Původní sdělení | Original research article

Cardiovascular Risk Factors and DXA-Assessed Body Composition Changes after Laparoscopic Sleeve Gastrectomy: A One-Year Retrospective Study

Matej Pekař[a,b,c], Pavol Holéczy[d,e], Jitka Macháčková[g,h,ch,i], Aleš Foltys[e,i], Zdeněk Švagera[j], Marek Bužga[a,f]

[a] *Department of Physiology and Pathophysiology, Faculty of Medicine, University of Ostrava, Ostrava, the Czech Republic*
[b] *Complex Cardiovascular Center, Hospital AGEL Třinec-Podlesí, Třinec, the Czech Republic*
[c] *Department of Physiology, Faculty of Medicine, Masaryk University, Brno, the Czech Republic*
[d] *Department of Surgery, Hospital AGEL Ostrava-Vítkovice, Ostrava, the Czech Republic*
[e] *Department of Surgical Studies, Faculty of Medicine, University of Ostrava, Ostrava, the Czech Republic*
[f] *Centre for Nutrition Research and Obesity, Faculty of Medicine, University of Ostrava, Ostrava, the Czech Republic*
[g] *Department of Epidemiology and Public Health, Faculty of Medicine, University of Ostrava, Ostrava, the Czech Republic*
[h] *Department of Internal Medicine and Cardiology, University Hospital Ostrava, Ostrava, the Czech Republic*
[ch] *Department of Clinic Subjects, Faculty of Medicine, University of Ostrava, Ostrava, the Czech Republic*
[i] *Department of Surgery, University Hospital Ostrava, Ostrava, the Czech Republic*
[j] *Department of Clinical Biochemistry, Institute of Laboratory Medicine, University Hospital Ostrava, Ostrava, the Czech Republic*

ARTICLE INFO

Article history:
Submitted: 9. 1. 2025
Accepted: 2. 2. 2025
Available online: 25. 9. 2025

Klíčová slova:
Dyslipidemie
DXA
HDL cholesterol
Kardiovaskulární riziko
Rukávová resekce žaludku
Složení těla

SOUHRN

Úvod: Laparoskopická rukávová resekce žaludku (LSG) se ukázala jako účinný zákrok při léčbě těžké obezity, avšak její vliv na kardiovaskulární rizika přes změny tělesného složení dává prostor k bližšímu zkoumání.
Metody: Tato retrospektivní studie hodnotila 98 pacientů, kteří podstoupili LSG, analyzovali jsme tělesné složení pomocí duální rentgenové absorpciometrie (DXA) a metabolické parametry před operací a 12 měsíců po operaci. Byly hodnoceny změny hmotnosti, tukové hmoty, netukové hmoty, lipidového profilu a glukózového metabolismu, včetně jejich vzájemných vztahů.
Výsledky: Dvanáct měsíců po operaci byly pozorovány významné redukce celkové tělesné hmotnosti, tukové hmoty a netukové hmoty (všechny p < 0,001). Metabolické parametry vykazovaly výrazné zlepšení, s významným poklesem glykemie nalačno, glykovaného hemoglobinu (HbA_{1c}) a triglyceridů, spolu se zvýšením HDL cholesterolu (všechny p < 0,001). LDL/HDL poměr se zlepšil z mediánu (interkvartilové rozpětí [IQR]) 2,79 (1,59) na 2,20 (0,91) (p < 0,001). Aterogenní index plazmy se snížil z 0,23 (0,30) na –0,10 (0,29) (p < 0,001), což představuje posun ze zvýšeného na nízké kardiovaskulární riziko. Byla zjištěna střední negativní korelace mezi změnami netukové hmoty a HDL cholesterolu (r = –0,331, p < 0,001), zatímco slabé, ale významné korelace byly nalezeny mezi změnami poměru pas/boky a glykemickými parametry.
Závěr: LSG vede k významnému zlepšení kardiovaskulárního rizika jeden rok po operaci s pozitivním ovlivněním lipidových parametrů a složení těla. Nově objevená korelace mezi ztrátou netukové hmoty a změnami HDL cholesterolu naznačuje, že zachování netukové hmoty by mohlo být klíčové pro optimalizaci metabolických benefitů po bariatrické operaci.

