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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Determinants of Successful Weight Loss After Bariatric Surgery A Retrospective Cohort Study

Margot Vos

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

PROMOTOR :
Prof. dr. Kenneth VERBOVEN

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This study is situated within the research of Kenneth Verboven, PhD, and Wim Bouckaert, MD, "Prevalence of sarcopenia in morbid obesity: a retrospective study" (Z-2023023). The study is part of the broader context of internal disorders. It is a collaboration between REVAL Rehabilitation Research Center, BIOMED Biomedical Research Institute, Faculty of Rehabilitation Sciences, Hasselt University, Diepenbeek, Belgium, and Ziekenhuis Oost-Limburg, Obesity Center, Genk, Belgium. The data were collected by first-year master's students in Rehabilitation Sciences and Physiotherapy at Hasselt University from patient files at Ziekenhuis Oost-Limburg. The student determined the research question in consultation with the supervisor, Kenneth Verboven, PhD.

Determinants of Successful Weight Loss After Bariatric Surgery – A Retrospective Cohort Study

Abstract

Background: Obesity, increasing in prevalence worldwide, results in increased mortality and morbidity. One of the most effective strategies for weight loss and reduction in comorbidities is bariatric surgery, although some patients may experience suboptimal weight loss.

Objective: This study aims to investigate which preoperative patient characteristics can predict successful weight loss.

Methods: Preoperative patient characteristics, such as age, sex, anthropometric measurements, and comorbidities, were collected from patient files. Participants were eligible if they had undergone bariatric surgery in 2021-2022, were aged 18-70, and had a body mass index (BMI) ≥ 35kg/m². Successful weight loss was defined as percentage excessive weight loss (%EWL) > 50% and percentage total weight loss (%TWL) > 20%.

Results: Higher age (estimate = –.19, p = .009) and higher preoperative BMI (estimate = –2.32, p < .001) showed a lower %EWL at 6 months. At 12 months, higher age (estimate = –.42, p < .001) and BMI (estimate = –2.57, p < .001), total body lean mass (estimate = –.0003, p = .004) and BMI at 6 months (estimate = –2.94, p < .001) resulted in a lower %EWL, while higher %TWL at six months (estimate = 1.37, p < .001) positively influenced %EWL at 12 months. A higher age showed a lower %TWL at 6 (estimate = –.10, p < .001) and 12 months (estimate = –.17, p

$< .001$). A higher android fat percentage (estimate = .22, $p = .004$) and %TWL at 6 months (estimate = 1.09, $p < .001$) resulted in a higher %TWL at 12 months.

Conclusion: Preoperative characteristics, particularly age and BMI, are significantly associated with weight loss outcomes in bariatric surgery patients. These findings suggest the importance of in-depth phenotyping of bariatric patients to optimise personalized care.

Keywords: bariatric surgery, successful weight loss, preoperative predictors

Introduction

Obesity, defined by a Body Mass Index (BMI) ≥30 kg/m^2, is a condition that affects one in eight adults worldwide. In 2022, 890 million adults aged 18 and older were living with obesity. Additionally, over 160 million children and adolescents aged five to 19 were also affected by obesity (World Health Organization, 2024). At the WHO European Region level, obesity is slightly more common in women than in men, with a prevalence of 24% and 22%, respectively (World Health Organization, 2022). It has been shown that an increased BMI is an independent risk factor for type 2 diabetes mellitus (T2DM) (Sanada et al., 2012). The likelihood of developing T2DM rises by 20% with every 1 kg/m^2 increase in BMI (Hartemink et al., 2006). Hubert et al. showed that obesity is also a predictor of cardiovascular disease (CVD) incidence in men and women (Hubert et al., 1983). A meta-analysis of 2.88 million participants showed that obesity was linked to a significantly higher all-cause mortality, with a hazard ratio of 1.88 compared to individuals with a normal BMI (Flegal et al., 2013).

Effective weight loss strategies for individuals with obesity are bariatric surgery (BS), pharmacological interventions, hypocaloric diets, and physical exercise (Valenzuela et al., 2023). A systematic review by Abhishek et al. showed that BS, compared to non-surgical therapies, consistently resulted in substantial weight loss, as well as a significant improvement in hypertension and glycemic control, and a significant reduction in cardiovascular risk (Abhishek et al., 2024). BS is indicated for patients with a BMI ≥ 40 kg/m^2 without coexisting comorbidities, as well as for patients with a BMI of 35-40 kg/m^2 who do suffer from at least one obesity-related comorbidity, such as T2DM, hypertension, or hyperlipidemia (Stahl & Malhotra, 2025). BS is a surgical procedure that chronically affects satiety and hunger control, nutrient absorption, and energy expenditure regulation (Chacon et al., 2022), aiming to lose weight and reduce comorbidities (Wolfe et al., 2016). The remission of T2DM after BS is attributed to weight loss, weight-loss-independent changes in gut hormones, energy balance regulation, and changes in the gastrointestinal anatomy (Abhishek et al., 2024). Weight-loss-dependent effects are more evident in comorbidities related to excess body weight, namely psychosocial and mechanical comorbidities, like joint problems and osteoarthritis (Perdomo et al., 2024). There are different types of BS. The most common surgery is the Roux-en-Y Gastric Bypass (RYGB), which bypasses the largest part of the stomach and the first portion of the small intestine, resulting in decreased nutrient absorption. Another common type of BS is the laparoscopic sleeve gastrectomy (LSG). This procedure reduces the stomach size, making consuming large amounts of food difficult, thereby limiting caloric intake (American Society for Metabolic and Bariatric Surgery, 2021).

To evaluate the success of BS, the percentage excessive weight loss (%EWL) and percentage total weight loss (%TWL) are considered. %EWL indicates the weight the patient has lost relative to the excess weight (Masnyj et al., 2020). An often-used marker of successful weight loss is %EWL > 50% (Figura et al., 2015). %TWL is the weight lost relative to the preoperative weight (American Society for Bariatric Surgery Standards, 2005). Adequate weight loss is %TWL > 20% (Corcelles et al., 2016). A study investigating %EWL at the 12-month time point after BS found that about 83% of patients reached the %EWL target of > 50% (D'Eusebio et al., 2021). It is known that over 90% of patients achieve and maintain this %EWL and %TWL target at two years post-operative, this percentage reduces to 75% and 61% at five and ten years post-operative, respectively, indicating that not every patient who undergoes BS meets long-term success criteria (Grover et al., 2019). This raises the question of whether we can predict which patients will achieve the success criteria of %EWL and %TWL.

As previously mentioned, patients are treated with bariatric surgery based on their BMI and any comorbidities present. However, while these factors are used to guide treatment decisions, they may also influence the outcome of the surgery. Remmel et al. investigated the effect of various comorbidities on %EWL and found that a higher BMI, DM, and hyperthyroidism resulted in a smaller %EWL compared to patients without these comorbidities. They also found that depression and anxiety did not result in a statistically significant difference in weight loss (Remmel et al., 2024). Stenberg et al. found no difference in weight loss after BS in people with or without CVD (Stenberg et al., 2022). Recently, in addition to these more commonly studied comorbidities, increasing attention has been given to conditions related to body composition, such as the presence of sarcopenia, which may also impact weight loss outcomes (Ciudin et al., 2020). Sarcopenia is the loss of skeletal muscle mass and muscle function, based on the definition of European Working Groups on Sarcopenia in Older People 2 (EWGSOP2) (Cruz-Jentoft et al., 2019). Due to metabolic changes, sedentary lifestyle, and comorbidities, sarcopenia is very common in people with obesity (Donini et al., 2022). This co-existence of obesity and sarcopenia is referred to as sarcopenic obesity (SO). Preoperative SO and body composition could influence the outcome of BS, besides psychological, behavioural, and socioeconomic factors (Masnyj et al., 2020).

