

Outcomes of Metabolic and Bariatric Surgery in Adolescent and Young Adult versus Adult Patients: A Comparative Cohort Study

Ana Luiza Almeida Medel

up202007474@up.pt

University of Porto

Research Article

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Abstract

Background

Metabolic and bariatric surgery (MBS) is an effective treatment for severe obesity, but comparative data between adolescents and young adults (AYA) and adults remain limited. This study aimed to evaluate weight loss and metabolic outcomes after MBS in AYA compared with adults.

Methods

We conducted a retrospective cohort study including AYA (≤ 21 years) and adults (> 21 years) who underwent MBS (sleeve gastrectomy and Roux-en-Y gastric bypass) between 2013 and 2023. Propensity score matching was performed separately for each outcome using nearest-neighbor matching (up to three adult controls per AYA, without replacement) based on baseline characteristics (type of surgery, sex, BMI, prediabetes, hypertension, and dyslipidemia). Weight loss and metabolic outcomes (prediabetes, hypertension, dyslipidemia) were assessed at 1-, 2-, and 3-year follow-up.

Results

At 1 year, adolescents and young adults achieved lower percentage total weight loss (%TWL) compared with adults (21.2% vs 32.5%; average treatment effect on the treated (ATT) – 11.2%; 95% CI – 14.2 to – 8.3; $p < 0.001$). Similar differences were observed at 2 years (25.9% vs 31.7%; ATT – 5.8%; 95% CI – 9.9 to – 1.7; $p = 0.006$), and 3 years (29.8% vs 31.5%; ATT – 1.7%; 95% CI – 5.2 to 1.7; $p = 0.324$). Prevalence of dyslipidemia was lower in AYA at 3 years (18.9% vs 35.1%; ATT – 16.2; 95% CI – 32.1 to – 0.4; $p = 0.045$).

Conclusions

MBS was effective in both groups, leading to significant weight loss and metabolic improvements. Despite lower early weight loss, AYA achieved comparable metabolic benefits. Earlier surgical intervention may be beneficial to reduce consequences of adipotoxicity exposure.

Key points

- o Metabolic bariatric surgery led to significant weight loss in both groups.
- o Early weight loss was lower in adolescents and young adults but similar between groups at 3 years follow-up.
- o Metabolic outcomes were similar between groups.
- o Dyslipidemia improved significantly in adolescents and young adults at 3 years follow-up.

Introduction

Pediatric obesity is a growing public health concern worldwide. Children and adolescents with obesity are more likely to remain obese into adulthood (1). Early-onset obesity is associated with cumulative adverse health effects (2).

Although first-line interventions—diet, physical activity, and behavioral therapy—can be effective, they are associated with high relapse rates in patients with severe obesity and are often insufficient (3). Therefore, metabolic and bariatric surgery (MBS) during adolescence has emerged as an effective intervention for achieving sustained weight loss and improving obesity-related conditions (4, 5). Studies have shown favorable metabolic and weight outcomes in these groups without compromising safety (6).

Available evidence suggests that MBS in younger patients can lead to substantial and durable weight loss, with reported excess weight loss of approximately 30–35% at 5 years, along with remission of obesity-related conditions such as hypertension and dyslipidemia (7).

While most of the MBS literature focuses on adult patients, direct comparisons between younger and adult patients undergoing similar procedures in comparable clinical settings remain scarce (6, 8). As a result, it remains uncertain whether younger individuals achieve superior, comparable, or inferior outcomes in terms of weight loss and resolution of obesity-related conditions compared with adults.

Given this knowledge gap, this study aimed to compare weight loss and remission of obesity-related conditions between adolescents and young adults (AYA) and adults undergoing MBS over a 3-year follow-up.

Methods

Study Design and Population

This retrospective observational study compared two groups: AYA group (≤ 21 years) and older adults (> 21 years) with obesity (body mass index [BMI] ≥ 30 kg/m²) who underwent MBS (sleeve gastrectomy and Roux-en-Y gastric bypass) at a tertiary referral center between 2013 and 2023. Adolescents and young adults were matched to up to three adult controls using propensity score matching without replacement.

Data Sources and Data Collection

Clinical data were obtained from an institutional database derived from information extracted from the electronic health record (EHR) system. This database was prospectively developed and maintained for longitudinal clinical research purposes. Data were originally collected from structured and unstructured clinical records, including outpatient consultations and laboratory results. Patients were excluded if they had a history of previous MBS, pregnancy during the predefined follow-up period, or secondary obesity due to identifiable causes such as genetic syndromes or endocrinopathies. Patients who underwent laparoscopic adjustable gastric banding were also excluded.

Patients were evaluated preoperatively and followed at 1, 2, and 3 years after surgery. For each time point, the value closest to the scheduled follow-up was used, considering a window of ± 30 days before surgery for baseline and ± 6 months around each postoperative follow-up year.

Clinical and Laboratory Variables

Demographic, clinical, anthropometric, and laboratory variables were obtained. Demographic variables included age and sex. Clinical variables included type of MBS, previous diagnosis of Type 2 diabetes (T2DM), and systolic and diastolic blood pressure (BP). Anthropometric measurements included height, weight, and BMI. Laboratory parameters included glycated hemoglobin (HbA1c), fasting plasma glucose, C-peptide, insulin, lipid profile (LDL-C, HDL-C, and triglycerides), liver enzymes (ALT, AST, gamma-GT), urinary albumin excretion, and estimated glomerular filtration rate (eGFR). Medication use was also recorded, including antihypertensive drugs, oral antidiabetic agents, insulin, statins, fibrates, and glucagon-like peptide-1 receptor agonists (GLP-1RAs). Treatment use was assessed at baseline and continuity of therapy was evaluated during the follow-up period.