Keywords:
Atherogenic dyslipidemia
Body composition
Cardiovascular risk
DXA
HDL cholesterol
Sleeve gastrectomy

ABSTRACT

Background: While laparoscopic sleeve gastrectomy (LSG) is known to reduce weight, its impact on cardiovascular risk profile through changes in body composition remains unclear.
Methods: This retrospective study evaluated 98 patients who underwent LSG, analyzing body composition via dual-energy X-ray absorptiometry (DXA) and cardiovascular risk parameters at baseline and 12 months post-surgery. Changes in weight, fat mass, lean mass, atherogenic lipid profile, and glucose metabolism were assessed, along with their interrelationships.
Results: Significant reductions were observed in total body weight, fat mass, and lean mass at 12 months post-surgery (all p <0.001). Metabolic parameters showed marked improvements, with significant decreases in fasting glucose, HbA_{1c}, and triglycerides, alongside an increase in HDL cholesterol (all p <0.001). The LDL/

Address: MUDr. Matej Pekař, Ph.D., MBA, Complex Cardiovascular Center, Hospital AGEL Třinec-Podlesí, Konská 453, 739 61 Třinec, the Czech Republic, e-mail: matej.pekar@gmail.com

DOI: 10.33678/cor.2025.020

Please cite this article: Pekař M, Holéczy P, Macháčková J, et al. Cardiovascular Risk Factors and DXA-Assessed Body Composition Changes after Laparoscopic Sleeve Gastrectomy: A One-Year Retrospective Study. Cor Vasa 2025;67:555–560.

HDL ratio improved from median (IQR) 2.79 (1.59) to 2.20 (0.91) (p <0.001). The atherogenic index of plasma decreased from 0.23 (0.30) to –0.10 (0.29) (p <0.001), representing a shift from increased to low cardiovascular risk. A moderate negative correlation was identified between changes in lean mass and HDL cholesterol (r = –0.331, p <0.001), while weak but significant correlations were found between changes in waist-to-hip ratio and glycemic parameters.

Conclusions: LSG results in significant improvements in cardiovascular risk profile at one year post-surgery, with favorable changes in atherogenic lipid parameters and body composition. The novel correlation between lean mass preservation and HDL cholesterol suggests that maintaining muscle mass might be crucial for optimizing cardiovascular benefits following bariatric surgery.

Introduction

Obesity has emerged as one of the most pressing public health challenges of the 21st century, with its prevalence reaching epidemic proportions worldwide.[1] Beyond its direct health implications, obesity represents a major modifiable risk factor for cardiovascular disease, the leading cause of mortality worldwide.[2] The pathophysiological relationship between obesity and cardiovascular risk is complex and multifaceted, involving various metabolic perturbations including dyslipidemia, insulin resistance, and chronic inflammation.[3] Of particular concern is the impact of excess adiposity on lipid metabolism, specifically its association with decreased high-density lipoprotein (HDL) cholesterol levels and elevated triglycerides, both independent risk factors for cardiovascular disease.[4]

In cases of severe obesity, bariatric surgery has demonstrated superior efficacy compared to conventional weight loss approaches, not only in achieving sustained weight reduction but also in improving cardiovascular risk factors.[5,6] Among various bariatric procedures, laparoscopic sleeve gastrectomy (LSG) has gained prominence due to its favourable risk-benefit profile and significant metabolic effects.[7] LSG induces weight loss through both restrictive and hormonal mechanisms, leading to substantial improvements in obesity-related comorbidities. However, the procedure's impact extends beyond simple weight reduction, affecting body composition and metabolic parameters in ways that are not fully understood.