This study aims to determine whether BS success outcomes can be explained by preoperative variables related to body composition, either local or whole-body, and the presence of metabolic comorbidities.

Methods

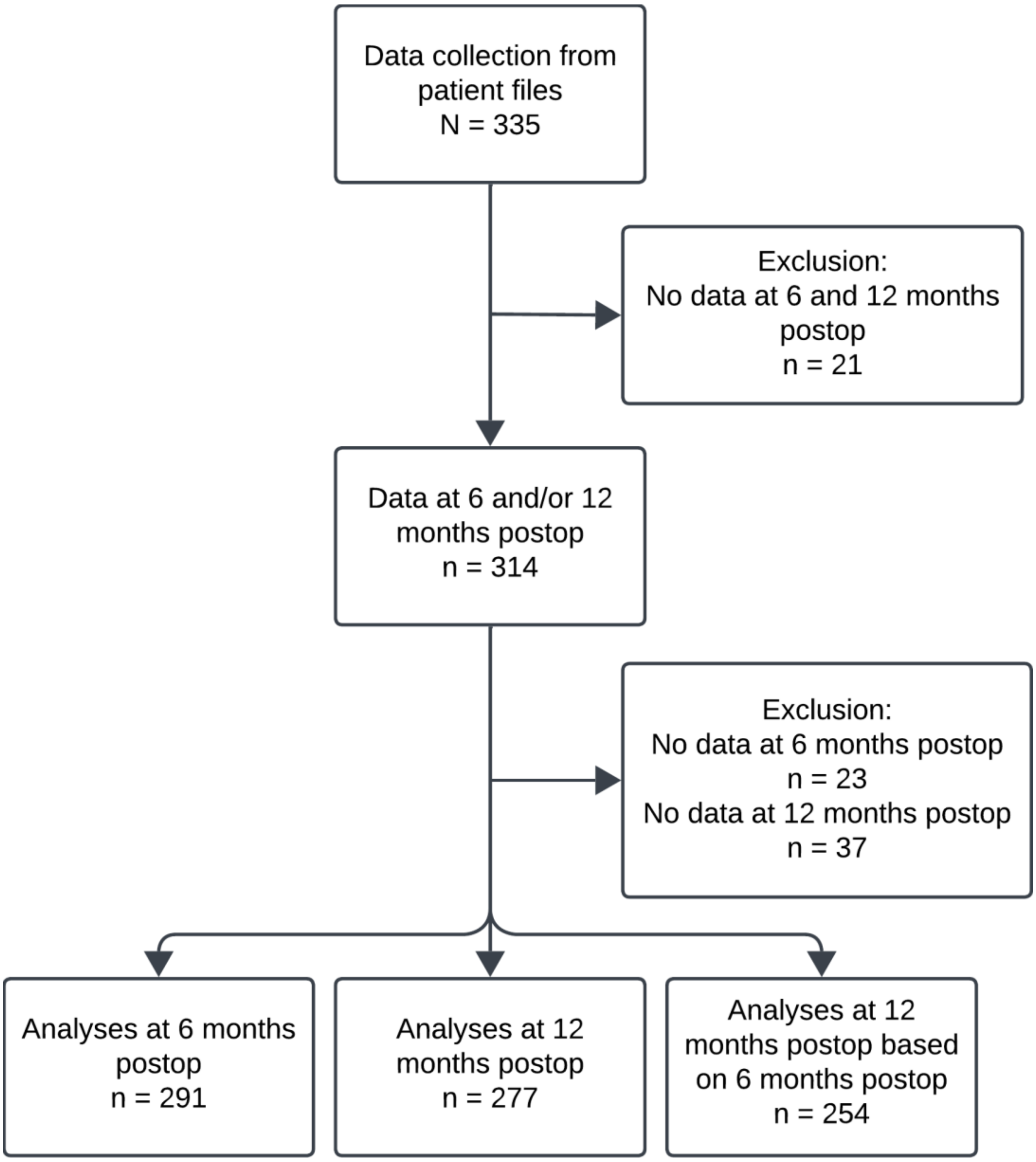
Participants

This retrospective cohort study was conducted at Ziekenhuis Oost-Limburg. Adults aged 18-70 years old with a BMI ≥ 35 kg/m² who registered for the obesity treatment program were eligible for inclusion if they had undergone BS in 2021 or 2022 and had a preoperative Dual Energy X-ray Absorptiometry (DEXA) scan available. Data were collected from 335 patient files. No informed consent was needed due to the retrospective nature of this study. The medical ethics committee ZOL approved the research protocol on February 20th, 2023 (reference number: Z-2023013).

Participants were excluded from analyses if they had no data on their postoperative body weight at 6 and 12 months. Some participants had missing data only for the 6-month or 12-month postoperative weight measurement; their data were only used for the respective analyses and excluded from the other analyses (see Figure 1).

Figure 1

Participant Exclusion Flowchart



Note. This figure shows a flowchart on the exclusion of participants for different analyses. Postop = postoperatively

Procedure

Patients' medical files were used to collect information about the following characteristics: age, sex, anthropometric measurements such as body weight, BMI and waist circumference, and body composition (i.e., DEXA scan results), as well as comorbidities. The data from the DEXA scan were not standardised since many participants needed to mirror the measurement images due to the scanner not being large enough to capture their entire body. Although findings on this reflection technique are promising, individual mistakes may be substantial and may surpass the technical measurement error and thus affect the accuracy of the measurement (Moco et al., 2019). The data that can be extracted from the DEXA scan are total body fat percentage, total body fat and lean mass, and their local distribution throughout the body, namely android fat percentage, gynoid fat percentage, and appendicular lean mass (ALM). The main area of interest is ALM, which represents the muscle mass of the arms and legs. An important measurement in the most suitable parameter for diagnosing SO is the ratio of ALM divided by body weight (ALM/W). According to the cut-offs by Poggiogalle et al., men and women suffer from SO if their ALM/W is < 0.2827 and < 0.2347, respectively, which equals less than two standard deviations (SD) below the mean of the younger reference group (Poggiogalle et al., 2016). These cut-offs will be used to describe SO in this study. Other patient characteristics included information about metabolic phenotype: presence of arterial hypertension (AHT), dyslipidemia, and diabetes mellitus (DM) type 1 or 2 or hyperinsulinemia. This last comorbidity, DM or hyperinsulinemia, will be referred to as DM in the remainder of this thesis, as the type and extent of dysglycemia were not always specified in the patient files.

This study's primary outcome was the BS success at 6 and 12 months postoperatively. As mentioned earlier, successful weight loss can be described as %EWL and %TWL. %EWL was calculated as (preoperative weight – postoperative weight)/(preoperative weight – ideal body weight) x 100. The ideal body weight is based on a BMI < 25 kg/m^2. %TWL was calculated as (preoperative weight – postoperative weight)/(preoperative weight) x 100 (Brethauer et al., 2015).

