UNIWERSYTET
MIKOŁAJA KOPERNIKA
W TORUNIU
Wydział Nauk o Zdrowiu
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Przebieg procesu zapalnego u pacjentów po zabiegu bariatrycznym na podstawie analizy poziomu wybranych cytokin

Rozprawa na stopień doktora nauk medycznych i nauk o zdrowiu

Promotor:
Dr hab. Mariusz Kozakiewicz, prof. UMK

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Pragnę wyrazić najgłębsze podziękowania Panu dr hab. Mariuszowi Kozakiewiczowi, prof. UMK, za nieocenione rady, życzliwość, poświęcony czas oraz inspirację, która uczyniła moją podróż naukową wyjątkową i pełną pasji.

Z całego serca dziękuję moim najbliższym za niezachwianą wiarę we mnie i moje możliwości oraz za wsparcie w trudnych chwilach.

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Pracę tę dedykuję Rodzicom

Spis treści

Wykaz skrótów

WHO – Światowa Organizacji Zdrowia (Word Health Ogranization)

LSG - Laparoskopowa rękawowa resekcja żołądka (Laparoscopic sleeve gastrectomy)

BMI – Wskażnik Masy Ciała (Body Mass Index)

IL-6 – Interelukina-6 (Interleukin 6)

TNF-α – Czynnik martwicy nowotworów alfa (Tumor Necrosis Factor Alpha)

CRP – Białko C-reaktywne (C-Reactive Protein)

IL-10 - Interelukina-10 (Interleukin 10)

EWL - Utrata nadmiarowej masy ciała (Excess Weight Loss)

1. Wstęp

Otyłość jest jednym z najpoważniejszych problemów zdrowotnych XXI wieku, prowadzącym do licznych powikłań metabolicznych i sercowo-naczyniowych. Według Światowej Organizacji Zdrowia (WHO) ponad miliard osób na świecie zmaga się z otyłością, a jej częstość występowania nadal rośnie [1]. Otyłość, jako choroba przewlekła, jest związana z utrzymującym się stanem zapalnym o niskim stopniu nasilenia, określanego jako „meta-zapalanie" (ang. metainflammation). Stan ten sprzyja rozwojowi insulinooporności, cukrzycy typu 2, chorób układu krążenia oraz niektórych nowotworów. Kluczowe mechanizmy tego procesu obejmują nadmierną produkcję cytokin prozapalnych przez tkankę tłuszczową oraz aktywację układu odpornościowego, co prowadzi do zaburzeń metabolicznych [2, 3]. Modyfikacja stylu życia, obejmująca interwencje dietetyczne oraz zwiększoną aktywność fizyczną, stanowi podstawową strategię terapeutyczną w leczeniu otyłości, jednak jej długoterminowa skuteczność jest ograniczona ze względu na trudności w utrzymaniu redukcji masy ciała [4]. Chirurgia bariatryczna jest obecnie uznawana za najskuteczniejszą metodę trwałej redukcji masy ciała u pacjentów z otyłością olbrzymią [5]. Laparoskopowa rękawowa resekcja żołądka (LSG) jest jednym z najczęściej wykonywanych zabiegów bariatrycznych na świecie [6]. Polega ona na usunięciu około 2/3 objętości żołądka, co prowadzi do zmniejszenia objętości spożywanych pokarmów oraz wpływa na mechanizmy hormonalne regulujące apetyt i metabolizm [7]. Wyniki badań jednoznacznie wskazują, że LSG prowadzi do trwałej redukcji masy ciała oraz poprawy parametrów metabolicznych, takich jak stężenie glukozy, insuliny i profilu lipidowego [8, 9]. Co więcej, operacja ta zmniejsza poziom markerów zapalnych, przyczyniając się do redukcji ryzyka chorób sercowo-naczyniowych i metabolicznych [10]. Badania nad wpływem chirurgii bariatrycznej na układ odpornościowy koncentrują się na analizie poziomów cytokin pro- i przeciwzapalnych. Tkanka tłuszczowa, zwłaszcza trzewna, działa jak aktywny narząd endokrynny, wydzielając adipokiny i cytokiny prozapalne, w tym IL-6, TNF-α i CRP, które odgrywają kluczową rolę w rozwoju insulinooporności, cukrzycy typu 2 i miażdżycy [11]. Z drugiej strony, cytokiny przeciwzapalne, takie jak IL-10, odgrywają rolę ochronną, ograniczając nadmierną odpowiedź zapalną [12].

Zagadnienia związane z analizą wybranych parametrów zapalnych u pacjentów otyłych poddanych operacjom bariatrycznym, zostały opisane w pracy poglądowej *Bracha M, Szady-Grad M. Selected blood parameters with potential diagnostic application in the course of inflammation in chronically obese individuals undergoing bariatric surgery. Pielęgniarstwo w Opiece Długoterminowej/Long-Term Care Nursing. 2023;8(2):39-45* będącej częścią cyklu publikacji prezentowanych w tej rozprawie doktorskiej (publikacja I).

1.1. Tekst publikacji I

Pielęgniarstwo w opiece długoterminowej
Kwartalnik międzynarodowy

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SELECTED BLOOD PARAMETERS WITH POTENTIAL DIAGNOSTIC APPLICATION IN THE COURSE OF INFLAMMATION IN CHRONICALLY OBESE INDIVIDUALS UNDERGOING BARIATRIC SURGERY

Wybrane parametry krwi o potencjalnie diagnostycznym zastosowaniu w przebiegu stanu zapalnego u osób przewlekle otyłych poddanych operacji bariatrycznej

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A - Koncepcja i projekt badania, B - Gromadzenie i/lub zestawianie danych, C - Analiza i interpretacja danych, D - Napisanie artykułu, E - Krytyczne zrecenzowanie artykułu, F - Zatwierdzenie ostatecznej wersji artykułu

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Abstract (in Polish):
Chirurgia bariatryczna została uznana za najskuteczniejszą długoterminową metodę leczenia otyłości. Prowadzi do radykalnej i trwałej utraty wagi, poprawy jakości życia oraz zmniejszenia ryzyka wystąpienia chorób metabolicznych. Poszukiwanie potencjalnego mechanizmu odpowiedzialnego za patogenezę

chorób związanych z otyłością ujawniło ścisły związek między nadmiarem składników odżywczych a rozwojem stanu zapalnego. Coraz większa ilość badań dotyczących wpływu chirurgii bariatrycznej na poziom parametrów stanu zapalnego we krwi dowodzi zmniejszenia ogólnoustrojowego stanu zapalnego.

Abstract (in English):
Bariatric surgery has been recognized as the most effective long-term treatment for obesity. It leads to radical and permanent weight loss, improved quality of life and reduced risk of metabolic diseases. The search for a potential mechanism responsible for the pathogenesis of obesity-related diseases has revealed a close relationship between excess nutrients and the development of inflammation. An increasing number of studies on the impact of bariatric surgery on the level of inflammatory parameters in the blood proves a decrease in systemic inflammation.

Keywords (in Polish): otyłość, stan zapalny, operacja bariatryczna.

Keywords (in English): obesity, inflammation, bariatric surgery.

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Short title
Parametry stanu zapalnego u osób po operacji bariatrycznej

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Authors (short)
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Introduction

Obesity is a rapidly growing public health problem, occurring both in highly industrialized and developing countries. The majority of the world's population lives in countries where overweight and obesity result in more deaths than undernutrition [1]. According to a report published by the WHO in May 2022, more than one billion people worldwide are obese – 650 million adults, 340 million adolescents and 39 million children. In Europe, 60% of the population is overweight or obese, and this figure is still growing [2]. This is due to excessive energy intake from food consumption coupled with reduced energy expenditure, leading to an increase in body fat mass. This leads to the development of low-grade inflammation, called metabolic inflammation or meta-inflammation [3].

Significant weight loss occurring after bariatric surgery gives the opportunity to learn about the mechanisms underlying the development of comorbidities in obesity [4]. Current research results allow us to assume that after bariatric surgery, the level of inflammatory parameters in the blood will gradually decrease.

The aim of the study was to present current knowledge on selected parameters of blood inflammation in chronically obese people undergoing bariatric surgery.

According to the WHO, overweight and obesity are defined as abnormal or excessive accumulation of body fat, which affects the deterioration of health. The main indicator for diagnosing abnormal body weight in adults is body mass index (BMI). BMI above 25 kg / m2 indicates overweight, while above 30 kg/m2 indicates obesity [1]. Obesity is a disease that affects most body systems - the heart, liver, kidneys, joints and reproductive system. It leads to a number of non-communicable diseases (NCDs), such as type 2 diabetes, cardiovascular diseases, respiratory diseases, different kind of cancers, as well as neurodegenerative diseases and mental health problems [5].

The search for a potential mechanism responsible for the pathogenesis of obesity-related diseases revealed a close relationship between excess nutrients and the development of inflammation [3]. Adipose tissue is mainly made of adipocytes, but other cells are also involved in its growth and functioning, including preadipocytes, lymphocytes, macrophages, fibroblasts and vascular cells. Currently, adipose tissue is considered to be an active endocrine organ synthesizing numerous, biologically active peptides called adipokines, which act within adipose tissue and on distant organs and tissues that can cause increased inflammation. Obesity can lead to significant changes in the cellular composition of adipose tissue and also modulate the phenotype of the cells present there [6]. Many factors are involved in the development of meta-inflammation, which include hypoxia and adipocyte death, oxidative stress, endoplasmic reticulum stress, activation of inflammasomes, activation of TLR receptors and disorders of the composition of the natural intestinal flora [7, 8, 9].

Although diet, lifestyle modification, and pharmacological therapy are common treatment options for obesity, current evidence indicates that these interventions do not show long-term weight reduction in cases of morbid obesity [10, 11, 12]. Bariatric surgery is currently the most effective treatment for patients with obesity whose BMI exceeds 40 kg/m2 or 35 kg/m2 with current obesity complications. Surgery leads to radical and permanent weight loss, improved quality of life and reduced risk of obesity-related disorders [13]. Among bariatric treatments, we distinguish three main types of surgeries: restrictive, exclusionary and restrictive-exclusionary. Among the restrictive methods, we distinguish adjustable gastric banding (AGB), vertical gastric banding (VGB), laparoscopic sleeve gastrectomy (LSG). Exclusionary surgeries significantly reduce the absorption of energy from food consumption by excluding part of the digestive tract from digestion and absorption. These include biliopancreatic diversion (BPD). Restrictive-exclusionary methods include: Roux-Y-gastric bypass (RYGB), mini-gastric bypass (OAGB, MGB), biliopancreatic diversion with duodenal switch (BPD-DS) [14 , 15]. RYGB and LSG together account for more than 80 % of bariatric surgery performed worldwide [16].