Traditional methods of assessing post-bariatric outcomes have primarily focused on total weight loss and basic anthropometric measurements. However, these metrics fail to capture crucial changes in body composition, particularly the relative loss of fat versus lean mass.[8] Dual-energy X-ray absorptiometry (DXA) has emerged as a valuable tool in this context, offering precise quantification of body composition components.[9] This technology enables detailed analysis of fat distribution and lean mass changes, providing insights that may be more relevant to cardiovascular risk assessment than total weight loss alone.

The preservation of lean mass during weight loss has gained increasing attention in bariatric medicine, as skeletal muscle plays a crucial role in metabolic health.[9] Emerging evidence suggests that muscle tissue functions as an endocrine organ, secreting myokines that influence lipid metabolism and insulin sensitivity.[10] However, the specific relationship between post-operative lean mass preservation and improvements in cardiovascular risk factors, particularly lipid profiles, remains inadequately characterized. This knowledge gap is especially relevant given that excessive loss of lean mass might potentially attenuate the metabolic benefits of bariatric surgery.

Furthermore, the dynamic interplay between body composition changes and metabolic parameters following LSG warrants investigation within the context of cardiovascular risk modification. While improvements in traditional cardiovascular risk factors after bariatric surgery are well-documented, current research is establishing precise body composition targets to optimize these cardiovascular benefits.[6] Understanding these relationships could inform post-operative care strategies and potentially enhance cardiovascular outcomes in bariatric patients.

Therefore, this retrospective study aimed to evaluate comprehensive changes in body composition via DXA and their correlation with metabolic parameters one year after LSG. Our investigation focused particularly on the relationship between lean mass preservation and metabolic improvements, with special attention to lipid profile changes. By elucidating these associations, we sought to provide insights that could guide post-operative care strategies and optimize metabolic outcomes in patients undergoing bariatric surgery.

Material and methods

Study design and population

The study retrospectively enrolled 98 patients who underwent laparoscopic sleeve gastrectomy (LSG) at two centers (Hospital 1 [Hospital AGEL Ostrava-Vítkovice]: 71 [72%] and Hospital 2 [University Hospital Ostrava]: 27 [28%] of patients) between the years 2010–2019. There were no significant differences in patient characteristics, surgical techniques, and protocols or outcomes between the two centers. Inclusion criteria followed the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) guidelines: body mass index (BMI) ≥40 kg/m² or BMI ≥35 kg/m² with obesity-related comorbidities. Exclusion criteria included active malignancy, and inability to complete follow-up visits. The study was approved by the institutional ethics committee.

Clinical assessments and measurements

Comprehensive evaluations were conducted at baseline and 12 months post-surgery. Anthropometric measurements included weight, height, waist circumference, and hip circumference, performed using standardized protocols. Body composition analysis was performed using DXA (Discovery A; Hologic, Waltham, MA, USA), which provided measurements of total body mass, fat mass, and lean

Table 1 – Baseline demographic and clinical characteristics	
Characteristics	**Value**
Total participants, n	98
Age (years), mean ± SD	43.8 ± 9.6
Sex, n (%)	
Male	25 (25.5 %)
Female	73 (74.5 %)
Height (cm), mean ± SD	169.5 ± 8.4

Baseline demographic and clinical characteristics of 98 patients undergoing laparoscopic sleeve gastrectomy. Data presented as mean ± standard deviation (SD) or number (percentage).

