17 ±30.20 (80–163)	92.17* ±19.85 (66–120)	40–200
Uric acid [mg/dl]	6.88 ±1.24 (4.87–8.73)	7.43 ±2.24 (3.56–9.33)	6.7 ±1.62 (4.34–1.62)	6.22 ±1.23 (66–120)	3.4–7.0
RBC [10^6/µl]	4.98 ±0.28 (4.61–5.3)	4.89 ±0.55 (3.88–5.43)	4.83 ±0.62 (4.02–5.53)	4.67 ±0.39 (4.81–7.8)	4.5–6.0
Hgb [g/dl]	14.43 ±1.05 (12.9–15.6)	14.17 ±1.31 (12.6–16.2)	14.15 ±1.39 (12.5–16)	13.52 ±1.13 (4.22–5.21)	14–18
WBC [10^3/µl]	7.98 ±1.73 (5.01–10.08)	7.31 ±1.32 (5.39–9.3)	7.49 ±1.35 (6.27–9.60)	7.24 ±1.40 (12.1–15.3)	4–10
PLT [10^3/µl]	311.83 ±64.72 (225–397)	285.33 ±77.04 (192–406)	273 ±36.81 (221–323)	263.17 ±28.88 (225–311)	130–350

**Statistical significance p < 0.05 in comparison to initial values (before the surgery).*

15 patients after RYGB, a significant decrease in serum concentration of insulin and LDL cholesterol 6 months after the surgery was observed [29]. Auguet *et al.* 6 months after laparoscopic sleeve gastrectomy noted a significant reduction of glucose, insulin, triglycerides and CRP concentration and an increase of serum HDL cholesterol concentration [30]. What is more, they proved that lowering of triglycerides concentration with a simultaneous increase of serum HDL cholesterol raises the risk of cardiovascular diseases. This risk significantly drops 12 months after the surgery [30]. Similar results were obtained by Ruiz-Tovar *et al.* [24].

A substantial role in arteriosclerosis pathogenesis and ischemic heart disease is also played by the inflammatory state connected with obesity (especially of visceral tissue) [31]. One of the active agents of the inflammatory reaction is CRP [32]. C-reactive protein is synthesized in the liver mainly as a response to interleukin 6 (IL-6) [31]. Based on values of serum CRP, the risk of cardiovascular incidents is estimated. According to the American Heart Association and the Centers for Disease Control and Prevention, low risk occurs when CRP < 1 mg/l, moderate when CRP is 1–3 mg/l and high when CRP > 3 mg/l [33]. One study proved that elevated level of CRP was positively correlated with BMI, concentration of glucose, total cholesterol, triglycerides and uric acid and negatively correlated with concentration of serum HDL cholesterol [34]. In this study, concentration of CRP > 3 mg/l was proved in 77% of patients qualified for surgical treatment.

Six months after the surgery this percentage fell to 31.6%. In the study of Hakeam *et al.*, before sleeve gastrectomy, CRP concentration exceeded 3 mg/l in 89.6% of obese patients [35]. Six months after the surgery CRP concentration had normalized in approximately 50% (44% of all examined patients) with high CRP [35].

Bariatric procedures, especially malabsorptive, may lead to insufficiencies in macro- and micronutrients. A deficit of protein, iron, vitamin B_{12} and folic acid manifests mainly in lowering of the number of erythrocytes and hemoglobin concentration. Furthermore, a deficit in folic acid and vitamin B_{12} causes disturbances in deoxyribonucleic acid synthesis, amino acids and bone proteins and hence leads to a decrease of the number of leukocytes and blood platelets. In the study of Coupane, average concentration of hemoglobin 6 months after sleeve gastrectomy was 13.5 ±1.3 g/dl and after gastric bypass 13.1 ±1.0 g/dl [25]. Blume *et al.* observed that 6 months after RYGB average concentration of hemoglobin was 13.0 ±1.1 g/dl [36]. Obtained values are comparable with the results obtained in this study.

Conclusions

Bariatric procedures support a significant reduction of body mass, BMI, and waist and hip circumference. Body mass loss is caused mainly by the reduction of fat tissue in the body. Due to application of surgical methods in treatment of morbid obesity, improvement of insulin, glucose and lipid metabolism has been achieved, which may influence the possibility of resolution of the symptoms resulting from metabolic disorders or cardiovascular diseases. What is more, in the early postoperative period, anemia, which may be the result of insufficient supply of iron in the diet, was not observed.

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Conflict of interest

The authors declare no conflict of interest.

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