Weight reduction interventions in obese patients are associated with improvements in systemic inflammation [17]. Inflammation in people with obesity can be measured by quantifying inflammatory parameters such as pro-inflammatory cytokines (e.g. tumor necrosis factor (TNF-α), interleukin 1 (IL-1), interleukin 6 (IL-6), interleukin 8 (IL-8), leukocyte counts, adipokines, C-reactive proteins (CRPs), high sensitivity CRP (hs-CRP) [5, 18]. An increasing number of studies indicate that bariatric surgery (BS) lowers inflammatory parameters in the blood [19].

A meta-analysis of 95 studies involving a total of 6232 patients undergoing bariatric surgery showed a significant decrease in leptin, ghrelin, CRP, hs-CRP, IL-6, TNF-α, IL-1β levels and an increase in adiponectin, GLP-1 and YY peptide (PYY) levels [20]. El-Zawawy et al. in their study showed a decrease in hs-CRP levels after just 3 months after BS [21]. This is accordance with the results of Lautenbach et al., which showed a significant reduction in hs-CRP after 6 months, 2 years and 4 years from BS respectively [19]. Furthemore, Oliveras et al. in their studies showed a significant reduction in hs-CRP after 1 year from BS [22]. The aim of the study of Lautenbach et al. was a long-term evaluation of the effect of BS on inflammatory markers. The results of a four-year study involving 163 patients showed that patients with optimal weight loss exhibited a significant decrease in leukocytes, CRP throughout the follow-up period. The most significant decrease in inflammatory state parameters was observed in the first 6 months after surgery. The reduction in inflammation was statistically significantly associated with a decrease in BMI and remission of type 2 diabetes [19]. In the research of Netto et al. the impact of RYGB surgery on pro-inflammatory, prothrombotic parameters and selected metabolic syndrome parameters was assessed. After 6 months from surgery, a statistically significant decrease was observed in PAI-1, CRP, intercellular adhesion molecules 1 (ICAM-1), leptin, resistin and TNF-α. Moreover, a decrease in the leptin/adiponectin ratio was also observed. Levels of anti-inflammatory IL-10 and adiponectin were elevated [23]. In addition, the ratio of adiponectin to leptin can be considered as a better parameter of inflammation than adipokines alone, since this ratio is characterized by high sensitivity and specificity for metabolic parameters, regardless of BMI values [24]. In the studies of Sachan et al. the profile of inflammatory adipocytokines: IL-6, IL-8, CRP, TNF-α and adiponectin and resistin in blood serum was evaluated. The tests were performed first immediately after BS (on the day of discharge from the hospital) and then 6 months after surgery. Postoperative evaluation of serum cytokines showed a significant reduction in serum TNF-α concentrations while lowering IL-8 levels. On the other hand, an increase in CRP and IL-6 was found. CRP is an acute phase protein, so its concentration in the immediate postoperative period may have been higher. After 6 months, the levels of CRP, MCP-1, IL-8 decreased, while the level of adiponectin increased significantly compared to its initial level. The study noted that IL-6 levels began to increase in the immediate postoperative period, while TNF-α levels decreased. Over time after surgery and during follow-up evaluation at 6 months, TNF-α showed an upward trend with an accompanying increase in IL-6 levels. The authors of the study point out that the interaction of cytokines can be much more complex [25]. In a meta-analysis of 116 studies examining the impact of bariatric surgery on the levels of IL-6, TNF-α, and CRP in blood serum, a statistically significant reduction in their concentrations was observed [18]. Also, studies conducted on a group of 126 LSG patients showed a statistically significant decrease in serum concentration of IL-1β, IL-6 and IFNγ during the 12-month observation period [26]. The results obtained by Carmona-Maurici et al. in a study of 62 OAGB patients reported a significant decrease in hs-CRP and IL-6 levels within 12 months after surgery. In terms of postoperative adipocytokine changes, serum adiponectin levels increased significantly, while leptin and resistin levels decreased. However, no significant changes were observed in the serum concentrations of IL-8 and TNF-α 12 months after surgery [27]. The study conducted by Schmatz et al. focused on inflammatory markers and oxidative stress markers in patients after RYGB surgery. The study demonstrated a significant decrease in the concentration of lipid peroxidation products, carbonyl groups of proteins, and non-protein thiol groups (NPSH). Additionally, there was an increase in the activity of superoxide dismutase (SOD) and catalase (CAT). Furthermore, the decrease in resistin levels was accompanied by a reduction in inflammatory markers IL-1, IL-6, and TNF-α, as well as an increase in the anti-inflammatory adiponectin [28].

Conclusions

Low-grade chronic inflammation plays a crucial role in the development of metabolic diseases in individuals with chronic obesity. This condition results from the increased release of pro-inflammatory factors in response to an increased number of adipocytes and immune cells in adipose tissue [29]. Bariatric surgery has been recognized as the most effective long-term treatment for obesity. In addition, long-term studies have proven that it is effective in the treatment of diabetes and cardiovascular diseases [30] An increasing number of studies on the impact of bariatric surgery on the level of inflammatory parameters in the blood prove a reduction in systemic inflammation due to fat loss. Recent studies show a decrease in the level of the following parameters: CRP, IL-1β, IL-6, Il-8, IFNγ, PAI-1, ICAM-1, leptin, resistin, ghrelin and an increase in the concentration of adiponectin, GLP-1 and PYY concentrations. Results may differ slightly, which may be attributed to differences in the type of bariatric surgery, patients' initial body weight, or the duration of observation (19). With the increasing use of bariatric surgery in the treatment of obesity, it is crucial to elucidate the underlying mechanisms responsible for improving the health status of individuals with chronic obesity [4].

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2. Cel pracy

Głównym celem prezentowanej pracy była ocena wpływu operacji bariatrycznej (laparoskopowej rękawowej resekcji żołądka - LSG) na stężenie wybranych cytokin w przebiegu redukcji masy ciała. Badanie koncentruje się na określeniu predyktorów sukcesu metabolicznego we wczesnych (3 miesiące) i późnych (12 miesięcy) okresach pooperacyjnych.

Cele szczegółowe

- Określenie sukcesu metabolicznego po 3 miesiącach od LSG
- Określenie sukcesu metabolicznego po 12 miesiącach od LSG

3. Cykl publikacji będący podstawą rozprawy doktorskiej

3. 1. Lista publikacji

3. 1. 1. Publikacja I

Praca poglądowa: Selected blood parameters with potential diagnostic application in the course of inflammation in chronically obese individuals undergoing bariatric surgery

Autorzy: Marietta Bracha, Małgorzata Szady-Grad

Czasopismo: Long-Term Care Nursing/ Pielęgniarstwo w Opiece Długoterminowej, 2023, 8(2), 39-45

Punktacja: MNiSW: 70 , Impact Factor = 1,63

3. 1. 2. Publikacja II

Praca oryginalna: Elevated Interleukin-6 Is Associated with Successful Weight Loss 3 Months Postlaparoscopic Sleeve Gastrectomy

Autorzy: Marietta Bracha, Alina Jaroch, Adrian Falkowski, Beata Zwierko, Magdalena Szwed, Maciej Michalik, Alina Borkowska, Krzysztof Szwed, Mariusz Kozakiewicz

Czasopismo: Obesity Surgery, 2024, 34(10), 3824-3832.

Punktacja: MNiSW: 100 , Impact Factor = 2,9

3. 1. 3. Publikacja III

Praca poglądowa: Waist circumference is a strong predictor of a positive outcome evaluated one year after sleeve gastrectomy

Autorzy: Marietta Bracha, Alina Jaroch, Jakub Wojtasik

Czasopismo: : Obesity Surgery, 2025, 1-7

Punktacja: MNiSW:100 , Impact Factor = 2,9

3.2.Tekst publikacji II

Obesity Surgery
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ORIGINAL CONTRIBUTIONS

Elevated Interleukin-6 Is Associated with Successful Weight Loss 3 Months Postlaparoscopic Sleeve Gastrectomy

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Abstract

Purpose Bariatric surgery poses an ever-increasing importance in the effective and long-lasting treatment of obesity, a condition strongly associated with inflammation and increased risk of other diseases and health problems. In obesity-related inflammation, maintaining a balance between pro-inflammatory and anti-inflammatory cytokines is crucial. In this study, we examined early effects of laparoscopic sleeve gastrectomy (LSG) on inflammatory and anti-inflammatory cytokines in obese patients, and assessed their effect on postoperative weight loss.

Materials and Methods This prospective cohort study was conducted from September 2022 till June 2023. Fifty obese adults were enrolled for LSG. All patients underwent assessments of body measurements, as well as levels of interleukin-6 (IL-6), interleukin-10 (IL-10), and TNF-alpha at baseline and 3 months postsurgery. We developed a decision tree model to predict the success of weight loss.

Results At 3 months postsurgery, patients lost 18.9 ± 6.9 kg of excess body weight. A significant decrease was observed for IL-10 ($p < 0.0001$), simultaneously with a significant increase in IL-6 ($p < 0.0001$). We found that high IL-6 (> 1.169 pg/mL) levels could contribute to an effective weight loss among patients with a baseline BMI less than 47.46 kg/m^2.

Conclusion Study revealed that 3 months after bariatric surgery, inflammation persists, and its markers significantly influence postoperative weight loss, as indicated by BMI range. Distinct behaviors of IL-10 and IL-6 in relation to obesity underline the necessity of considering individual cytokine profiles when evaluating bariatric surgery outcomes.

Keywords Bariatric surgery · Interleukin-6 · Interleukin-10 · Tumor necrosis factor-α · Body measures

Marietta Bracha and Alina Jaroch contributed equally to this work and share first authorship.

Key Points
1. Low-grade inflammation persists 3 months postbariatric surgery and contributes to ongoing weight loss.
2. Higher preoperative interleukin-6 levels predispose patients to a lower BMI category 3 months after bariatric surgery.
3. IL-6 could serve as a useful preoperative marker for predicting weight loss outcomes.

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Introduction

Overweight and obesity are still a pressing global health problem, despite numerous programs and strategies aiming to ease this epidemic. The number of people affected by excess body weight is growing dramatically, and this tendency shows no signs of slowing down [1]. As diet and physical activity become insufficient in obtaining

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and maintaining weight loss, new strategies are being employed, such as bariatric surgery.

Eligibility criteria for bariatric surgery include BMI greater or equal to 35 kg/m^2, and even BMI indicating first-degree obesity (30–34.9 kg/m^2) with comorbidities such as type 2 diabetes, hypertension, obstructive sleep apnea, and dyslipidemia. Laparoscopic sleeve gastrectomy (LSG) is one of the most common types of surgery, well-recognized for its very low risk of complications and proven long-term efficaciousness [2]. A 10-year follow-up revealed a good and sustainable weight loss measured as a percentage of excess body weight loss (%EBWL), remission of type 2 diabetes, dyslipidemia, obstructive sleep apnea, and lower prevalence of Barrett's esophagus [3]. These beneficial changes resulting from bariatric surgery are associated with strong metabolic change, especially changes in inflammatory biomarkers but also an unpredictability of the inflammation outcomes [4].