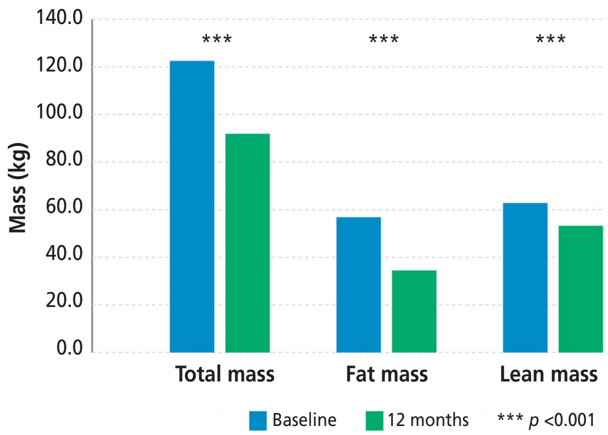

Fig. 1 – Body composition changes 12 months after laparoscopic sleeve gastrectomy.
Changes in body composition parameters measured by dual-energy X-ray absorptiometry (DXA) at baseline (blue bars) and 12 months post-surgery (green bars). Values are presented as medians. Total mass decreased from 122.5 kg to 91.8 kg, fat mass from 56.9 kg to 34.6 kg, and lean mass from 62.8 kg to 53.2 kg. *** indicates statistical significance at p <0.001 for all comparisons.

mass. Blood samples were collected after overnight fasting for analysis of lipid profile (triglycerides, high-density lipoprotein cholesterol, total cholesterol, and low-density lipoprotein cholesterol) and glucose metabolism (fasting glucose and glycated hemoglobin).

Statistical analysis

Statistical analyses were performed using IBM SPSS version 30.0.0. The Shapiro–Wilk test was used to assess data normality. For non-normally distributed variables (weight, DXA total mass, fat mass, lean mass, glycemia, triglycerides, HbA_{1c}, LDL/HDL ratio, atherogenic index and waist-to-hip ratios), the Wilcoxon signed-rank test was applied to compare baseline and 12-month values. Paired t-tests were used for normally distributed variables. Only parameters showing significant changes (p <0.05) were included in the subsequent correlation analysis. Relationships between changes in body composition and metabolic parameters were evaluated using Spearman's correlation coefficient. Correlation strength was categorized as weak (r = 0.2–0.3), moderate (r = 0.3–0.5), or strong (r >0.5).

Results

Patient demographics

The study cohort comprised 98 Caucasian patients (25 men, 73 women) with a mean age of 43.8 ± 9.6 years and mean height of 169.5 ± 8.4 cm (**Table 1**). Pre-existing comorbidities included hypertension in 49 patients (50%) and type 2 diabetes mellitus in 25 patients (25.5%). 26 patients (26.5%) were current smokers at the time of surgery. All patients completed the 12-month follow-up period.

Changes in body composition

Significant reductions were observed in all anthropometric measurements at 12 months post-surgery (**Table 2, Fig. 1**). Median body weight decreased by 31.7 kg, from 122.4 kg (IQR: 13.2) at baseline to 90.7 kg (IQR: 26.3) at 12 months (p <0.001). DXA analysis revealed substantial changes in body composition. Total body mass decreased from a median of 122.5 kg (IQR: 34.8) to 91.8 kg (IQR: 26.9) (p <0.001). Fat mass showed a median reduction of 22.3 kg, from 56.9 kg (IQR: 19.6) to 34.6 kg (IQR: 16.0) (p <0.001). Lean mass also decreased significantly, from 62.8 kg (IQR: 17.2) to 53.2 kg (IQR: 17.1) (p <0.001).

Table 2 – Changes in body composition and anthropometric parameters		
Parameter	**Baseline**	**12 months**
Weight (kg), median (IQR)	122.4 (13.2)	90.7 (26.3)
DXA total mass (kg), median (IQR)	122.5 (34.9)	91.8 (26.9)
DXA fat mass (kg), median (IQR)	56.9 (19.6)	34.6 (16.0)
DXA lean mass (kg), median (IQR)	62.8 (17.2)	53.2 (17.1)
Waist 1 (cm), mean ± SD	120.4 ± 14.5	97.3 ± 13.3
Waist 2 (cm), mean ± SD	129.7 ± 15.9	104.6 ± 14.1
Hip circumference (cm), mean ± SD	132.9 ± 13.5	112.00 ± 11.6
Waist 1-to-hip ratio, mean ± SD	0.91 ± 0.11	0.87 ± 0.10
Waist 2-to-hip ratio, mean ± SD	0.98 ± 0.10	0.93 ± 0.09

Body composition and anthropometric measurements at baseline and 12 months post-surgery (n = 98). Waist 1 measured at midpoint between 10th rib and iliac crest. Waist 2 measured at umbilicus level. All changes were statistically significant (p <0.001). Data presented as median (interquartile range, IQR) or mean ± standard deviation (SD).