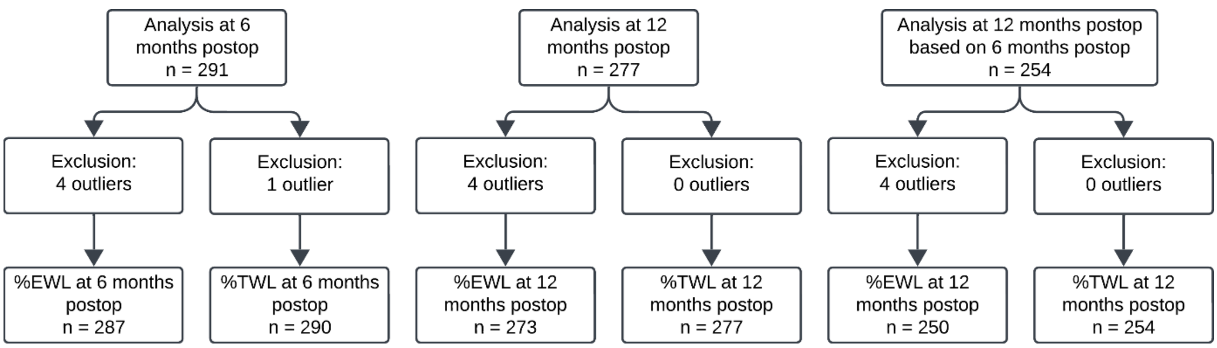
Statistical analysis

The data collected from the patient files was analysed using JMP Pro 17. Descriptive statistics were used to summarise the characteristics of the study population. Preoperative patient characteristics were described in mean and SD or in frequencies with percentages. The interquartile range (IQR) was also mentioned to clarify the degree of statistical dispersion.

Different statistical analyses were used to investigate which preoperative patient characteristics predict the outcome of %EWL and %TWL. For continuous variables, a simple linear regression was used. A significance level of 5% was used ($p < 0.05$). For categorical variables, the Student's *t*-test or Welch's test was used, depending on the variance of the variables, as all categorical variables had two levels. The two-sided p-value was evaluated to determine the statistical significance. If significant ($p < 0.05$), the one-sided p-value was also examined to determine the direction of the linear relationship. If not significant, the one-sided p-value was not interpreted to avoid potential bias. Following the simple linear regression and Student's *t*-test or Welch's test, a multiple linear regression was used to predict the value of %EWL and %TWL based on the value of more than one continuous variable, or a linear model was used in the case of both categorical and continuous variables.

Before the statistical analysis, %EWL and %TWL at 6 and 12 months were checked for outliers using the interquartile range (IQR) method, which dictates that any data point in the boxplot above 1.5 IQR points above the third quartile or 1.5 IQR points below the first quartile is an outlier (Mowbray et al., 2019). The outliers were excluded from the following statistical analysis when this was the case. For the analyses at 6 months postoperatively, four outliers were excluded from the analysis of %EWL, and one from the analysis of %TWL. At 12 months postoperatively, four and zero outliers were excluded from the analysis of %EWL and %TWL, respectively. Figure 2 shows the exclusions and final datasets for the statistical analyses.

Figure 2
Outlier Exclusion Flowcharts



Note. This figure shows a flowchart on the exclusion of participants for different analyses, based on the IQR method. Postop = postoperatively

The continuous variables were analysed in the simple linear regression to predict the outcome of %EWL and %TWL at 6 and 12 months. Firstly, all assumptions were checked. The data in this analysis were independent. Normality was checked using the Shapiro-Wilk test of the residuals. Homoscedasticity and linearity were checked using the Residuals by predicted plot. A transformation was applied to the predictor variable if the residuals were not normally distributed. A squared transformation was used for left-skewed variables, and a log transformation for right-skewed variables. The regression was then repeated with the transformed variable, and the assumptions were again checked.

The categorical variables were analysed using Student's t-test. Data were independent. The assumption of normal distribution did not have to be checked in this case, as there were more than 30 participants. The Brown-Forsythe test was used to check the equality of group variances. If variances were equal ($p > 0.05$), the pooled t-test was used to see if the results were statistically significant. The two-tailed p-value was reported. If significant, the one-tailed p-value was also reported to interpret the statistical significance better. If variances were unequal ($p < 0.05$), the Welch's test was used. For the Welch's test, only a one-sided p-value was reported.

All statistically significant variables from the previous simple model analyses were considered for inclusion in the multiple linear regression or linear model. When performing these analyses, all variables should be independent. First, the correlation between continuous variables was measured using Pearson's r to check this. If the correlation coefficient between two variables was higher than .70 ($r > .70$), a high correlation between those variables was present, possibly indicating multicollinearity. For this reason, only one of the two correlated variables was included in the multiple linear regression analysis. This selection process was based on clinical considerations and the variable's relevance in the clinical setting. After this, a variance inflation factor (VIF) was used to measure the level of multicollinearity in the regression analysis. This multicollinearity arises from the correlation between multiple independent variables in a multiple regression model. If a variable had a VIF > 10, it was removed from the model. Before the multiple linear regression or linear model analysis could be performed, the assumptions of linearity (scatterplot), normality (Shapiro-Wilk), and homoscedasticity (Residuals by predicted plot) still had to be checked, as described earlier. To optimise the model, a stepwise backwards elimination approach was applied. The variable with the highest p-value ($p > 0.05$) was removed iteratively until only significant predictors remained. The final model's assumptions were again checked and evaluated based on the corrected Akaike Information Criterion (AICc) and VIF to ensure the absence of multicollinearity. The stepwise elimination was stopped once the AICc increased, indicating that further variable removal deteriorated the model.

Results

Participants

A total of 314 participants were analysed (see Table 1). 68.8% of participants were female. The mean age of participants was 42 ± 13 years. Participants' mean preoperative weight was 118.0 ± 17.5kg, with a mean BMI of 41.25 ± 4.39 kg/m². DEXA scan results showed a mean total body fat percentage of 49 ± 5%. Based on the ALM/W ratio, 87.9% of participants suffered from SO.

Table 1

Baseline Patient Characteristics

Characteristic	**Mean ± SD**[a]	**IQR**
Age (y)	42 ± 13	32-52
Male (n, %)	98 (31.2%)	-
Female (n, %)	216 (68.8%)	-
Anthropometric measurements		
Weight (kg)	118.0 ± 17.5	104-132
BMI (kg/m²)	41.25 ± 4.39	38.02-43.42
Waist circumference (cm)	128.8 ± 12.2	120-137
DEXA scan		
Total body fat percentage (%)	49.11 ± 5.97	44.70-53.60
Total body fat mass (kg)	55.75 ± 10.18	48.96-61.55
Total body lean mass (kg)	57.06 ± 12.55	48.17-65.36
Android fat percentage (%)	56.93 ± 5.89	53.68-60.70
Gynoid fat percentage (%)	49.07 ± 8.12	43.45-55.53
Android/gynoid ratio	1.19 ± 0.20	1.06-1.27
Male	1.33 ± 0.22	1.21-1.43
Female	1.12 ± 0.16	1.04-1.17
Appendicular lean mass (kg)	26.04 ± 6.37	21.62-29.73
ALM/W	0.22 ± 0.04	0.19-0.24
Sarcopenia (n, %)	276 (87.9%)	-
No sarcopenia (n, %)	38 (12,1%)	-
Comorbidities		
AHT (n, %)	98 (31.2%)	-
Dyslipidemia (n,%)	82 (26.1%)	-
DM (n, %)	100 (31.8%)	-

Note. This table shows patient characteristics preoperatively (n = 314). SD = standard deviation; IQR = interquartile range; BMI = body mass index; ALM/W = appendicular
lean mass/weight; AHT = arterial hypertension; DM = diabetes mellitus.
[a]Unless otherwise specified in characteristic title. [b]Sarcopenia is defined based on the ALM/W measurements and cut-off values (Poggiogalle et al., 2016).