Obesity is associated with a chronic inflammatory process of low intensity, defined as metabolic inflammation or "metainflammation" that affects important metabolic tissues such as adipose tissue, liver, skeletal muscle, pancreas, intestines, and hypothalamus [5]. An increased mass of adipose tissue may activate the immune process in the white adipose tissue (WAT), liver, and immune cells [6]. Adipocytes directly release cytokines, but in addition, the immune cells that take up residence in the adipose tissue independently secrete cytokines [7]. Among the most well-studied cytokines concerning obesity are the inflammatory cytokines such as TNF-α (tumor necrosis factor alpha), interleukin-6 (IL-6), and the anti-inflammatory cytokine IL-10 [7].

Considering the link between obesity and inflammation, we aimed to examine the early effects of bariatric surgery (laparoscopic sleeve gastrectomy) on inflammatory and anti-inflammatory cytokines (TNF-α, IL-6, IL-10). We hypothesized that low-grade inflammation is present 3 months after bariatric surgery, and that inflammation marker concentrations have a significant impact on postoperative weight loss.

Materials and Methods

Study Participants

This prospective cohort study was conducted from September 2022 till June 2023, according to the guidelines laid down in the Declaration of Helsinki. Study was approved by the local Bioethics Committee. Study participants were adults (age ≥ 18 years old) scheduled for a standard laparoscopic sleeve gastrectomy. Participants were recruited prospectively and consecutively from the bariatric surgical clinic. Written informed consent was obtained from all patients. Exclusion criteria were severe untreated diseases (e.g., psychiatric disorders, addiction to alcohol or drugs, cancer, acute inflammatory diseases) and use of any pharmacological management of obesity, not comorbidities. Measurements were taken 1 week before laparoscopic sleeve gastrectomy and at follow-up 3 months after surgery. All biochemical and anthropometric measurements were taken at both time points.

Blood Biochemical Analysis

Blood was collected from subjects after 12 h of fasting via the ulnar vein into 6 mL tubes containing EDTA. Within 1 h postcollection, the blood samples were centrifuged for 15 min at 1500 rpm and 4 °C. Subsequently, the plasma was aliquoted into 400-μL portions and transferred into Eppendorf tubes, then stored at − 80 °C until further analysis. Plasma levels of high-sensitivity IL-10 (hsIL-10), high-sensitivity IL-6 (hsIL-6), and high-sensitivity TNF-α (hsTNF-α) were determined using specific enzyme-linked immunosorbent assay (ELISA) kits supplied by Cloud-Clone Corp. (Katy, TX, USA), adhering strictly to the manufacturer's guidelines. The intra- and inter-assay variabilities were maintained within ± 10/12% for hsIL-10, ± 10/12% for hsIL-6, and ± 10/12% for hsTNF-α with detection sensitivities of less than 0.61 pg/mL, 0.31 pg/mL, and 0.55 pg/mL, respectively. Absorbance readings were taken at a wavelength of 450 nm using a SPECTROstar Nano Microplate Reader (BMG LABTECH, Ortenberg, Germany).

Anthropometric Measurements

Anthropometric measurements were made in accordance with the principles of nutritional assessment [8, 9]. A total of twenty measurements were obtained: ideal body weight (IBW), typical weight, current weight, height, BMI, overweight (kg), overweight loss (kg), %EBWL, waist, hips waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), body adiposity index (BAI %), body fat (BF%), body fat (BF, kg), resting energy expenditure (REE, kcal), skeletal muscle mass (SMM, kg), skeletal muscle index (SMI, kg/m^2), fat-free mass (FFM, kg), total body water (TBW, kg). Height was measured with a portable height measure stadiometer (Seca 213). Weight and parameters assessing body composition—body fat (BF), fat-free mass (FFM), skeletal muscle mass (SMM), and skeletal muscle index (SMI)—were measured using the segmental body composition analyzer InBody 570.

Body circumferences—waist and hips—were measured using anthropometric tape with a millimeter scale SECA 201. Measured circumferences allowed to calculate WHR and WHtR. BMI was calculated according to the World Health Organization (WHO) formula. EBWL% was calculated using preoperative weight, weight at follow-up and IBW calculated from Broca's formula.

Statistical Analysis

Statistical analyses included parametric and non-parametric tests. The normality of the distribution of the analyzed variable was assessed using the Shapiro–Wilk test. The significance of differences between anthropometric and biochemical variables was calculated using the Student's *t*-test for paired samples or its non-parametric alternative, the Wilcoxon signed-rank test. Normally distributed continuous variables are described as the mean ± standard deviation (SD), while variables non-normally distributed are expressed as medians (interquartile ranges). Values of body measures were assessed 3 months after surgery in accordance with interleukin concentrations. Based on the calculation of interleukin-6 and interleukin-10 median concentrations, patients were divided into 3 groups: low, medium, and high concentration. The significance of differences was measured using a one-way ANOVA or non-parametric Kruskal–Wallis one-way analysis of variance. After one-way ANOVA, Tukey's test was used for post hoc analysis. This statistical analysis was performed using STATISTICA 13.3 (version 13.3, StatSoft, Palo Alto, USA).

Next, out of 20 body measures examined, we selected ten continuous variables and added three variables for cytokine concentrations to predict changes in BMI category during the initial 3 months following surgery. As previously, the normal distribution of the data was investigated using Shapiro–Wilk tests. To compare continuous variables between patients who experienced a decrease in BMI category 3 months after surgery (termed "BMI responder") and those who did not ("BMI non-responder"), we used the independent *t*-test for variables with normal distribution and the Mann–Whitney test for variables without normal distribution.

A decision tree model was developed to predict BMI category change ("responder" or "non-responder"), based on all 13 potential predictors (measured at baseline): weight (kg), BMI (kg/m^2), overweight (kg), waist circumference (cm), WHR, WHtR, BF%, BF (kg), SMI (kg/m^2), SMM (kg), TNF-alpha (pg/mL), IL-10 (pg/mL), IL-6 (pg/mL). The model was tested through leave-one-out cross-validation. In brief, given a dataset with n observations, this technique partitions the data into two subsets for each iteration of the model evaluation process. Specifically, for each iteration, one observation is designated as the test set, while the remaining $n-1$ observations form the training set. The model is subsequently trained on these $n-1$ observations and then tested on the single reserved observation. This procedure is iterated n times, ensuring each of the n observations serves as the test set exactly once. After each iteration, the prediction error for the solitary observation used as the test set is documented. The overall prediction error is then calculated as the mean of the errors from the n models constructed during the cross-validation process.

The decision tree algorithm was used with a Gini impurity measure, a maximum tree depth of 3, a minimum of 2 cases in parent nodes, and at least 1 case in child nodes. To prevent overfitting, the algorithm underwent cost-complexity pruning with the parameter alpha set to 0.01. The statistical and machine learning methodology used in this study are comprehensively explained in [10].

The model's performance was rated using well-established metrics such as accuracy, recall, precision, F1, and the area under the receiver operating characteristic curve (AUC) and the corresponding *p*-value calculated using the Mann–Whitney U test. These performance indicators were calculated as follows:

- Accuracy = (TP + TN) / (TP + FP + FN + TN).
- Recall = TP / (TP + FN).
- Precision = TP / (TP + FP).
- F1 Score = 2 / ((1 / recall) + (1 / precision)).

Here, TP represents the count of true positives, TN denotes true negatives, FP is the false positives, and FN indicates false negatives. The development and analysis of prediction models were conducted with a custom Python script, incorporating the sklearn and SciPy libraries.

Results

Fifty-four patients scheduled for sleeve gastrectomy were assessed for eligibility 1 week before surgery. Among them, four met the exclusion criteria, and eight chose not to participate in the study. Of the 42 participants enrolled, two declined to take part in the follow-up due to non-medical reasons. Consequently, 40 of them had biochemical profiling performed (mean age 41.6 ± 11.4 years old, 30 women) (Table 1).

All anthropometric and biochemical parameters, except for TNF-α, differed significantly 3 months after bariatric surgery (Table 1). Patients lost on average 18.9 ± 6.9 kg of excess body weight (%EBWL 37.6 ± 15.5%), and their BMI values began to indicate second-degree obesity (35.68 kg/m^2). A significant decrease was observed for anti-inflammatory interleukin-10 concentration, simultaneously with a significant increase in pro-inflammatory interleukin-6.

Interleukin concentrations were compared with anthropometric measurements (BMI, overweight, overweight loss,

Table 1 Anthropometric and biochemical characteristics

	Baseline	Follow-up	p
Weight, kg	123.3 ± 27.1	104.3 ± 23.7	< 0.0001
BMI, kg/m²*	41.52 (35.50–50.80)	35.68 (29.50–41.34)	< 0.0001
Overweight, kg*	52.6 (34.5–75.0)	32.5 (19.8–49.6)	< 0.0001
Waist, cm	122.1 ± 16.2	106.7 ± 15.8	< 0.0001
Hips, cm	133.7 ± 17.0	122.3 ± 16.9	< 0.0001
WHR	0.92 ± 0.09	0.88 ± 0.10	< 0.0001
WHtR	0.72 ± 0.096	0.63 ± 0.097	< 0.0001
BF, kg	60.7 ± 19.4	45.8 ± 18.2	< 0.0001
SMM, kg	35.1 ± 6.9	32.2 ± 6.1	< 0.0001
SMI, kg/m²*	8.9 (8.2–10.3)	8.5 (7.4–9.7)	< 0.0001
IL-10, pg/mL*	0.478 (0.220–2.255)	0.051 (0.036–0.057)	< 0.0001
IL-6, pg/mL*	1.144 (0.986–1.345)	5.201 (3.534–8.295)	< 0.0001
TNF-α, pg/mL*	2.267 (2.187–2.400)	2.290 (2.185–2.345)	0.7063

BMI Body Mass Index, *WHR* waist-to-hip ratio, *WHtR* waist-to-height ratio, *BF* body fat, *SMM* skeletal muscle mass, *SMI* skeletal muscle index, *TNF-α* tumor necrosis factor alpha, *IL-10* interleukin-10, *IL-6* interleukin-6

*Median and interquartile values shown as data did not have a normal distribution

waist, hips, WHR, WHtR, body fat, SMM, SMI) at follow-up. For this comparison, IL-10 and IL-6 follow-up concentrations were sorted into three groups: low, medium, and high concentration (Table 2).

Analyzing IL-10 follow-up concentrations' significant differences were found for waist circumference ($p = 0.0389$) and WHR ($p = 0.0199$). Further post hoc analysis showed no significant difference for waist, while WHR value differed significantly between groups with low and moderate IL-10 concentration ($p = 0.0343$). It was noticeable in box plot analysis that low and high IL-10 concentrations were associated with lower values of anthropometric parameters, whereas the relationship between IL-6 follow-up concentrations and anthropometric values was linear—with increasing IL-6 values of anthropometric parameters also increased (Fig. 1).