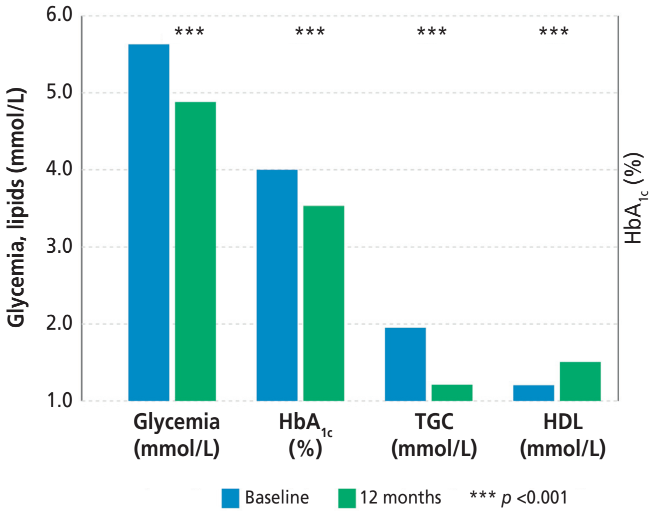

Fig. 2 – Changes in metabolic parameters 12 months after laparoscopic sleeve gastrectomy. Changes in metabolic parameters at baseline (blue bars) and 12 months post-surgery (green bars). Values are shown for glycemia (mmol/L), glycated hemoglobin (HbA_{1c}, %), triglycerides (TGC, mmol/L), and HDL cholesterol (mmol/L). Significant improvements were observed in all parameters, with decreases in glycemia (5.63 to 4.88 mmol/L), HbA_{1c} (4.0 to 3.6%), and TGC (1.95 to 1.21 mmol/L), while HDL cholesterol increased (1.20 to 1.51 mmol/L). *** indicates statistical significance at p <0.001 for all comparisons.

Metabolic outcomes

Glucose metabolism markers showed significant improvements (**Table 3, Fig. 2**). Median fasting glucose levels decreased from 5.63 mmol/L (IQR: 1.75) to 4.88 mmol/L (IQR: 0.75) (p <0.001). HbA_{1c} levels reduced from a median of 4.0% (IQR: 1.4) to 3.6% (IQR: 0.6) (p <0.001). The lipid profile demonstrated favourable changes, with median triglyceride levels decreasing from 1.95 mmol/L (IQR: 0.99) to 1.21 mmol/L (IQR: 0.64) (p <0.001). Mean HDL cholesterol increased from 1.20 ± 0.30 mmol/L to 1.51 ± 0.32 mmol/L (p <0.001). Total cholesterol and LDL cholesterol did not show statistically significant changes over the study period.

Correlation analysis

Analysis of the relationships between changes in body composition and metabolic parameters revealed several significant correlations (**Table 4**). The most notable was a moderate negative correlation between changes in lean mass and HDL cholesterol (r = –0.331, p <0.001). Weak but significant correlations were observed between changes in hip circumference and HbA_{1c} (r = –0.258), between changes in glycemia and waist-to-hip ratio (first measurement: r = 0.235; second measurement: r = 0.250), and between changes in HbA_{1c} and waist-to-hip ratio (first measurement: r = 0.224; second measurement: r = 0.245).

Additional analysis of atherogenic profile

The comprehensive analysis of cardiovascular risk markers revealed significant improvements in the atherogenic profile (**Table 5**). The LDL/HDL ratio decreased from median (IQR) 2.79 (1.59) to 2.20 (0.91) (p <0.001). Analysis of the atherogenic index of plasma (AIP), calculated as log10(triglycerides/HDL cholesterol), showed significant improvement from baseline to 12-month follow-up. The median (IQR) AIP decreased from 0.23 (0.30) at baseline, indicating increased cardiovascular risk, to –0.10 (0.29) at 12 months, representing low cardiovascular risk (p <0.001).