The mean postoperative weight was 87.4 ± 14.9 kg at 6 months and 80.0 ± 15.5kg at 12 months. At 6 months postoperatively, successful weight loss (i.e. %EWL > 50%, and %TWL > 20%) was achieved by 84.5% of participants based on %EWL and 81.8% based on %TWL. The number of participants who achieved successful weight loss increased at 12 months, with 92.4% of participants based on %EWL and 93.9% based on %TWL (see Table 2 and Figure 3).

Table 2

Success of the Bariatric Surgery

Criterium	**Mean ± SD**[a]
6 months postoperatively	
Weight (kg)	87.4 ± 14.9
%EWL	68.03 ± 19.46
Successful[b] (n, %)	246 (84.5%)
Not successful (n, %)	45 (15.5%)
%TWL	25.74 ± 5.84
Successful[c] (n, %)	238 (81.8%)
Not successful (n, %)	53 (18.2%)
12 months postoperatively	
Weight (kg)	80.0 ± 15.5
%EWL	84.64 ± 23.32
Successful (n, %)	256 (92.4%)
Not successful (n, %)	21 (7.6%)
%TWL	32.07 ± 7.74
Successful (n, %)	260 (93.9%)
Not successful (n, %)	17 (6.1%)

Note. This table shows the mean and SD of weight, as well as the success of the bariatric surgery at 6 months (n = 291) and at 12 months (n = 277). SD = standard deviation; %EWL = percentage excessive weight loss; %TWL = percentage total weight loss.

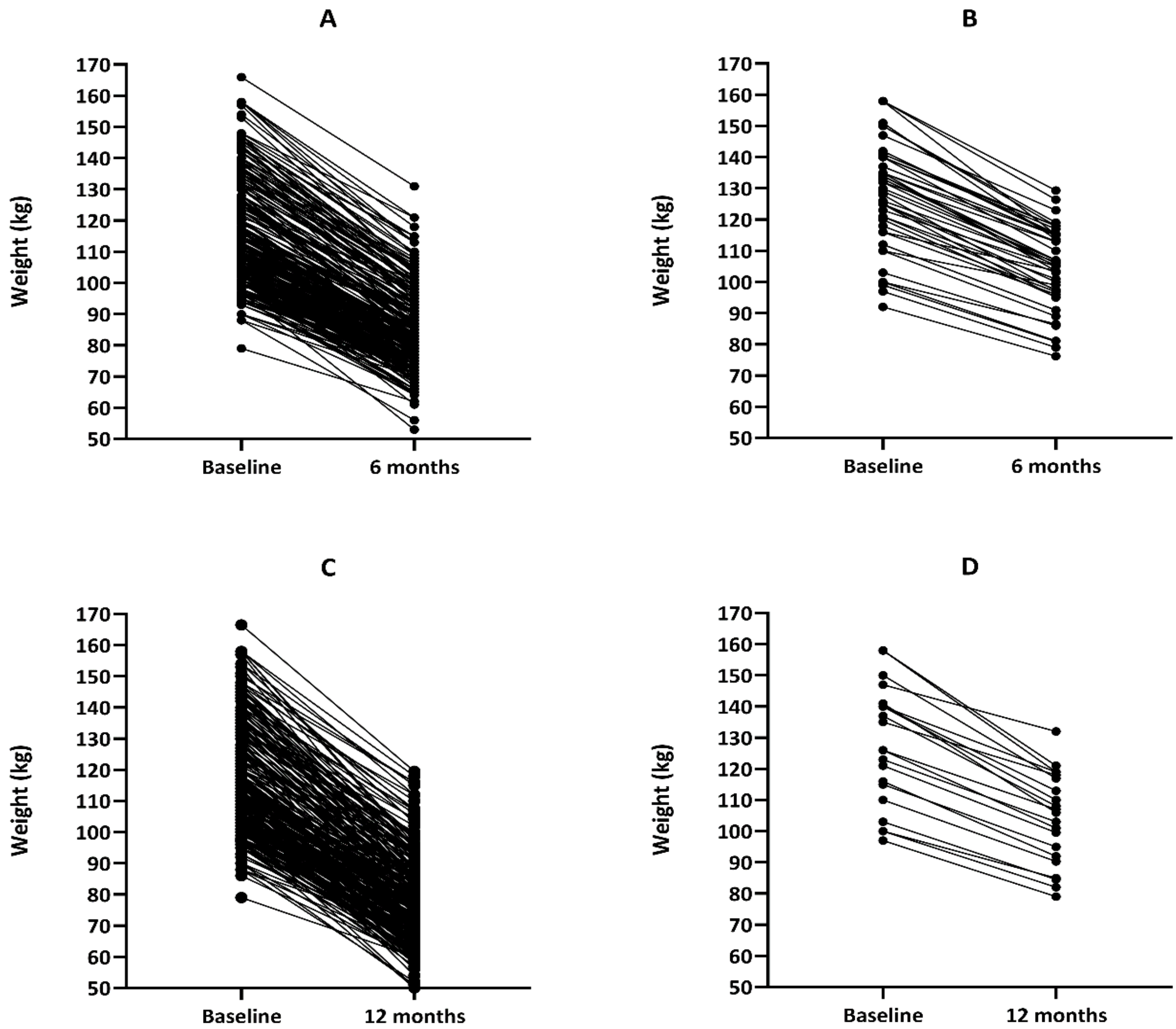
[a]Unless otherwise specified in criterium title.

[b]Weight loss was successful if %EWL > 50%.

[c]Weight loss was successful if %TWL > 20%.

Figure 3

Successful and unsuccessful weight loss



Note. This figure shows the progression from baseline weight to weight at 6 and 12 months, for participants with successful weight loss and those without, based on %EWL. **A**: Successful weight loss at 6 months, **B**: Unsuccessful weight loss at 6 months, **C**: Successful weight loss at 12 months, **D**: Unsuccessful weight loss at 12 months

Simple models

Simple linear regression analyses showed that, of all examined variables, age (p = .045, R^2 = .014), body weight (p < .001, R^2 = .092), waist circumference (p < .001, R^2 = .091), BMI (p < .001, R^2 = .285), gynoid fat percentage (p = .041, R^2 = .015), total body fat percentage (p = .003, R^2 = .032), and total body fat mass (p < .001, R^2 = .139) were significantly negatively associated with %EWL at 6 months postoperatively, and ALM/W (p = .002, R^2 = .034) was significantly positively associated with %EWL. In the analysis for %TWL at 6 months postoperatively, only age (p < .001, R^2 = .054) was a significant negative predictor. Age (p < .001, R^2 = .056), weight (p < .001, R^2 = .103), waist circumference (p < .001, R^2 = .083), BMI (p < .001, R^2 = .219), total body fat mass (p < .001, R^2 = .056), total body lean mass (p < .001, R^2 = .047), and appendicular lean mass (p = .003, R^2 = .032) were all significant negative predictors of %EWL at 12 months postoperatively. Also at 12 months postoperatively, age (p < .001, R^2 =.114), total body lean mass (p = .005, R^2 = .028), appendicular lean mass (p = .014, R^2 = . 022), and ALM/W (p = .003, R^2 = .033) were significantly negatively associated with %TWL, while android fat percentage (p < .001, R^2 = .062), gynoid fat percentage (p < .001, R^2 = .045), and total body fat percentage (p < .001, R^2 = .041) were significant positive predictors of %TWL (Table 3).