Further analysis was aimed at investigating whether there is a parameter or group of parameters which would be predictive of a substantial decline in body weight. Thus, continuous variables were compared between patients who experienced a decrease in BMI threshold (e.g., from second-degree obesity to first-degree) 3 months after surgery (termed "BMI responder") and those who did not ("BMI non-responder"). A decision tree model was developed to predict a decrease in BMI threshold, based on finally ten potential predictors at baseline values, and a significant difference was found for several variables (Table 3).

In the leave-one-out cross-validation procedure, the decision tree model achieved an AUC of 81%, with a p-value < 0.001. The confusion matrix showed that the model correctly classified change status in 25 out of 27 participants in the BMI responder group and 9 out of 13 participants in the BMI non-responder group (Fig. 2). This resulted in an accuracy of 85%, a recall of 93%, a precision of 86%, and an F1 score of 89%.

The decision tree was created to investigate predictors of BMI change 3 months postsurgery. It showed that participants with a baseline BMI of at least 47.46 kg/m² had a minimal chance of changing their BMI category, with only 1 out of 12 achieving this. A low IL-10 baseline level (less than or equal to 0.209 pg/mL) could assist in this scenario. On the contrary, participants with a baseline BMI less than 47.46 kg/m² had a significant chance of changing their BMI. However, low IL-6 baseline levels (less than or equal to 1.169 pg/mL) could be a risk factor for not achieving weight loss 3 months after surgery (Fig. 3).

Conclusion

In this study, we have demonstrated that 3 months after bariatric surgery the level of anti-inflammatory IL-10 significantly decreased, while pro-inflammatory IL-6 was significantly higher. This pro-inflammatory effect is a result of weight loss, especially among patients with a BMI < 47.46 kg/m² at baseline. Moreover, we found that patients with a baseline BMI ≥ 47.46 kg/m² were considerably less prone to lose body weight in terms of changing their BMI category.

Significant postoperative change in interleukin-10 levels coupled with an increase in interleukin-6, and suggests an exacerbation of the inflammatory state, particularly with an observed increase in TNF-alpha, although not statistically significant. This finding aligns with other studies

Table 2 IL-10 and IL-6 concentrations grouping (follow-up measurements)

	Follow-up median concentration	Min–max
IL-10, pg/mL	0.051 (0.036–0.057)	
1 low (*n* = 16)	0.031 (0.029–0.040)	0.025–0.040
2 medium (*n* = 19)	0.053 (0.051–0.058)	0.046–0.066
3 high (*n* = 5)	0.100 (0.100–0.103)	0.096–0.113
IL-6, pg/mL	5.200 (3.534–8.295)	
1 low (*n* = 12)	2.971 (2.305–3.408)	1.608–3.818
2 medium (*n* = 17)	5.202 (4.574–6.039)	4.137–7.611
3 high (*n* = 11)	15.159 (8.374–50.720)	8.220–63.653

n number of patients

indicating that while IL-6 and TNF-alpha are closely linked to inflammation, their changes may not always correlate with statistical significance in clinical outcomes [6]. It is widely known that chronic inflammation is inextricably linked with adipose tissue hypertrophy. This process is expressed through an increase in pro-inflammatory TNF-alpha and IL-6 concentrations, simultaneously with an IL-10 decrease reflecting an impaired regulatory mechanism against inflammation [11]. In the presented study, patients experienced a significant, rapid weight loss; at only 3 months after surgery, they had already lost a mean of almost 19 kg, equating to 37.6% loss of excess body weight. In line with other authors, body circumferences (waist, hips) and body composition compartments (BF, SMM) also significantly decreased [12]. Inflammatory factors (IL-6, TNF-α, CRP) are hypothesized to decrease after bariatric surgeries, but typically studies focus on follow-up measurements made at six or 12 months after bariatric surgery [6]. In our study, we decided to examine our patients early on postsurgery, and discovered that IL-6 follow-up concentration was significantly higher than baseline. This may be explained by the fact that postsurgical recovery and/or weight loss can induce an increase in free fatty acid release, which triggers inflammation [13, 14]. Many studies showed that bariatric surgery reduces circulating levels of pro-inflammatory marker IL-6, but not typically before 6 months [15–19].

Our study showed a non-significant increase ($p = 0.7063$) in TNF-alpha serum level 3 months after bariatric surgery, and this outcome is in line with the findings of other researchers [20–22]. Kelly et al. reported a slight reduction in TNF-α in the long-term observation, while for short-term results TNF-α level was increased; in either case, no statistically significant difference was found [23]. This pattern could be attributed to the multifaceted roles of TNF-alpha in inflammation and its regulation, which may not always

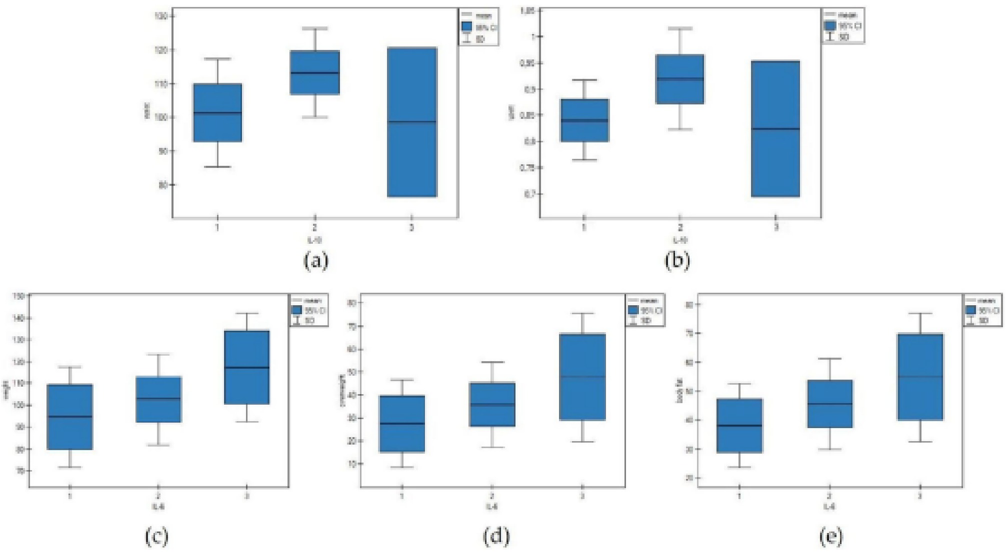


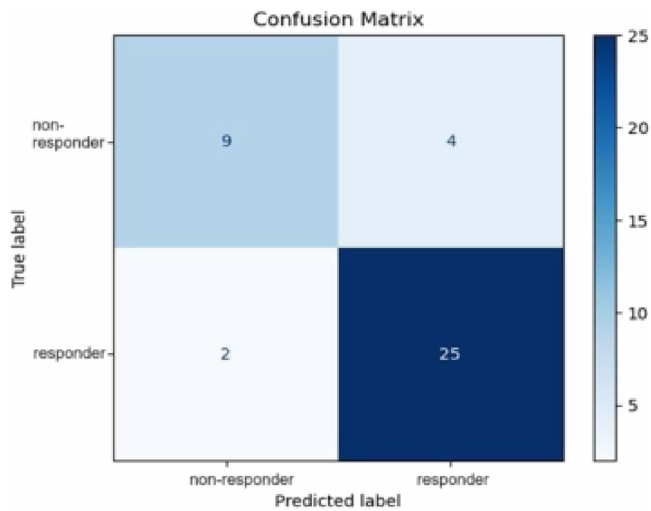
Fig. 1 Box plots for IL-10 and IL-6 concentrations (pg/mL) (1, low concentration; 2, moderate concentration; 3, high concentration) and anthropometric parameters: **a** IL-10 and waist circumference (cm); **b** IL-10 and waist-to-hip ratio (WHR); **c** IL-6 and weight (kg); **d** IL-6 and overweight (kg); **e** IL-6 and body fat (kg)

Table 3 Differences in examined parameters according to a decrease in BMI threshold

	BMI responder Shapiro–Wilk; *p*	BMI non-responder Shapiro–Wilk; *p*	*t*-test; *p*	Mann–Whitney *U* test; *p*
Weight (kg)	0.135	0.135	< 0.0001	< 0.0001
BMI (kg/m^2)	0.247	0.247	< 0.0001	< 0.0001
Overweight (kg)	0.483	0.483	< 0.0001	< 0.0001
Waist (cm)	0.073	0.073	< 0.0001	< 0.0001
WHR	0.405	0.405	0.937	0.817
WHtR	0.446	0.446	< 0.0001	< 0.0001
BF (%)	0.001	0.001	< 0.0001	< 0.0001
TNF-α (pg/mL)	< 0.0001	< 0.0001	0.581	0.225
IL-10 (pg/mL)	< 0.0001	< 0.0001	0.616	1
IL-6 (pg/mL)	0.611	0.611	0.304	0.299

BMI Body Mass Index, *WHR* waist-to-hip ratio, *WHtR* waist-to-height ratio, *BF* body fat, *TNF-α* tumor necrosis factor alpha, *IL-10* interleukin-10, *IL-6* interleukin-6

Fig. 2 Confusion matrix for BMI prediction



be directly measurable in short-term or small-scale studies. Additional insights from Lira et al. suggest that reductions in visceral fat significantly correlate with decreases in pro-inflammatory markers like IL-6 and TNF-alpha, indicating that changes in body composition can influence cytokine profiles, which may explain variations in TNF-alpha significance across studies [24]. According to a meta-analysis, at least 12 months are required before a consistent decrease in TNF-α is noticed [25].

After grouping IL-6 follow-up levels into three concentrations (low, medium, high), we found that with rising IL-6 concentrations, the values of anthropometric measurements (body weight, overweight, and body fat mass) also increased 3 months after LSG; however, these results were not statistically significant. Adipose tissue is an important endocrine organ secreting several inflammatory markers, and a number of adipokines, such as adiponectin, leptin, and resistin. In the state of obesity, the pro-inflammatory adipokines derived from adipose tissue are overexpressed, and among which, increased production and secretion of inflammatory mediator IL-6 is marked [26]. Further, these inflammatory markers stimulate oxidative stress and cause inflammation [27]. The lack of significant differences between IL-6 follow-up levels and anthropometric parameters might indicate that while IL-6 is elevated in obese states, it may not directly correlate with changes in body dimensions over short-term interventions. This is supported by the broader literature which suggests that IL-6 levels are more reflective

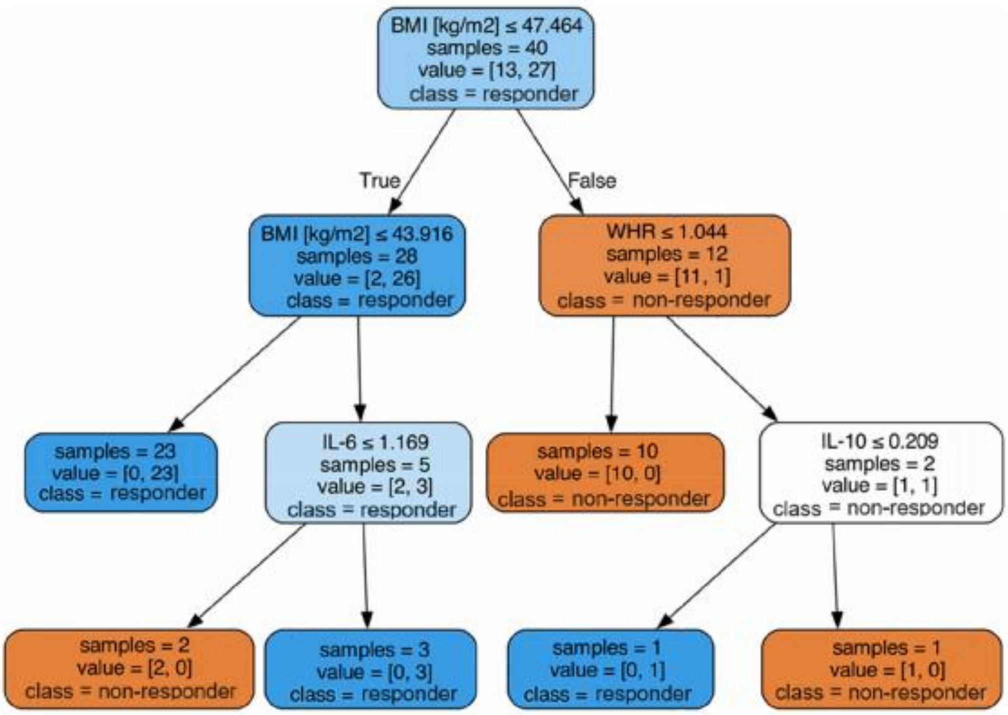


Fig. 3 Decision tree

of acute inflammatory responses rather than changes in adiposity [28].