Table 3 – Changes in metabolic parameters

Parameter	Baseline	12 months	*p*-value
Glycemia (mmol/L), median (IQR)	5.63 (1.75)	4.88 (0.75)	<0.001
HbA_{1c} (%), median (IQR)	4.0 (1.4)	3.6 (0.6)	<0.001
TGC (mmol/L), median (IQR)	1.95 (0.99)	1.21 (0.64)	<0.001
HDL cholesterol (mmol/L), mean ± SD	1.20 ± 0.30	1.51 ± 0.32	<0.001
Total cholesterol	Not significant change		NS
LDL cholesterol	Not significant change		NS

Changes in metabolic parameters from baseline to 12 months post-surgery (n = 98). Data presented as median (IQR) or mean ± SD.
NS – not significant; TGC – triglycerides.

Table 4 – Correlation analysis of changes in body composition and metabolic parameters

Parameters	Correlation coefficient (R)	Strength
Δ DXA lean mass vs. Δ HDL	–0.331	Moderate
Δ Hip circumference vs. Δ HbA_{1c}	–0.258	Weak
Δ Glycemia vs. waist 1-to-hip ratio	0.235	Weak
Δ Glycemia vs. waist 2-to-hip ratio	0.250	Weak
Δ HbA_{1c} vs. waist 1-to-hip ratio	0.224	Weak
Δ HbA_{1c} vs. waist 2-to-hip ratio	0.245	Weak

Correlation analysis between changes in body composition and metabolic parameters over 12-month follow-up. All correlations significant at p <0.05. Correlation strength: weak (r = 0.2–0.3), moderate (r = 0.3–0.5), strong (r >0.5).

Table 5 – Changes in atherogenic profile after laparoscopic sleeve gastrectomy

Parameter	Baseline	12 months	*p*-value
LDL/HDL ratio, median (IQR)	2.79 (1.59)	2.20 (0.91)	<0.001
Atherogenic index of plasma, median (IQR)	0.23 (0.30)	–0.10 (0.29)	<0.001

AIP was calculated as log10(triglycerides/HDL cholesterol)
Cardiovascular risk interpretation:
- *AIP >0.21 increased risk; AIP 0.11–0.21 intermediate risk; AIP <0.11 low risk;*
- *LDL/HDL ratio interpretation: Ideal: <2.0; good: <5.0; poor: >5.0*

Discussion

This retrospective study demonstrates significant improvements in both body composition and cardiovascular risk factors one year after laparoscopic sleeve gastrectomy, with several notable findings regarding the interrelationship between these changes. The median weight loss of 31.7 kg observed in our cohort aligns with previous studies,[11] which reported mean excess weight loss ranging from 60–70% at one year post-LSG. This weight loss represents substantial cardiovascular risk reduction, particularly considering established evidence that each 10 kg of weight loss associates with a 6 mmHg reduction in systolic blood pressure and improved insulin sensitivity.[12]

The comprehensive body composition analysis via DXA revealed substantial reductions in both fat mass (median reduction 22.3 kg) and lean mass (median reduction 9.6 kg). These findings are comparable to those reported by previous studies.[13] However, our study extends beyond these observations by examining the metabolic implications of these compositional changes.

Our analysis revealed clinically significant improvements in cardiovascular risk markers. The marked increase in HDL cholesterol and substantial decrease in triglycerides, combined with the improvement in LDL/HDL ratio, represent meaningful reductions in cardiovascular risk. The magnitude of HDL increase (0.31 mmol/L) is particularly noteworthy, given that previous studies have associated each 0.03 mmol/L increase in HDL with a 2–3% reduction in cardiovascular events.[14]

The most significant finding of our study was the moderate negative correlation ($r = -0.331$, $p < 0.001$) between changes in lean mass and HDL cholesterol levels. This novel observation suggests that excessive lean mass loss may attenuate improvements in this cardioprotective lipoprotein. This relationship likely reflects the role of skeletal muscle as an endocrine organ,[10] through myokine secretion. Our findings add to this body of knowledge by suggesting that lean mass preservation during post-bariatric weight loss might be crucial for optimizing cardiovascular risk reduction.