Furthermore, a linear regression analysis was performed to check whether there was a linear relationship between characteristics at 6 months postoperatively, namely %EWL, %TWL, weight and BMI and %EWL and %TWL at 12 months postoperatively. %EWL at 6 months postoperatively (p < .001, R^2 = .739), and %TWL at 6 months postoperatively (p < .001, R^2 = .508) were significant positive predictors, and weight at 6 months postoperatively (p < .001, R^2 = .366), and BMI at 6 months postoperatively (p < .001, R^2 = .640) were significant negative predictors of %EWL at 12 months postoperatively. Both %EWL (p < .001, R^2 = .365), and %TWL at 6 months postoperatively (p < .001, R^2 = .679) were significant positive predictors of %TWL at 12 months postoperatively, and weight (p < .001, R^2 = .160), and BMI at 6 months postoperatively (p < .001, R^2 = .204) were significant negative predictors (Table 3).

Table 3

Results of Simple Models

	6 months postoperatively							
	%EWL				%TWL			
Continuous variable	Estimate	Std Error	p-value*	R^2	Estimate	Std Error	p-value	R^2
Age	–0.16	0.08	**0.045**	0.014	–0.10	1.09	**<.001**	0.054
Weight	–0.31	0.06	**<.001**	0.092	–0.01	0.02	0.712	0.001
Waist circumference	–0.43	0.09	**<.001**	0.091	0.003	0.03	0.920	<0.001
BMI	–2.24	0.21	**<.001**	0.285	–0.07	0.08	0.411	0.002
Android fat percentage	–0.23	0.20	0.252	0.005	0.07	0.07	0.279	0.004
Gynoid fat percentage	–0.26	0.13	**0.041**	0.015	0.01	0.04	0.890	<0.001
Total body fat percentage	–0.53	0.18	**0.003**	0.032	–0.03	0.06	0.583	0.001
Total body fat mass	–0.0007	0.0001	**<.001**	0.139	0.00003	0.00003	0.298	0.004
Total body lean mass	–0.0002	0.0001	0.074	0.011	0.00001	0.00003	0.593	0.001
Appendicular lean mass	–0.0001	0.0002	0.513	0.002	0.00001	0.0001	0.884	<0.001
ALM/W	82.45	26.03	**0.002**	0.034	3.37	8.53	0.693	0.001
Categorical variables	Difference	Std Err Dif	p-value	R^2	Difference	Std Err Diff	p-value	R^2
Sex	0.61	2.27	0.789	<0.001	0.46	0.73	0.527	0.001
SO	–2.60	3.21	0.418	0.002	0.22	1.02	0.827	<0.001
AHT	–1.78	2.24	0.427	0.002	–1.10	7.86	0.431[a]	-
Dyslipidemia	–1.59	2.39	0.506	0.002	–0.05	0.76	0.947	<0.001
DM	–2.26	2.24	0.346[a]	-	–0.25	0.72	0.732	<0.001

Table 3 (continued)

Results of Simple Models

	12 months postoperatively							
	%EWL				%TWL			
Continuous variable	Estimate	Std Error	p-value	R^2	Estimate	Std Error	p-value	R^2
Age	–0.39	0.10	**<.001**	0.056	–0.20	0.03	**<.001**	0.114
Weight	–0.40	0.07	**<.001**	0.103	–0.01	0.03	0.631	<0.001
Waist circumference	–0.51	0.11	**<.001**	0.083	0.01	0.05	0.888	<0.001
BMI	–2.32	0.27	**<.001**	0.219	0.08	0.11	0.427	0.002
Android fat percentage	0.31	0.23	0.174	0.007	0.33	0.08	**<.001**	0.062
Gynoid fat percentage	0.16	0.16	0.320	0.004	0.20	0.06	**<.001**	0.045
Total body fat percentage	0.03	0.22	0.899	<0.001	0.27	0.08	**<.001**	0.041
Total body fat mass	–0.0005	0.0001	**<.001**	0.056	0.0001	0.00004	0.065	0.012
Total body lean mass	–0.0003	0.0001	<.001	0.047	–0.0001	0.00003	**0.005**	0.028
Appendicular lean mass	–0.0006	0.0002	**0.003**	0.032	–0.0002	0.0001	**0.014**	0.022
ALM/W	8.41	33.43	0.802	<0.001	–35.59	11.64	**0.003**	0.033
Categorical variables	Difference	Std Err Dif	p-value	R^2	Difference	Std Err Diff	p-value	R^2
Sex	6.89	2.85	**0.016**[b]	0.021	3.22	0.99	**0.001**[b]	0.037
SO	2.80	4.23	0.508	0.002	2.79	1.47	0.059	0.013
AHT	–8.06	2.79	**0.004**[b]	0.030	–3.00	0.99	**0.001**[a, b]	-
Dyslipidemia	–6.65	2.96	**0.026**[b]	0.018	–1.71	1.04	0.103	0.010
DM	–4.29	2.85	0.134	0.008	–0.49	1.01	0.626	0.001

Table 3 (continued)

Results of Simple Models

	12 months postoperatively							
	%EWL				%TWL			
6 months	Estimate	Std Error	p-value	R^2	Estimate	Std Error	p-value	R^2
Weight 6 months	–0.91	0.08	**<.001**	0.366	–0.21	0.03	**<.001**	0.160
BMI 6 months	–4.42	0.21	**<.001**	0.640	–0.88	0.11	**<.001**	0.204
%EWL 6 months	1.07	0.04	**<.001**	0.739	0.24	0.02	**<.001**	0.365
%TWL 6 months	0.05	0.003	**<.001**	0.508	1.09	0.05	**<.001**	0.679

Note. This table shows the results of the simple linear regression, Student's t-test, and Welch's test. For the student's t-test, the two-sided p-value was shown. Statistically significant p-values were highlighted in bold. P-values were reported to three decimal places, with values below .001 reported as "<0.001". R^2 values were rounded to three decimal places. All other values were rounded to two decimal places, except for extremely small values to avoid misleading rounding to zero. Std Error = standard error; R^2 = coefficient of determination; Std Err Dif = standard error difference; %EWL = percentage excessive weight loss; %TWL = percentage total weight loss; BMI = body mass index; ALM/W = appendicular lean mass/weight; SO = sarcopenic obesity; AHT = arterial hypertension; DM = diabetes mellitus.

[a]Welch's test was used due to unequal variances. No R^2 was given for these variables.