The same grouping was performed for IL-10 follow-up concentrations. IL-10 is a major anti-inflammatory and immunoregulatory cytokine that inhibits inflammatory, and cell-mediated immune responses [29]. Significant differences were observed in the levels of IL-10 and anthropometric measurements such as waist circumference and WHR at follow-up time point. It can be generalized that with increasing IL-10 concentrations, body measures also increased. We observed that in the group with high IL-10 concentration, anthropometric parameters decreased; however, there were only five patients in this group. This finding aligns with previous research showing that IL-10, an anti-inflammatory cytokine, has a complex interplay with metabolic factors in obese populations. For example, Esposito et al. noted that low baseline IL-10 levels correlate with obesity and metabolic syndrome, suggesting that improving IL-10 levels could ameliorate some metabolic disturbances in obesity [30].

Regarding the impact of high BMI and cytokine levels such as IL-10 and IL-6 on weight loss effectiveness is rooted in a deep understanding of their roles in weight regulation and inflammatory response within the body. High BMI often poses significant challenges in achieving substantial and lasting weight reduction through conventional weight loss methods, such as diet and exercise, due to complex metabolic and psychological barriers [31]. IL-10, an anti-inflammatory cytokine, plays a protective role against chronic inflammation associated with obesity. Lower levels of IL-10 may contribute to persistent inflammation, complicating weight loss efforts. Research shows that patients with lower IL-10 levels experience higher inflammation, negatively impacting weight loss [32]. IL-6, on the other hand, has both pro-inflammatory and anti-inflammatory effects, depending on the context.

This study presents potential limitations. Firstly, the inflammation panel included interleukins and TNF-alpha but did not measure C-reactive protein (CRP). We opted to concentrate on the role of cytokines in the inflammatory response following bariatric surgery. Given that IL-6 significantly influences the hepatocytic secretion of acute-phase proteins, including CRP, we can reasonably infer that CRP levels would also be elevated. We decided to use a decrease in BMI category within the decision tree model because of the very limited literature on a specific %EBWL threshold that a patient should achieve as early as 3 months postbariatric surgery. Each BMI category encompasses a specific range, and transitioning to a different BMI category is more feasible when the initial BMI is near the threshold of that range. However, the first 3 months following surgery typically coincide with a significant reduction in body mass, thereby facilitating the shift to a different BMI category. Another limitation is the relatively small sample size, which was constrained by the exclusion criteria, number of surgeries scheduled, and focusing on assessing inflammation associated with a single type of bariatric surgery procedure. Lastly, as previously stated, there were only five patients in the group with high IL-10 follow-up levels. This unique group, categorized according to IL-10 levels, cannot be subdivided differently; a larger sample size is necessary to ensure a more balanced patient distribution.

Our study revealed that 3 months after bariatric surgery, inflammation persists, and its markers significantly influence postoperative weight loss, as indicated by BMI range. Interactions among cytokines within inflammatory pathways are complex, especially in obesity-related inflammation, where maintaining a balance between pro-inflammatory and anti-inflammatory cytokines is crucial. The distinct behaviors of IL-10 and IL-6 in relation to obesity underline the necessity of considering individual cytokine profiles when evaluating inflammation and obesity interventions. It highlights the potential for targeted therapies that specifically modulate cytokine activity to improve obesity-related outcomes. Such insights are crucial for developing more effective treatments for obesity, which address both metabolic and inflammatory components of the disease.

Data Availability Data available in the Research Data Repository of Nicolaus Copernicus University in Toruń, Collegium Medicum in Bydgoszcz, Poland.

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare no competing interests.

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3.3. Tekst publikacji III

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RESEARCH

Waist Circumference Is a Strong Predictor of a Positive Outcome Evaluated One Year After Sleeve Gastrectomy

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Abstract

Background Bariatric surgeries, such as laparoscopic sleeve gastrectomy (LSG), not only result in significant weight loss but also improve the inflammatory state in obese patients. This study aimed to investigate the effects of LSG on weight loss and inflammation status in bariatric patients 1-year post-procedure.
Methods This prospective cohort study was conducted from September 2022 to May 2024. Fifty obese adults were enrolled for LSG. All patients underwent assessments of body measurements, as well as levels of interleukin-6 (IL-6) and interleukin-10 (IL-10) at baseline, and then at 3 and 12 months post-surgery.
Results Twelve months post-surgery, body measurements showed a significant reduction, with a median excess weight loss (%EWL) of 56.8%, indicating the clinical success of the bariatric procedure. %EWL showed a strong correlation with waist circumference ($R = -0.738$, $p < 0.00001$). A logistic regression model indicated that a reduction of just 1 cm in initial waist circumference increases the likelihood of a positive outcome in laparoscopic sleeve gastrectomy by 12%. Moreover, a significant increase was observed for IL-10 ($p < 0.0001$), simultaneously with a significant decrease in IL-6 ($p < 0.0001$).
Conclusions This study provides valuable evidence supporting the benefits of laparoscopic sleeve gastrectomy for both weight loss and reducing inflammation. Waist circumference emerged as a strong predictor of metabolic success 1-year post-surgery, while increased IL-10 levels signaled positive immunological changes.

Keywords Bariatric surgery · Interleukin-6 · Interleukin-10 · Tumor necrosis factor-α · Body measures

Key Points:
1. A significant increase in IL-10 levels, accompanied by a significant decrease in IL-6, was observed 1 year after surgery.
2. Patients with higher IL-10 concentrations 1 year post-surgery showed greater reductions in waist circumference.
3. IL-10 levels and waist circumference could offer valuable insights into the long-term effectiveness of bariatric surgery.

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Introduction

Obesity stands as some of the most prevalent health challenges of our time [1, 2]. It is associated with low-grade chronic inflammation, which can lead to tissue damage, impaired metabolic function, and the production of oxidative stress [3–5]. This type of inflammation differs from typical inflammation by lacking the usual visible signs, yet it shares similar disruptions caused by common inflammatory mediators and signaling pathways. Recent studies suggest a link between obesity and inflammation, as an increase in adipose tissue mass may activate immune processes in white adipose tissue (WAT), the liver, and immune cells [6, 7].

Low-grade chronic inflammation is driven by immune cell infiltration into adipose tissue, resulting in an increased production of inflammatory cytokines such as interleukin-6 (IL-6) and interleukin-10 (IL-10) [8]. IL-6 is a key cytokine associated with inflammation and is directly linked to insulin resistance and an increased risk of cardiovascular diseases (CVDs) [1, 5]. Interleukin-10 is

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known as an anti-inflammatory cytokine with a wide range of immunomodulatory functions during inflammation, playing a crucial role particularly in the resolution phase [9]. IL-10 has been associated with several inflammatory diseases, such as inflammatory bowel disease, atherosclerosis, as well as metabolic syndrome and type 2 diabetes [10–13]. Additionally, the IL-10 production is decreased in morbidly obese individuals [14].

Bariatric and metabolic surgery (BS) improves medical conditions related to severe obesity and metabolic syndrome (MetS), with surgically induced weight loss known to enhance inflammatory status [15]. Bariatric surgery is now one of the most recommended and effective long-term treatment options for obesity and its related comorbidities, especially when primary lifestyle modifications fail. This surgery is particularly effective in addressing weight-related comorbidities and has received excellent promotion worldwide [16–18].

Weight loss is a common metric for assessing post-operative success, with various indices calculated based on changes in patients' weight. The percentage of excess weight loss (%EWL) is a commonly used metric, calculated using preoperative weight, postoperative weight, and ideal body weight (IBW) [19]. Bariatric surgery success is typically defined as achieving at least 50% excess weight loss; however, accurately and consistently defining preoperative weight and ideal body weight presents challenges. The use of additional metrics, such as percentage total weight loss (%TWL) and percentage excess BMI loss (%EBMIL), is becoming more common, and employing multiple metrics to define postsurgical success is necessary to reliably assess a patient's progress [20].

Waist circumference (WC) is a simple, easily standardized method to assess abdominal adiposity, strongly associated with obesity-related health risks, especially cardiovascular diseases. Reducing waist circumference can help reverse these risks [21], and indications are that it should even be considered a more important parameter than weight loss [22]. In clinical evaluations, WC should be measured alongside body mass index (BMI) to accurately assess cardiovascular risk [23]. Wider waist was one of the risk factors of prolonged type 2 diabetes remission after metabolic surgery [24]; therefore, it is worth considering its significance for bariatric postsurgical success.

In the present study, we aimed to investigate the effect of laparoscopic sleeve gastrectomy on weight loss and inflammation status of bariatric patients 1 year after the procedure. We hypothesized that 1 year after bariatric surgery, levels of cytokines would indicate a lack of inflammation and that these immune factors would influence the extent of weight loss. Moreover, we assumed that waist circumference may serve as an important anthropometric measurement contributing significantly to postoperative success, as defined by weight loss.

Materials and Methods

Study Participants

This prospective cohort study was conducted from September 2022 to May 2024, according to the guidelines laid down in the Declaration of Helsinki. The study was approved by the local Bioethics Committee, and written informed consent was obtained from all patients. The participants of the study group were described in a separate manuscript that summarized results obtained 3 months after LSG [25]. Briefly, enrolled bariatric patients were adults (age $\geq$ 18) with no severe untreated diseases and not undergoing pharmacological management for obesity who were awaiting laparoscopic sleeve gastrectomy. All anthropometric and biochemical measurements were taken 1 week before the procedure and then at 3 and 12 months after.