The marked reduction in atherogenic index of plasma represents a clinically significant shift from high to low cardiovascular risk category. This improvement in AIP, which is considered a sensitive predictor of cardiovascular risk, particularly in obesity, suggests that the beneficial effects of sleeve gastrectomy extend beyond simple weight reduction to fundamental improvements in lipoprotein metabolism. The magnitude of AIP reduction shows that bariatric surgery can lead to substantial improvements in cardiovascular risk markers, even before maximal weight loss is achieved.

The improvements in glycemic parameters (median fasting glucose reduction from 5.63 to 4.88 mmol/L) and lipid profile (triglycerides reduction from 1.95 to 1.21 mmol/L) are consistent with previous research.[6] However, our study uniquely demonstrates weak but significant correlations between changes in waist-to-hip ratio and both glycemia ($r = 0.235$–0.250) and HbA_{1c} ($r = 0.224$–0.245), suggesting that improvements in body fat distribution contribute to enhanced glucose metabolism. These changes in glycemic parameters contribute to cardiovascular risk reduction through reduced glycation end-products, improved endothelial function, decreased inflammatory markers, and enhanced insulin sensitivity.

These findings have important implications for cardiovascular risk management. The significant improvements in cardiovascular risk factors support considering LSG in high-risk cardiovascular patients with obesity who have failed conservative management. When monitoring these patients, careful attention should be paid to exercise testing protocols and safety measures, particularly in times of increased infectious disease risk.[15] The inverse relationship between lean mass loss and HDL improvement suggests that muscle preservation strategies should be integrated into post-operative cardiovascular risk management. This aligns with recent guidelines by major bariatric societies recommending structured resistance training and adequate protein intake post-operatively.[16–19] Furthermore, regular monitoring of lipid parameters is essential for optimizing cardioprotective medication regimens.

Several limitations warrant consideration. The absence of inflammatory marker data limits our understanding of inflammation-mediated cardiovascular risk reduction. We also lack endothelial function measurements and direct assessment of cardiovascular events. While our one-year follow-up provides valuable insights, longer-term studies are needed to evaluate the durability of these relationships.

Future research directions should explore three critical areas: determining the optimal fat-to-lean mass reduction ratio for maximal metabolic benefits, evaluating post-operative protocols focused on lean mass preservation through prospective studies, and developing personalized strategies based on individual body composition profiles. These investigations would help establish evidence-based guidelines for optimizing metabolic outcomes after bariatric surgery. composition patterns

Conclusions

This study demonstrates that laparoscopic sleeve gastrectomy leads to significant improvements in cardiovascular risk factors at one year post-surgery, characterized by favourable changes in atherogenic lipid profile and body composition. The novel finding of a relationship between lean mass preservation and HDL cholesterol levels suggests that maintaining muscle mass might be crucial for optimizing cardiovascular benefits. These results support the role of LSG in cardiovascular risk reduction strategies for patients with severe obesity.

Conflict of interest
The authors declare no conflict of interest.

Funding
This research was supported by grant no. 24-09-00016 (NW24-09-00016) from the Ministry of Health of the Czech Republic.

Ethical statement
This study was approved by the local Ethics Committee (Hospital AGEL Ostrava-Vítkovice, EK/94/2024). Due to the retrospective nature of the study, the requirement for informed consent was waived by the local Ethics Committee.