[b]Two-tailed p-values are shown in this table, one-tailed p-values are reported in the results section

*p < .05

The assumptions for the analyses of categorical variables were checked. At 6 months postoperatively, there was no significant difference in %EWL based on sex, nor the presence of SO, AHT, dyslipidemia, and DM. Again, no significant differences were found for %TWL at 6 months postoperatively. At 12 months postoperatively, a significantly higher %EWL was observed in women ($p = .008$, $R^2 = .021$), participants without dyslipidemia ($p = .013$, $R^2 = .018$), and those without AHT ($p = .002$, $R^2 = .030$). A significantly higher %TWL was found in women ($p < .001$, $R^2 = .037$) and participants without AHT ($p < .001$) (see Table 3).

Multiple models

For the analysis of %EWL at 6 months postoperatively, there was a high correlation ($r > .70$) between weight and waist circumference ($r = .7320$), as well as between gynoid fat percentage and total body fat percentage ($r = .8968$). Based on clinical relevance, it was decided to continue with waist circumference and total fat percentage. Based on the outcomes of the simple linear regression analyses, other significant continuous variables were also included in the model; in this case, no categorical variables were further analysed. No variable in this analysis had a VIF > 10, so all variables were kept in the analysis. The assumptions were met. In the simplified model predicting %EWL at 6 months postoperatively, the overall model was statistically significant ($p < .001$, R^2 adjusted = .298), indicating that the following predictors explained approximately 29.8% of the variance in %EWL. Age was significantly negatively associated with %EWL (estimate = –.19, $p = .009$, $\beta = –.14$), indicating that each additional year of age decreases the %EWL at 6 months postoperatively by .19 percentage points. Similarly, BMI showed a significant negative association with %EWL (estimate = –2.32, $p < .001$, $\beta = –.57$). For each one-unit increase in BMI, the expected %EWL decreases by 2.32 percentage points. The standardised indicates that BMI has the most substantial impact on %EWL 6 months postoperatively (see Table 4).

No multiple regression analysis was performed for %TWL at 6 months postoperatively, as there was only one significant continuous variable and no significant categorical variable predicting %TWL (see Table 4).

For the analysis of %EWL at 12 months postoperatively, there was a high correlation between weight and waist circumference ($r = .7510$), and between appendicular lean mass and total body lean mass (r = .7673). The analysis continued with waist circumference and total body lean mass for their clinical relevance. All other significant continuous variables were included in the linear model, as well as the statistically significant categorical variables. Again, none of the analysed variables had a VIF > 10. The assumptions were met. For %EWL at 12 months postoperatively, the simplified model (p < .001, adjusted R^2 = .291) explained 29.1% of the variance. Age was significantly negatively associated with %EWL (estimate = –.42, p <.001, β = –.25), indicating that for each additional year, %EWL decreased by 0.42 percentage points. BMI was also significantly negatively associated with %EWL (estimate = –2.57, p < .001, β = –.52), meaning that for each unit increase in BMI, %EWL decreased by 2.57 percentage points. Additionally, total body lean mass showed a small but significant negative association (estimate = –.0003, p = .004, β = –.17), suggesting that higher lean mass was linked to a slightly lower %EWL (see Table 4).

A high correlation was found between total body fat percentage and android fat percentage (r = .7103), total body fat percentage and gynoid fat percentage (r = .8914), total body lean mass and appendicular lean mass (r = .7682), and appendicular lean mass and ALM/W (r = .7690), in the analysis of %TWL at 12 months. The analysis continued without total body fat percentage, as android and gynoid fat percentage give a better understanding of metabolic consequences (Muscogiuri et al., 2024). Total body lean mass was again chosen over appendicular lean mass. ALM/W was further included in the model, as it gives a clearer picture of appendicular lean mass, being adjusted for weight. The assumptions were met, and no variables showed a VIF > 10. At 12 months, the simplified model significantly explained 13.4% of the variance in %TWL (p < .001, R^2 adjusted = .134). Age was negatively associated with %TWL (estimate = –.17, p < .001, β = –.29), indicating that for each additional year, %TWL decreased by 0.17 percentage points. In contrast, android fat percentage was positively associated with %TWL (estimate = .22, p = .004), meaning that a higher percentage of android fat was linked to a greater %TWL at 12 months postoperatively (see Table 4).

In the analysis of %EWL at 12 months postoperatively, assessing the predictors at the 6-month time point, there was a high correlation between BMI and %EWL at 6 months postoperatively (r = –.9126), and between %TWL and %EWL at 6 months postoperatively (r = .8051). %EWL at 6 months postoperatively was removed from the analysis. The assumptions were met, and no included variables showed a VIF > 10. The model was not further simplified, as removing one of the remaining variables increased the AICc. The full model was statistically significant ($p < .001$, R^2 adjusted = .721), explaining 72.1% of the variance in %EWL at 12 months. BMI at 6 months was a significant negative predictor (estimate = –2.94, $p < .001$, $\beta = –.54$), meaning that a higher BMI at 6 months was strongly associated with a lower %EWL at 12 months. %TWL at 6 months was a significant positive predictor (estimate = 1.37, $p < .001$, $\beta = .35$), indicating that a greater percentage of total weight loss at 6 months was associated with a higher %EWL at 12 months (see Table 4).

In the analysis of %TWL at 12 months postoperatively, there was a high correlation between BMI and weight at 6 months ($r = .7031$), BMI and %EWL at 6 months ($r= –.9102$), and between %TWL and %EWL at 6 months ($r = .8156$). Both BMI and %EWL at 6 months were removed from the analysis. The assumptions were met, and the remaining variables did not have a high VIF. At 12 months, the simplified model significantly explained 67.7% of the variance in the %TWL ($p < .001$, R^2 adjusted = .677). Only %TWL at 6 months was a significantly positive predictor of %TWL at 12 months (estimate = 1.09, $p < .001$, $\beta = .82$), implying that a higher %TWL at 6 months resulted in a higher %TWL at 12 months. The results of all multiple linear regressions or linear models before and after the stepwise backwards elimination are shown below (see Table 4).

Table 4

Results of Multiple Models

%EWL 6m (n = 287)						
	p-value	R^2 adjusted	AICc			
Full model	<0.001	0.313	2072			
	Estimate	Std Error	t Ratio	p-value*	Std β	VIF
Intercept	178.05	20.67	8.61	<.001	0.00	-
Age	–0.21	0.07	–2.84	**0.005**	–0.17	1.10
Waist circumference	0.07	0.10	0.67	0.502	0.04	1.85
BMI	–2.17	0.30	–7.23	**<.001**	–0.52	1.91
Total body fat percentage	–0.28	0.27	–1.04	0.299	–0.10	2.98
Total body lean mass	–0.0002	0.0001	–1.36	0.174	–0.12	2.62
ALM/W	5.88	30.07	0.20	0.845	0.01	1.73
	p-value	R^2 adjusted	AICc			
Simplified model	<0.001	0.298	2069			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	166.58	11.14	14.96	<.001	0.00	
Age	–0.19	0.07	–2.62	**0.009**	–0.14	1.02
Waist circumference	0.06	0.10	0.58	0.565	0.04	1.83
BMI	–2.32	0.27	–8.61	**<.001**	–0.57	1.55
Total body lean mass	–0.0001	0.0001	–0.70	0.482	–0.04	1.25

Table 4 (continued)