Blood Biochemical Analysis

Blood was collected from subjects after 12 h of fasting via the ulnar vein into 6 mL tubes containing EDTA. Within 1 h post-collection, the blood samples were centrifuged for 15 min at 1500 rpm and 4 °C. Subsequently, the plasma was aliquoted into 400-μL portions and transferred into Eppendorf tubes, then stored at − 80 °C until further analysis. Plasma levels of high-sensitivity IL-10 (hsIL-10) and high-sensitivity IL-6 (hsIL-6) were determined using specific enzyme-linked immunosorbent assay (ELISA) kits supplied by Cloud-Clone Corp. (Katy, TX, USA), adhering strictly to the manufacturer's guidelines. The intra- and inter-assay variabilities were maintained within ± 10/12% for hsIL-10 and ± 10/12% for hsIL-6 with detection sensitivities of less than 0.61 pg/mL and 0.31 pg/mL, respectively. Absorbance readings were taken at a wavelength of 450 nm using a SPECTROstar Nano Microplate Reader (BMG LABTECH, Ortenberg, Germany).

Anthropometric Measurements

Anthropometric measurements were made in accordance with the principles of nutritional assessment [26]. Height was measured with a portable height measure stadiometer (Seca 213). Weight and parameters assessing body composition — body fat (BF) and skeletal muscle mass (SMM) — were measured using segmental body composition analyzers — InBody 570 at baseline and after 3 months and Tanita MC780 MA after 12 months. Body circumferences, waist and hips, were measured using anthropometric tape with a millimeter scale SECA 201. Measured circumferences allowed to calculate WHR and WHtR indexes. BMI was calculated according to the World Health Organization (WHO) formula.

The 1-year postoperative %EWL was calculated in accordance with other authors: (weight at baseline − weight at 12 months follow-up) / (weight at baseline − ideal body weight) × 100. Ideal body weight (IBW) was calculated from Broca's formula (height − 100) depending on the participant's gender (female: subtract 10% of the calculated value, male: subtract 5%) [27].

Statistical Analysis

Statistical analyses included parametric and non-parametric tests, with statistical significance at $p < 0.05$. The normality of the distribution of the analyzed variables was assessed using the Shapiro–Wilk test. Normally distributed continuous variables are described as the mean ± standard deviation (SD), while variables non normally distributed are expressed as medians (interquartile ranges).

The significance of differences between anthropometric and biochemical variables at three time points was calculated using repeated measures ANOVA. In the absence of sphericity (checked by Mauchley's test), Greenhouse-Gaisser correction was used. In the absence of a normal distribution, the Friedman test was used. When comparing only two time points, a non-parametric Wilcoxon signed-rank test was used.

Values of body measures were assessed 12 months after surgery in accordance with interleukins concentrations. Based on the calculation of interleukin-6 and interleukin-10 median concentrations, patients were divided into three groups: low, medium, high concentration. The significance of differences was measured using a one-way ANOVA or non-parametric Kruskal–Wallis one-way analysis of variance. After one-way ANOVA, Tukey's test was used for post-hoc analysis and Dunn's test after the non-parametric Kruskal–Wallis test. This statistical analysis was performed using STATISTICA 13.3 (version 13.3, StatSoft, Palo Alto, USA).

Subsequently, we aimed to create a model able to predict changes in waist circumference 1 year after laparoscopy sleeve gastrectomy indicating a correct cutoff point of < 88 cm for women and < 102 cm for men [28]. We selected nine continuous variables as predictors (baseline values of weight, BMI, overweight, waist circumference, WHR, skeletal muscle mass, body fat [%], IL-10, IL-6). Spearman correlation ρ was determined for all potential predictors to reduce the number of predictors and select variables with the lowest ρ values leaving waist, waist-to-hip ratio, IL-10, and IL-6 to build a logistic regression model.

The created model showed statistical significance for waist and waist-to-hip ratio. The model was then tested through leave-one-out cross-validation. To reduce the chance that a patient who has reached the correct waist circumference value will be incorrectly assigned to a group not reaching this value, the optimal cutoff point was determined by maximizing the Youden index. Based on this criterium, the threshold for the probability obtained from the classification model was set at level $p = 0.291$ (Mann–Whitney U test). The model's performance was rated using well-established metrics such as accuracy, recall, precision, F1, and the area under the receiver operating characteristic curve (AUC). Analyses were performed using Python programming language (v 3.11.6) with libraries pandas (v. 2.2.2), numpy (v. 1.23.5), statsmodels (v 0.15.0), scikit-learn (v. 1.4.2), scipy (v. 1.13.0), matplotlib (v. 3.9.0), and seaborn (v. 0.13.2).

Results

Fifty-four patients scheduled for sleeve gastrectomy were assessed for eligibility 1 week before surgery. Among them, four met the exclusion criteria, and eight chose not to participate in the study. Of the 42 participants enrolled, two declined to take part in the follow-up due to non-medical reasons. Consequently, 40 of them had biochemical profiling performed (mean age 41.6 ± 11.4 y old, 30 women) (Table 1).

In summary, complete anthropometric data from the final follow-up measurement were obtained from 49 patients (mean age 42.7 ± 11.8 years old, 38 female), 39 of them had biochemical profiling performed.

All measurements presented in Table 1 were significantly different between the groups ($p < 0.0001$). Intergroup differences calculated by post-hoc test were also statistically significant ($p < 0.05$), only IL-6 concentration at baseline and at 12 months follow-up were not significantly different ($p = 0.8989$). Body measures decreased, and the median of excess weight loss was 56.8%, indicating a clinical success of the performed bariatric procedure.

One-year %EWL strongly correlated with waist circumference ($p < 0.00001$, $R = -0.738$). Moreover, waist circumference significantly differed ($p = 0.0352$) depending on the three levels of interleukin 10. Based on the median value, 1-year IL-10 concentration was sorted into three groups: low, medium, and high concentration. The same grouping and analysis were made for IL-6 (Table 2); however, no statistical significance was found when comparing with anthropometric measurements.

For waist circumference and IL-10, a linear trend was evident — lower IL-10 concentrations were corresponding to the smallest waist circumferences (89.96 cm, 100.83 cm, and 104.86 cm, respectively) (Fig. 1).

Table 1 Body measures and cytokines concentration in three-time points

	Baseline	3 months follow-up	12 months follow-up	*p*
Weight, kg	123.2 ± 25.3	104.5 ± 22.5	93.0 ± 19.9	< 0.0001
BMI, kg/m^2*	41.91 (36.29–48.14)	34.84 (30.69–41.38)	31.67 (27.65–36.80)	< 0.0001
Overweight, kg*	53.4 (38.1–72.1)	32.6 (20.4–49.3)	22.5 (10.5–36.5)	< 0.0001
EWL, %*	-	35.4 (25.2–46.5)	56.8 (40.7–70.3)	< 0.0001
Waist, cm	122.0 ± 15.6	107.1 ± 15.7	98.5 ± 15.0	< 0.0001
Hips, cm	134.9 ± 16.3	123.3 ± 16.4	116.5 ± 15.6	< 0.0001
WHR	0.91 ± 0.08	0.87 ± 0.09	0.85 ± 0.08	< 0.0001
WHtR	0.72 ± 0.09	0.63 ± 0.10	0.58 ± 0.09	< 0.0001
BF, %*	50.5 (46.3–53.2)	45.2 (40.7–49.0)	34.7 (28.3–40.7)	< 0.0001
SMM, kg*	33.4 (30.1–39.5)	31.7 (28.1–35.1)	24.8 (23.6–29.1)	< 0.0001
IL-10, pg/mL*	0.520 (0.211–2.511)	0.051 (0.034–0.058)	0.726 (0.275–0.984)	< 0.0001
IL-6, pg/mL*	1.142 (0.972–1.310)	5.202 (3.554–8.371)	0.159 (0.102–0.214)	< 0.0001

*Median and interquartile values shown as data did not have a normal distribution

p-value < 0.05; *BMI* body mass index, *EWL* excess weight loss, *WHR* waist-to-hip ratio, *WHtR* waist to height ratio, *BF* body fat, *SMM* skeletal muscle mass, *IL-10* interleukin 10, IL-6 interleukin 6

Table 2 IL-10 and IL-6 concentrations grouping (1-year follow-up)

	One-year median concentration	Min–max
IL-10, pg/mL	0.726 (0.275–0.984)	
1 low (*n* = 14)	0.204 (0.146–0.312)	0.111–0.370
2 medium (*n* = 18)	0.773 (0.658–0.968)	0.407–0.995
3 high (*n* = 7)	1.237 (1.096–2.298)	1.092–4.172
IL-6, pg/mL	0.159 (0.102–0.214)	
1 low (*n* = 10)	0.079 (0.069–0.088)	0.052–0.102
2 medium (*n* = 18)	0.159 (0.117–0.185)	0.106–0.208
3 high (*n* = 11)	0.254 (0.232–0.287)	0.213–0.354

Subsequent analyses were aimed to demonstrate whether there was a relationship between the positive outcome of LSG 1 year after the procedure and values of anthropometric and biochemical measurements before the procedure. Positive outcome of LSG was determined as reaching specific waist circumference cut-off points made for overweight or obese patients (women < 88 cm, men < 102 cm). A logistic regression model with four independent predictors was built and used to verify this relationship. Assuming that other parameters remain constant, it can be estimated that a reduction of 1 cm in waist circumference during baseline

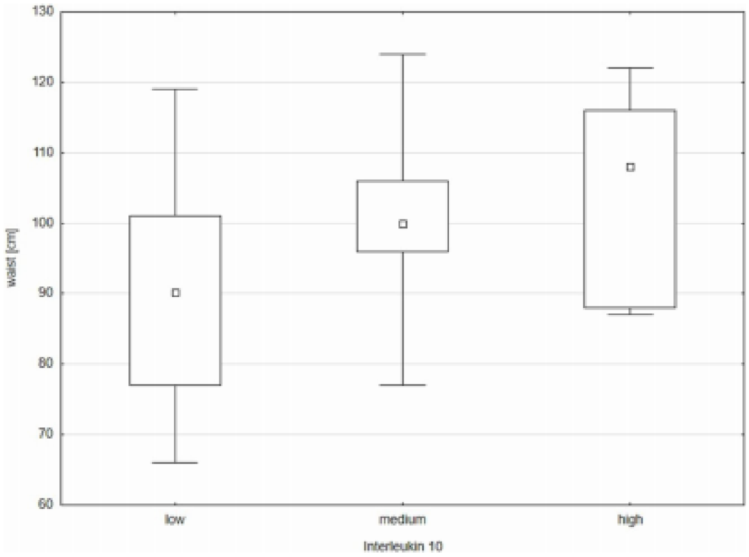

Fig. 1 Box plot for IL-10 grouped into three categories and waist circumference

Table 3 Logistic regression values

	AOR (95% CI)	*p*
Waist, cm	0.888 (0.819; 0.964)	0.0046
WHR	1.142 (1.030; 1,266)	0.0120
IL-10, pg/mL	0.850 (0.518; 1.393)	0.5183
IL-6, pg/mL	4.401 (0.136; 141.995)	0.4031

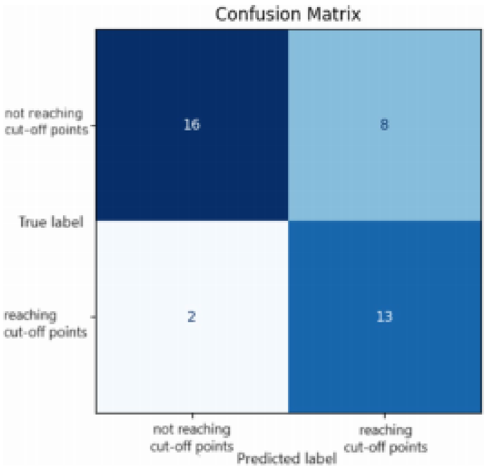

Fig. 2 Confusion matrix for predicting reaching waist circumference cutoff points

measurement increases the chance of LSG-positive outcome after 1 year by 12% (Table 3).