References

1. Mulrenan C, Jenner K, Knai C. Tackling the obesity epidemic. BMJ 2023;381:1072.
2. Wu J, Mu Z, Jiang S, et al. Trends in all-cause mortality and leading causes of death from 2009 to 2019 among older adults in China. BMC Geriatr 2023;23:645.
3. Silveira Rossi JL, Barbalho SM, Reverete de Araujo R, et al. Metabolic syndrome and cardiovascular diseases: Going beyond traditional risk factors. Diabetes Metab Res Rev 2022;38:e3502.
4. Flock MR, Green MH, Kris-Etherton PM. Effects of adiposity on plasma lipid response to reductions in dietary saturated fatty acids and cholesterol. Adv Nutr 2011;2:261–274.
5. Powell-Wiley TM, Poirier P, Burke LE, et al. American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; Council on Epidemiology and Prevention; and Stroke Council. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation 2021;143:e984–e1010.
6. Horká V, Bužga M, Macháčková J, et al. The effect of bariatric--metabolic surgery on selected components of metabolic syndrome and visceral adipose tissue – the pilot study. Physiol Res 2023;72(S5):S523–S534.
7. Desiderio J, Trastulli S, Scalercio V, et al. Effects of laparoscopic sleeve gastrectomy in patients with morbid obesity and metabolic disorders. Diabetes Technol Ther 2013;15:1004–1009.
8. Salmón-Gómez L, Catalán V, Frühbeck G, Gómez-Ambrosi J. Relevance of body composition in phenotyping the obesities. Rev Endocr Metab Disord 2023;24:809–823.
9. Pekař M, Pekařová A, Bužga M, et al. The risk of sarcopenia 24 months after bariatric surgery - assessment by dual energy X-ray absorptiometry (DEXA): a prospective study. Wideochir Inne Tech Maloinwazyjne 2020;15:583–587.
10. Ruby MA, Riedl I, Massart J, et al. Protein kinase N2 regulates AMP kinase signaling and insulin responsiveness of glucose metabolism in skeletal muscle. Am J Physiol Endocrinol Metab 2017;313:E483–E491.
11. Praveenraj P, Gomes RM, Kumar S, et al. Comparison of weight loss outcomes 1 year after sleeve gastrectomy and Roux-en-Y gastric bypass in patients aged above 50 years. J Minim Access Surg 2016;12:220–225.
12. Shariq OA, McKenzie TJ. Obesity-related hypertension: a review of pathophysiology, management, and the role of metabolic surgery. Gland Surg 2020;9:80–93.
13. Tałałaj M, Bogołowska-Stieblich A, Wąsowski M, et al. The Influence of Laparoscopic Sleeve Gastrectomy on Body Composition and Fat Distribution in Obese Caucasian Men and Women. Obes Surg 2020;30:3974–3981.
14. Barter P, Gotto AM, LaRosa JC, et al.; Treating to New Targets Investigators. HDL cholesterol, very low levels of LDL cholesterol, and cardiovascular events. N Engl J Med 2007;357:1301–1310.
15. Tuka V, Jiravská Godula B, Jiravský O et al. Exercise stress tests at times of increased risk of communicable infections. Expert consensus statement of the Sports Cardiology Section of the Czech Association of Preventive Cardiology of ČKS and the Sports Cardiology Section of the Czech Society of Sports Medicine, the Czech Association of Outpatient Cardiology and Czech Pneumological and Phthisiological Society of ČLS JEP. Cor Vasa 2020;62:529–532.
16. Shiau J, Biertho L. Canadian Adult Obesity Clinical Practice Guidelines: Bariatric Surgery: Postoperative Management. Online. Available from: https://obesitycanada.ca/guidelines/postop. [cited 2024-12-12].
17. Aguas-Ayesa M, Yárnoz-Esquíroz P, Olazarán L, et al. Precision nutrition in the context of bariatric surgery. Rev Endocr Metab Disord 2023;24:979–991.
18. Mechanick JI, Youdim A, Jones DB, et al. American Association of Clinical Endocrinologists; Obesity Society; American Society for Metabolic & Bariatric Surgery. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient – 2013 update: cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Obesity (Silver Spring) 2013;21 (Suppl 1)(0 1):S1–S27.
19. Fernández-Alonso M, Bejarano G, Creel DB, et al. Expert-based physical activity guidelines for metabolic and bariatric surgery patients: a systematic review of randomized controlled trials. Surg Obes Relat Dis 2025;21:606–614.