Results of Multiple Models

%EWL 12m (n = 273)						
	p-value	R^2 adjusted	AICc			
Full model	<0.001	0.289	2120			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	199.42	16.50	12.08	<.001	0.00	
Age	–0.36	0.10	–3.43	**<.001**	–0.21	1.29
Waist circumference	0.15	0.14	1.02	0.311	0.08	2.20
BMI	–2.80	0.39	–7.18	**<.001**	–0.56	2.08
Total body fat mass	0.0002	0.0002	0.83	0.407	0.07	2.55
Total body lean mass	–0.0002	0.0001	–1.65	0.100	–0.14	2.41
Sex	–1.13	2.14	–0.53	0.597	–0.05	2.77
Dyslipidemia	1.05	1.40	0.75	0.455	0.04	1.13
AHT	0.78	1.46	0.53	0.594	0.03	1.32
	p-value	R^2 adjusted	AICc			
Simplified model	<0.001	0.291	2115			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	204.30	14.06	14.53	<.001	0.00	
Age	–0.42	0.09	–4.58	**<.001**	–0.25	1.03
Waist circumference	0.16	0.13	1.23	0.221	0.09	1.86
BMI	–2.57	0.34	–7.54	**<.001**	–0.52	1.60
Total body lean mass	–0.0003	0.0001	–2.87	**0.004**	–0.17	1.24

Table 4 (continued)

Results of Multiple Models

%TWL 12m (n = 277)						
	p-value	R^2 adjusted	AICc			
Full model	<0.001	0.124	1886			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	32.63	8.95	3.65	0.0003	0.00	
Age	–0.17	0.04	–4.70	**<.001**	–0.29	1.16
Android fat percentage	0.16	0.10	1.64	0.101	0.12	1.61
Gynoid fat percentage	0.04	0.09	0.41	0.683	0.04	2.54
Total body lean mass	0.00004	0.0001	–0.88	0.380	–0.07	2.14
ALM/W	–6.98	13.72	–0.51	0.611	–0.04	1.54
Sex	0.35	0.81	0.44	0.663	0.04	2.96
Dyslipidemia	0.23	0.50	0.46	0.644	0.03	1.05
	p-value	R^2 adjusted	AICc			
Simplified model	<0.001	0.134	1878			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	26.55	5.04	5.27	<.001	0.00	
Age	–0.17	0.03	–4.98	**<.001**	–0.29	1.08
Android fat percentage	0.22	0.08	2.88	**0.004**	0.17	1.08

Table 4 (continued)

Results of Multiple Models

%EWL 12m (n = 250)						
	p-value	R^2 adjusted	AICc			
Full model	<0.001	0.721	1932			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	147.41	10.12	14.56	<.001	0.00	
Weight 6 months	–0.11	0.07	–1.62	0.106	–0.07	1.87
BMI 6 months	–2.94	0.28	–10.50	**<.001**	–0.54	2.34
%TWL 6 months	1.37	0.16	8.45	**<.001**	0.35	1.56
%TWL 12m (n = 254)						
	p-value	R^2 adjusted	AICc			
Full model	<0.001	0.676	1471			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	3.91	2.80	1.39	0.165	0.00	
Weight 6 months	–0.0023	0.02	–0.11	0.915	–0.0044	1.30
%TWL 6 months	1.09	0.05	20.13	**<.001**	0.82	1.30
	p-value	R^2 adjusted	AICc			
Simplified model	<0.001	0.677	1469			
	Estimate	Std Error	t Ratio	p-value	Std β	VIF
Intercept	3.64	1.26	2.88	**0.004**	0.00	
%TWL 6 months	1.09	0.05	23.07	**<.001**	0.82	1.00

Note. This table shows the results of the multiple linear regression and linear models. P-values were reported to three decimal places, with values below .001 reported as "<0.001". R^2 values were rounded to three decimal places. AICc values were rounded to the nearest whole number. All other values were rounded to two decimal places, except for extremely small values to avoid misleading rounding to zero. In cases where values were extremely small, more decimal places were reported to maintain accuracy. R^2 adjusted = adjusted coefficient of determination; AICc = corrected Akaike Information Criterion; Std Error = standard error; Std β = standardised β; VIF = variance inflation factor; %EWL = percentage excessive weight loss, %TWL = percentage total weight loss; BMI = body mass index; ALM/W = appendicular lean mass/weight; AHT = arterial hypertension.

*p < .05

Discussion

This study aimed to identify preoperative predictors of successful weight loss after bariatric surgery. At 6 months, the mean %EWL was 68.0%, which increased to 84.6% at 12 months. Mean %TWL also increased over time, from 25.7% at 6 months to 32.0% at 12 months. Compared to an extensive systematic review and meta–analysis by O'Brien et al., where the mean %EWL and %TWL at 1 year postoperatively were 45.8% and 18.1%, respectively, the current values of %EWL and %TWL were relatively high. This difference may be due to the moderately high inter-individual variability found in the SD in the study by O'Brien et al (O'Brien et al., 2019). This highlights the heterogeneity in outcomes of bariatric surgery. Understanding the underlying factors contributing to this variability is essential. Their study also showed that the peak of weight loss was reached at 2 years postoperatively, and remained stable for up to 20 years, where 54% of participants reached the success marker of 50% EWL, with a mean %EWL of 48.9%, and a mean %TWL of 22.2% (O'Brien et al., 2019).

Our results showed that age and baseline BMI negatively predicted variation in %EWL at 6 months. At 12 months, %EWL was also explained by these factors, in addition to total body lean mass, which again negatively influenced %EWL. %TWL at 6 months was only predicted by age, while %TWL at 12 months was predicted by age, and android fat percentage. Some of these findings align with previous literature. A systematic review by Livhits et al. found that a higher preoperative BMI is linked to less favourable weight loss outcomes, mainly when measured in relative terms like %EWL (Livhits et al., 2012). A recent study by Giustacchini et al., analysing preoperative body composition by bioelectrical impedance, confirmed that a older age, and higher BMI lead to a lower, and therefore suboptimal (based on weight loss below the 25th percentile of %EWL), weight loss (Giustacchini et al., 2025), which corresponds with the present results. Lu et al. showed that umbilical subcutaneous adipose tissue (measured by computerized tomography) positively influences postoperative weight loss outcomes. Although this measurement is not exactly the same as android fat percentage, these findings align with the positive association of android fat percentage on %TWL at 12 months (Lu et al., 2025). Related to body composition, it was shown recently that that baseline weight, BMI, waist and hip circumference, total body fat mass and percentage, visceral fat mass, obesity degree, and fat mass of the trunk and legs were all negatively associated with %EWL after 3 months in individuals with obesity undergoing bariatric surgery (Ji et al., 2025).

Furthermore, in our study no effect of sex was found, and this was confirmed by Risi et al., who found that sex had no clear effect on the weight loss results of BS (Risi et al., 2022). At 6 months, BMI, %EWL, and %TWL also had a predictive value at 1 year postoperatively. A higher BMI and %TWL at 6 months, resulted in a higher %EWL at 12 months, and a higher %TWL at 6 months resulted in a higher %TWL at 12 months. This shows that a higher early weight loss leads to better long term outcomes. This has previously been shown by Chu et al., who demonstrated that a greater %EWL at 3 months results in a significantly greater %EWL at 24 months, with %EWL ≥ 30% at 3 months being a predictor of successful weight loss (%EWL > 50%) at both 12 and 24 months (Chu et al., 2019).