The optimal cutoff point for the generated model was set at $p = 0.291$. The confusion matrix showed that the model correctly classified reaching waist cutoff points for 13 out of 15 participants and predicted not reaching cutoff points for 16 out of 18 participants. Still, some patients were misclassified in not reaching the cutoff group (8 out of 24) (Fig. 2). The created logistic regression model achieved an AUC of 83.9%, an accuracy of 74.4%, a recall of 86.7%, a precision of 61.9%, and an F1 score of 72.2%.

Discussion

In this study, a follow-up of bariatric patients was conducted, with anthropometric and biochemical assessments performed. In contrast to the results observed 3 months after bariatric surgery, a significant increase in IL-10 levels alongside with a significant decrease in IL-6 was noted 1 year post-surgery. A logistic regression model indicated that a reduction of just one centimeter in initial waist circumference increases the likelihood of a positive outcome in laparoscopic sleeve gastrectomy by 12%.

Bariatric surgeries, such as laparoscopic sleeve gastrectomy (LSG), not only result in significant weight loss but also improve the inflammatory state in obese patients. Recarte et al. demonstrated that bariatric surgery reduces inflammation, as indicated by lower levels of pro-inflammatory cytokines like IL-6 [15]. In another 1-year analysis following metabolic surgery, there was a significant decrease in levels of IL-6, particularly in the context of weight loss and improved inflammation, along with reductions in other markers like C-reactive protein (CRP) and insulin resistance [29]. However, in another study, 1 year post gastric banding IL-6 levels did not change [30]. Viana et al. demonstrated that bariatric surgery, including both Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy, significantly lowers patients' serum IL-6 levels [31]. Salman et al. indicate that bariatric surgery significantly reduces IL-6 levels, potentially protecting obese patients from obesity-related comorbidities [32]. In another prospective study, IL-6 concentration was significantly reduced 6 months after BS [33]. In addition, meta-analysis that included up to 116 studies also concluded that BS can reduce IL-6 serum levels, particularly 1 year after the procedure [34]. Furthermore, the authors highlighted that BS can significantly reduce inflammatory markers such as TNF-α and CRP, which is crucial for improving metabolic health.

Waist circumference is a well-established predictor of metabolic risk. According to the World Health Organization (WHO), a waist circumference above 88 cm in women and 102 cm in men is associated with a higher risk of metabolic disorders, such as type 2 diabetes and cardiovascular diseases (WHO, 2011). In this study, patients who achieved waist circumference values below these thresholds 1 year after surgery showed better health outcomes. Furthermore, reducing waist circumference by 1 cm during the initial measurement increased the likelihood of a positive postoperative outcome by 12%, highlighting the clinical value of monitoring this parameter [1]. A decrease in baseline waist circumference emphasizes waist circumference as a key metric for assessing bariatric surgery success. The logistic regression model indicated that %EWL was insignificant for predicting the success of bariatric surgery. These findings align with other literature suggesting that waist circumference, as an indicator of central obesity, may better reflect metabolic risk and outcomes compared to BMI alone [23]. A noteworthy finding in the present study is the correlation between IL-10 levels and waist circumference. Patients with higher IL-10 concentrations 1 year after surgery demonstrated greater reductions in waist circumference. This suggests that IL-10, an anti-inflammatory cytokine, may play a crucial role in improving health outcomes following bariatric surgery. Previous studies have shown that higher IL-10 levels are correlated with better metabolic outcomes in obese patients, aligning with the findings of this research [6, 15]. Turkoglu et al. demonstrated that 1 year after LSG, levels of IL-10, an anti-inflammatory cytokine, had significantly increased, suggesting an improved immunological balance in patients [5]. Dai et al. demonstrated that bariatric surgery led to changes in B cell inflammatory status associated with reduced obesity. The study found that, after surgery, circulating B cells showed a significantly increased frequency of IL-10-producing cells and a reduced frequency of IL-6-producing cells [35]. The rise in IL-10 may play a critical role in reducing chronic inflammation and protecting against further metabolic complications [5]. Focus on abdominal adiposity rather than overall body weight may reflect the specific inflammatory and metabolic mechanisms in obesity that bariatric surgery targets, further highlighting the importance of IL-10 in these processes. These findings have significant implications for clinical practice. Monitoring parameters such as IL-10 levels and waist circumference can provide valuable insights into the long-term effectiveness of bariatric surgeries. Furthermore, bariatric surgery should not be evaluated solely by weight loss but also by improvements in metabolic health markers, such as inflammation and waist circumference [1].

This study has certain limitations that should be considered. Firstly, a relatively small sample size was primarily due to the restriction to a single type of bariatric surgery. Nonetheless, patient engagement and adherence were high, with only one patient missing the 1-year follow-up assessment. Secondly, dividing patients based on the median IL-10 level does not ensure equal group sizes; a larger sample is necessary to achieve a more balanced distribution.

The present study provides valuable evidence for the benefits of laparoscopic sleeve gastrectomy in both weight loss and inflammation reduction. Waist circumference proved to be a strong predictor of metabolic success 1 year after surgery, and an increase in IL-10 levels indicated beneficial immunological changes. For these reasons, regular monitoring of these parameters should be a priority in the care of bariatric surgery patients.

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Author contribution Marietta Bracha and Alina Jaroch contributed equally to this work and share first authorship conceptualization: Marietta Bracha and Alina Jaroch methodology: Marietta Bracha and Alina Jaroch, Jakub Wojtasik software: Jakub Wojtasik validation: Marietta Bracha and Alina Jaroch formal analysis: Marietta Bracha and Alina Jaroch investigation: Marietta Bracha and Alina Jaroch resources: Marietta Bracha and Alina Jaroch data curation: Jakub Wojtasik writing—original draft preparation: Marietta Bracha and Alina Jaroch writing—review and editing: Marietta Bracha and Alina Jaroch visualization: Marietta Bracha and Alina Jaroch supervision: Marietta Bracha and Alina Jaroch project administration: Marietta Bracha and Alina Jaroch All authors have read and agreed to the published version of the manuscript.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interest The authors declare no competing interests.

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4. Podsumowanie

Wyniki przeprowadzonych badań dostarczyły istotnych dowodów na efektywność laparoskopowej rękawowej resekcji żołądka (LSG) w leczeniu otyłości, zarówno pod względem redukcji masy ciała, jak i poprawy stanu zapalnego organizmu. Analiza efektów po 3 oraz 12 miesiącach od zabiegu pozwoliła na identyfikację kluczowych mechanizmów metabolicznych i immunologicznych, które wpływają na skuteczność tego rodzaju leczenia. Wykazano, że LSG prowadzi do znaczącej redukcji masy ciała zarówno w krótkim, jak i długim okresie. Już po 3 miesiącach pacjenci tracili średnio 37,6% nadmiarowej masy ciała (%EWL), podczas gdy po roku utrata ta wzrastała do 56,8%. Efektywność zabiegu była szczególnie widoczna u pacjentów z początkowym BMI poniżej 47,46 kg/m², co wskazuje na istotną rolę początkowej masy ciała jako predyktora sukcesu metabolicznego. Wyniki podkreślają znaczenie LSG jako skutecznej interwencji chirurgicznej dla osób z otyłością, która pozwala na poprawę zarówno wskaźników antropometrycznych, jak i jakości życia. Badania nad interleukiną-6 (IL-6) i interleukiną-10 (IL-10) dostarczyły nowych informacji na temat roli cytokin w odpowiedzi organizmu na utratę masy ciała. Po 3 miesiącach od zabiegu zaobserwowano istotny wzrost poziomu IL-6, (średnio do 5,201 pg/mL z poziomu wyjściowego 1,144 pg/mL), co można tłumaczyć aktywacją procesu lipolizy i uwalnianiem wolnych kwasów tłuszczowych, które mogą pobudzać odpowiedź zapalną. Ten stan zapalny, choć przejściowy, był związany z efektywną utratą masy ciała. Z kolei po roku stężenie IL-6 znacząco spadło, co świadczy o stopniowym wygaszaniu przewlekłego stanu zapalnego. W odróżnieniu od IL-6, poziom IL-10, będącej kluczową cytokiną przeciwzapalną, znacząco obniżył się po 3 miesiącach, co może sugerować osłabioną odpowiedź przeciwzapalną w początkowej fazie utraty masy ciała. Po 12 miesiącach zaobserwowano znaczny wzrost IL-10 (średnio do 0,726 pg/mL z wyjściowego 0,520 pg/mL), co wskazuje na poprawę równowagi immunologicznej i procesów przeciwzapalnych. Wyższe poziomy IL-10 były silnie skorelowane z lepszymi wynikami metabolicznymi, w tym redukcją obwodu talii. Zaobserwowane rezultaty mogą świadczyć, że modulacja stanu zapalnego odgrywa istotną rolę w procesie poprawy metabolicznej po LSG, co może Przedkładać się do zmniejszenia ryzyka najczęściej spotykanych chorób współistniejących, takich jak cukrzyca typu 2 i choroby sercowo-naczyniowe. Obwód talii okazał się jednym z kluczowych wskaźników metabolicznego sukcesu po zabiegu. Po 12 miesiącach obwód talii znacząco zmniejszył się z początkowej wartości 122 cm (średnio) do 98,5 cm, co było silnie skorelowane z procentową utratą nadmiarowej masy ciała (%EWL, R = -0,738, p < 0,00001). Jego redukcja wykazała korelację z procentową utratą nadmiarowej masy ciała (%EWL) oraz poprawą wyników zdrowotnych. Stwierdzono, że zmniejszenie obwodu talii o każdy dodatkowy centymetr w momencie wyjściowym zwiększało szansę na osiągnięcie sukcesu metabolicznego o 12%. Wartości obwodu talii poniżej 88 cm dla kobiet i 102 cm dla mężczyzn są wskaźnikiem lepszego zdrowia metabolicznego i niższego ryzyka wystąpienia chorób współistniejących, takich jak cukrzyca typu 2 i choroby sercowo-naczyniowe. Wyniki niniejszej pracy potwierdzają, że obwód talii jest bardziej precyzyjnym wskaźnikiem oceny ryzyka metabolicznego i skuteczności leczenia niż samo BMI. Pomimo, że badania dostarczyły istotnych wyników, należy podkreślić, że ich ograniczenia obejmują przede wszystkim stosunkowo małą liczebność grupy badawczej oraz koncentrację na jednym rodzaju procedury chirurgicznej. Należy podkreślić, że wymienione wyżej ograniczenia powinny być uwzględnione w planowanych w przyszłości badaniach na większych populacjach pacjentów i powinny obejmować dłuższe okresy obserwacji oraz analizę innych markerów zapalnych (powszechnie stosowanych w przypadku hospitalizacji), takich jak CRP (oraz rzadziej stosowanych jednak dających bardziej precyzyjny pogląd na przebieg procesu zapalnego), prokalcytonina – stosowana do diagnozy zakażeń bakteryjnych i sepsy czy cytometryczne badanie populacji leukocytów. Niewątpliwie pozwoli to na lepsze zrozumienie długoterminowych efektów LSG. Laparoskopowa rękawowa resekcja żołądka jest skuteczną metodą leczenia otyłości, która nie tylko prowadzi do znaczącej redukcji masy ciała, ale także poprawia stan zapalny organizmu. Wyniki badań wskazują na możliwość dalszej optymalizacji tej procedury, poprzez uwzględnienie molekularnych mechanizmów indukcji, przebiegu, dokładnej roli stanu zapalnego oraz parametrów antropometrycznych w prognozowaniu sukcesu metabolicznego. Wnioski płynące z niniejszego opracowania mogą przyczynić się do poprawy jakości życia pacjentów oraz ograniczenia ryzyka chorób związanych z otyłością.