Different from our study, where the comorbidity of DM did not affect weight loss success, Luo et al. found that the presence of DM before surgery negatively influenced weight loss outcomes (Luo et al., 2023). These findings were corroborated by Dixon et al., where hyperinsulinemia and insulin resistance were associated with a lower %EWL at 12 months follow-up (Dixon et al., 2001). This difference in outcomes between these studies and our study could be due to the poor description of the type of dysglycemia in the patient files, and therefore, suboptimal collection of data on this comorbidity.

The results showed that only part (13.4-72.1%) of the success of bariatric surgery could be explained by the predictors examined in this study, which means that there must be other explanatory variables for weight loss success, such as psychological and socioeconomic factors, dietary habits, and motivation, which were not included in this study due to the lack thereof in the patient files. Livhits et al. investigated multiple other preoperative factors, such as preoperative weight loss, eating disorders, eating habits, and psychiatric disorders. Results showed that preoperative weight loss was associated with more significant weight loss after the surgery. This review lacked studies about eating habits and psychiatric disorders to make a clear association with postoperative weight loss (Livhits et al., 2012). However, maladaptive eating habits, such as binge eating and emotional eating, have been associated with poor outcomes from bariatric surgery (Masnyj et al., 2020). Another study by Aylward et al. found that higher anxiety before surgery was linked to reduced long-term weight loss. Other psychological predictors, such as depression, binge eating, and disinhibition, were not found to be related to weight loss success (Aylward et al., 2022). Jacobs et al. investigated the influence of preoperative and postoperative psychological and behavioural factors on weight loss in a meta-analyis and found that the preoperative presence of binge eating and depression did not impact weight loss, while postoperative binge eating and low compliance did negatively effect weight loss after BS (Jacobs et al., 2024).

It is important to note that success is not only determined by the patient's preoperative characteristics, but is also strongly influenced by their postoperative behaviour. A study investigating eating behaviour demonstrated a lower percentage of weight loss due to disordered behaviour and attitudes towards eating (Allison et al., 2023). Exercise training after BS can improve weight and fat loss, and may even prevent weight regain postoperatively (Bellicha et al., 2021). More self-reported active coping behaviour was more favourable for higher postoperative weight loss. However, no evidence was found that motivation was important in weight loss success after bariatric surgery (Figura et al., 2015).

In this study, the presence of SO was recorded from the patient files. An important note that must be made is that SO was based solely on an indicator of fat-free mass (ALM/W) in this study, collected from the DEXA scan data, and not on the combination of muscle mass and muscle function as described in the recent definition of the ESPEN and EASO Consensus Statement (Donini et al., 2022). The results of the analyses might have been different if data on muscle function were available. As mentioned before, the reflection technique was used where necessary in the DEXA scan, which could also have affected the accuracy of the results of this study. Mastino et al. investigated whether SO before BS influenced the success of weight loss. Compared to our study, their definition of SO was based on muscle strength and mass. They found that SO did not impact the BS success outcomes (% excessive BMI loss, %EWL, % mean weight loss, and mean absolute weight loss) one year postoperatively (Mastino et al., 2016). Another study showed that patients undergoing BS with the most severe SO lost the smallest amount of skeletal muscle mass, while having the most significant reduction in fat mass (Rodrigues et al., 2024). While this study solely focused on preoperative sarcopenia, it is equally important to consider the development and/or evolution of sarcopenia in the postoperative period. Weight loss after BS can lead to unintended loss of lean mass, potentially increasing the risk of sarcopenia (Faria et al., 2024). Pekař et al. found a significant decrease in fat mass, associated with a significant decrease in muscle mass at 2 years postoperatively. They also found that a low level of physical activity postoperatively might contribute to this loss of lean mass (Pekař et al., 2020). Of interest, data by Molero et al. showed that a low level of skeletal muscle mass is present in 25% of patients 1 year after BS, and a low level of skeletal muscle mass before BS is an independent risk factor for loss of lean mass after BS (Molero et al., 2022). This low amount of lean mass was found to be associated with a higher risk of all-cause mortality (Liu et al., 2022). Given the development and potential consequences of sarcopenia after BS, it is important to develop strategies that help prevent the loss of lean mass by providing adequate support to patients postoperatively. Exercise therapy, supervised by physiotherapists, could be considered to counteract the loss of lean muscle mass after BS and therefore prevent the negative consequences of sarcopenia.

This study has limitations related to the lack of information on individual differences in preoperative characteristics such as psychosocial, behavioural and lifestyle factors. Furthermore, the follow-up of this study was limited to 12 months, which means that the prediction of success cannot be made in the long term. A follow-up period of at least 2 years is indicated, as the peak of weight loss is reached around this time period and then stabilizes (O'Brien et al., 2019). Postoperatively, there was a lack of information on comorbidities and body composition via the DEXA scan, which were analysed preoperatively. As a result, the impact of bariatric surgery on these outcomes could not be investigated. As mentioned before, sarcopenia does not only occur before surgery, but can also develop after surgery and cause unwanted consequences (Faria et al., 2024). For this reason, sarcopenia should be monitored postoperatively. A review by Sandoval et al. explored the potential mechanisms leading to DM remission after BS, highlighting that improvements in glucose metabolism are related not only to the magnitude of weight loss after BS but also to the early improvement of glycemic control observed shortly after the surgery, even before substantial weight loss has occurred (Sandoval & Patti, 2023). Other metabolic comorbidities, including dyslipidemia, AHT, and inflammation, improved after BS, with the amount of sustained weight loss related to the magnitude of long-term improvements in these metabolic conditions (Iqbal et al., 2020). Silva et al. observed a decrease in total body fat percentage and an increase in percentage of skeletal muscle mass and total body lean mass, independent of the surgery type (Silva et al., 2019). There was a lack of data on satisfaction or remission of comorbidities after surgery, which suggests that 'success' should not solely be based on weight loss. Although this is the primary goal of BS, the remission of comorbidities and the improvement of quality of life should also be considered when evaluating if the surgery was successful.

The findings of these studies offer valuable insights for clinical practice, particularly regarding preoperative screening. Since age, BMI, and body composition measurements such as fat distribution, waist and hip circumference are valuable predictors of success, as well as psychosocial factors, it should be considered to monitor these parameters prior to surgery. This way, surgeons and other health care professionals can better identify which patients are eligible for bariatric surgery, or even measure which patients would need more preoperative or postoperative support such as nutritional advice, exercise therapy or counselling.

Conclusion

In conclusion, this study identified preoperative predictors of successful weight loss after bariatric surgery, including age, baseline BMI, and body composition measurements such as total body lean mass and android fat percentage. The results showed improvements in both %EWL and %TWL over the first 12 months. However, only part of the success of bariatric surgery could be found to be explained by the predictors examined in this study. Other factors, both preoperative and postoperative, such as psychological conditions, eating habits, behaviour; and motivation, likely play an important role in the success of weight loss following surgery. While our study provides valuable insights into the role of preoperative factors in predicting weight loss success, future research should include these additional factors to provide a more complete view of bariatric surgery outcomes. Incorporating these factors into future research can improve patient management and optimise long-term weight loss success.

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