5. Wnioski

Wyniki prezentowanego cyklu publikacyjnego wchodzącego w skład prezentowanej rozprawy doktorskiej pozwoliły na sformułowanie następujących wniosków odpowiadających na cel główny i cele szczegółowe prezentowanej rozprawy:

- Laparoskopowa rękawowa resekcja żołądka (LSG) jest skuteczną metodą leczenia otyłości, prowadzącą do znaczącej i trwałej redukcji masy ciała oraz poprawy zdrowia metabolicznego pacjentów.
- Zmiany w poziomach interleukiny-6 (IL-6) i interleukiny-10 (IL-10) podkreślają ich znaczenie jako markerów adaptacji organizmu do utraty masy ciała oraz sukcesu metabolicznego. IL-6 odgrywa kluczową rolę w krótkoterminowej odpowiedzi organizmu, natomiast IL-10 wskazuje na poprawę równowagi immunologicznej w długim okresie.
- Krótkoterminowa utrata masy ciała po LSG wiąże się z przejściowym stanem zapalnym, natomiast w dłuższym okresie dochodzi do stabilizacji metabolicznej i immunologicznej.
- Obwód talii jest bardziej precyzyjnym predyktorem sukcesu metabolicznego niż ogólne wskaźniki masy ciała, takie jak BMI. Jego uwzględnienie w ocenie efektów leczenia pozwala na lepsze prognozowanie wyników i ocenę ryzyka zdrowotnego
- Wyniki badań mają potencjał do poprawy praktyki klinicznej poprzez lepsze monitorowanie pacjentów oraz identyfikację czynników ryzyka.

6. Oświadczenia wszystkich współautorów określające indywidualny wkład każdego z nich w powstanie publikacji.

Toruń, dnia 17.01.2025

Dr Małgorzata Szady-Grad

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Collegium Medicum w Bydgoszczy

Rada Dyscypliny Wydziału Nauk o Zdrowiu CM w Bydgoszczy UMK w Toruniu

Uniwersytetu Mikołaja Kopernika w Toruniu

Oświadczenie o współautorstwie

Niniejszym oświadczam, że w pracy *Bracha M, Szady-Grad M. Selected blood parameters with potential diagnostic application in the course of inflammation in chronically obese individuals undergoing bariatric surgery. Pielęgniarstwo w Opiece Długoterminowej / Long-Term Care Nursing. 2023;8(2):39-45.*, mój udział polegał na sprawdzeniu i akceptacji końcowej wersji manuskryptu.

Mój udział w powstaniu pracy wynosi 10%.

M. Szady-Grad
(podpis)

Toruń, dnia 17.01.2025

mgr inż. Jakub Wojtasik

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Uniwersytetu Mikołaja Kopernika w Toruniu

Oświadczenie o współautorstwie

Niniejszym oświadczam, że w pracy: *Bracha M, Jaroch A, Wojtasik J. Waist Circumference Is a Strong Predictor of a Positive Outcome Evaluated One Year After Sleeve Gastrectomy. Obes Surg. 2025 Jan 15.*, mój udział polegał na współtworzeniu części statystycznej.

Mój udział w powstaniu pracy wynosi

20%

Jakub Wojtasik
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Oświadczenie o współautorstwie

Niniejszym oświadczam, że w pracy: *Bracha M, Jaroch A, Falkowski A, Zwierko B, Szwed M, Michalik M, Borkowska A, Szwed K, Kozakiewicz M. Elevated Interleukin-6 Is Associated with Successful Weight Loss 3 Months Postlaparoscopic Sleeve Gastrectomy. Obes Surg. 2024 Oct;34(10):3824-3832*, mój udział polegał na sprawdzeniu i akceptacji końcowej wersji manuskryptu.

B. Zwierko

(podpis)

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Niniejszym oświadczam, że w pracy: *Bracha M, Jaroch A, Falkowski A, Zwierko B, Szwed M, Michalik M, Borkowska A, Szwed K, Kozakiewicz M. Elevated Interleukin-6 Is Associated with Successful Weight Loss 3 Months Postlaparoscopic Sleeve Gastrectomy. Obes Surg. 2024 Oct;34(10):3824-3832.*, mój udział obejmował nadzór nad przeprowadzeniem analiz biochemicznych, współtworzenie dyskusji i wniosków oraz sprawdzenie i akceptację końcowej wersji manuskryptu.

....

(podpis)

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Alina Jaroch
(podpis)

Bydgoszcz, dnia 29.01.2025

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Alina Jaroch
(podpis)

Załącznik nr 5 do uchwały Nr 38 Senatu UMK z dnia 26 września 2023 r.

w sprawie postępowania o nadanie stopnia doktora

na Uniwersytecie Mikołaja Kopernika w Toruniu

Toruń, dnia ....

.........dr Adrian Falkowski..

(tytuł, stopień, imię i nazwisko kandydata/współautora)

..Katedra Teorii Prawdopodobieństwa i Analizy Stochastycznej Wydział Matematyki i Informatyki UMK w Toruniu...

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Rada Dyscypliny Wydziału Nauk o Zdrowiu CM w Bydgoszczy UMK w Toruniu

Uniwersytetu Mikołaja Kopernika w Toruniu

Oświadczenie o współautorstwie

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Mój udział w powstaniu pracy wynosi

.........15%................

Adrian Falkowski...

(podpis)

Bydgoszcz, dnia 24.01.2025

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Oświadczenie o współautorstwie

Niniejszym oświadczam, że w pracy: *Bracha M, Jaroch A, Falkowski A, Zwierko B, Szwed M, Michalik M, Borkowska A, Szwed K, Kozakiewicz M. Elevated Interleukin-6 Is Associated with Successful Weight Loss 3 Months Postlaparoscopic Sleeve Gastrectomy. Obes Surg. 2024 Oct;34(10):3824-3832*, mój udział polegał na akceptacji końcowej wersji manuskryptu.

....

(podpis)

7. Streszczenia

7. 1. Streszczenie w języku polskim

Laparoskopowa rękawowa resekcja żołądka (LSG) stanowi jedną z najczęściej stosowanych metod chirurgicznego leczenia otyłości, prowadzącą do istotnej redukcji masy ciała oraz poprawy parametrów metabolicznych. Skuteczność tego zabiegu wykracza poza samą utratę masy ciała, obejmując także korzystne zmiany w układzie immunologicznym i procesach zapalnych. Istotną rolę w tych mechanizmach odgrywają cytokiny, w szczególności interleukina-6 (IL-6) i interleukina-10 (IL-10), które pełnią kluczowe funkcje w regulacji procesów prozapalnych i przeciwzapalnych.

W niniejszym badaniu przeanalizowano zmiany w stężeniach IL-6 i IL-10 po 3 i 12 miesiącach od LSG, wykazując istotną dynamikę ich poziomów. W okresie 3 miesięcy odnotowano wzrost IL-6, co może odzwierciedlać przejściową reakcję zapalną organizmu związaną z gwałtowną redukcją masy ciała. Po upływie 12 miesięcy zaobserwowano natomiast istotne obniżenie poziomu IL-6 oraz wzrost IL-10, co sugeruje stopniowe wygaszanie przewlekłego stanu zapalnego i przywracanie homeostazy immunologicznej.

Dodatkowo, analiza wykazała silną korelację między zmniejszeniem obwodu talii a skutecznością metaboliczną LSG. Obwód talii okazał się istotnym predyktorem sukcesu terapeutycznego, wykazując większą wartość diagnostyczną niż BMI w ocenie ryzyka metabolicznego. Wyniki te podkreślają znaczenie kompleksowego podejścia do oceny efektów bariatrycznych, uwzględniającego nie tylko klasyczne wskaźniki antropometryczne, ale także parametry immunologiczne, co może stanowić podstawę do optymalizacji strategii leczenia otyłości.

7. 2. Streszczenie w języku angielskim

Laparoscopic sleeve gastrectomy (LSG) is one of the most commonly performed bariatric procedures, leading to significant weight loss and metabolic improvement. The efficacy of LSG extends beyond weight reduction, encompassing beneficial immunological and anti-inflammatory effects. Key mediators in these processes include cytokines such as interleukin-6 (IL-6) and interleukin-10 (IL-10), which play a pivotal role in the regulation of pro- and anti-inflammatory pathways.

This study analyzed changes in IL-6 and IL-10 levels at 3 and 12 months post-LSG, revealing a dynamic pattern of cytokine modulation. At 3 months, IL-6 levels increased, potentially reflecting a transient inflammatory response associated with rapid weight loss. However, by 12 months, IL-6 levels significantly decreased, while IL-10 concentrations increased, suggesting a progressive resolution of chronic inflammation and restoration of immunological homeostasis.

Furthermore, the analysis demonstrated a strong correlation between waist circumference reduction and metabolic success after LSG. Waist circumference emerged as a superior predictor of positive metabolic outcomes compared to BMI, highlighting its clinical relevance in assessing postoperative success. These findings underscore the importance of a multidimensional approach to evaluate bariatric outcomes, integrating both anthropometric and immunological parameters to refine treatment strategies for obesity management.

8. Spis piśmiennictwa

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