Definitions of Outcomes

Weight loss was assessed as the percentage of total weight loss (%TWL) relative to preoperative weight, calculated as:

$$\%TWL = ((\text{Preoperative weight} - \text{follow-up weight}) / \text{Preoperative weight}) \times 100.$$

This outcome was analyzed as a continuous variable and reported at 1-, 2-, and 3-year follow-up.

Remission of obesity-associated conditions was also assessed. Prediabetes at baseline and follow-up was defined as fasting plasma glucose between 100 and 125 mg/dL and/or an HbA1c between 5.7% and 6.4%, according to the American Diabetes Association criteria (9). Patients with established diabetes were excluded from the prediabetes category. T2DM remission was not evaluated due to the absence of baseline cases in the AYA group.

Hypertension was defined as systolic BP ≥ 140 mmHg, diastolic BP ≥ 90 mmHg, or the use of antihypertensive medication. Remission was defined as systolic BP < 140 mmHg and diastolic BP < 90 mmHg without the use of any antihypertensive drugs.

Dyslipidemia was defined as the presence of abnormal lipid parameters, including LDL-C ≥ 130 mg/dL, triglycerides ≥ 200 mg/dL, or HDL-C < 40 mg/dL, or the use of lipid-lowering medication (statins or fibrates). Remission was defined as normalization of lipid parameters without lipid-lowering therapy.

Although pediatric-specific thresholds exist, adult cut-off values were applied given that all participants were aged 15 years or older.

Statistical Analysis

Statistical analyses were performed using Stata version 18.4 (StataCorp LLC, College Station, TX, USA). Continuous variables were analyzed as continuous measures when appropriate, whereas clinical outcomes such as prediabetes, hypertension, and dyslipidemia were evaluated as binary variables according to predefined diagnostic thresholds.

Continuous variables are presented as mean $\pm$ standard deviation (SD), and categorical variables as frequencies and percentages. Baseline comparisons between AYA and adult patients were performed using the independent samples t-test for continuous variables and the chi-square test or Fisher's exact test for categorical variables. All tests were two-sided, and a p-value <0.05 was considered statistically significant.

To allow meaningful comparisons between AYA group and older adults group while maximizing the number of AYA participants included in the analysis, **propensity score matching** was performed separately for each outcome. Propensity scores were estimated using a probit regression model. For each analysis, one AYA was matched with up to three older adult patients using **nearest-neighbor matching** without replacement based on relevant baseline covariates, including type of MBS, sex, BMI, prediabetes, hypertension, and dyslipidemia. **The matching ratio varied depending on the availability of adult comparators.** A caliper restriction of 0.15 was applied to improve the quality of matches. Covariate balance after matching was assessed using standardized mean differences (SMD), with values <0.1 considered indicative of adequate balance. Treatment effects were estimated as the average treatment effect on the treated (ATT). **Missing data were assessed, and analyses were performed using available data without imputation.**

Several potential sources of bias and confounding were considered in this study design and analysis. Propensity score matching was used to reduce baseline differences between AYA group and older adult group and to control for relevant confounders. **Selection bias** was minimized by including all eligible AYA and older adult patients from the merged cohort who met predefined inclusion criteria. **Information bias** was minimized by relying on standardized routinely collected data from the EHR and applying consistent outcome definitions across both groups. Nevertheless, due to the retrospective design, residual confounding cannot be fully excluded.

Ethical Considerations

This study was approved by the Ethics Committee of our tertiary care center, and conducted in accordance with the Declaration of Helsinki (10). Due to the retrospective design of the study requirement for informed consent was waived. Patient identifiers were used solely for database linkage and were accessible only by authorized personnel. All analyses were performed on de-identified data to ensure patient confidentiality.

Results

Participant selection

A total of 3422 patients who underwent MBS between 2013 and 2023 were initially identified. After applying eligibility criteria, **3147 patients were included**, comprising 65 AYA (≤ 21 years) and 3082 older adults (>21 years). AYA participants were subsequently matched to older adults using propensity score matching (see Methods section).

Baseline characteristics

The AYA group before propensity score matching consisted of 39 females (60.0%), whereas the older adult group included 2600 females (84.4%). Mean age was 18.2 ± 1.6 years in the AYA cohort (range: 15–21 years) and 44.3 ± 10.6 years in adults. The type of surgery differed between groups, with a higher proportion of AYA patients undergoing sleeve gastrectomy (84.6% vs 33.8%; $p < 0.001$). The AYA group also had a higher baseline BMI than adults (44.6 ± 8.0 vs 35.1 ± 18.1 kg/m²; $p < 0.001$).

Obesity-associated conditions were generally less frequent in younger patients. None of the AYA patients had pre-existing type 2 diabetes, whereas 19.5% of adults did ($p < 0.001$). Prediabetes (21.7% vs 45.1%; $p = 0.003$) and hypertension (25.8% vs 60.4%; $p < 0.001$) were also less prevalent in the AYA group, while dyslipidemia prevalence was similar between groups (53.2% vs 58.7%; $p = 0.37$).

Regarding medication use, AYA patients more frequently received GLP-1RAs (10.2% vs 1.0%; $p < 0.001$) and metformin (32.8% vs 20.7%; $p = 0.018$). In contrast, none of the AYA patients were receiving statins, whereas 20.9% of adults were ($p < 0.001$). Antihypertensive treatment was also less common in AYA patients (14.1% vs 39.7%; $p < 0.001$).

Baseline laboratory parameters were also assessed. Compared with adults, AYA patients had lower LDL-C (106.5 ± 28.6 vs 119.2 ± 32.7 mg/dL; $p = 0.003$) and HDL-C (44.4 ± 10.4 vs 49.9 ± 12.4 mg/dL; $p < 0.001$). Fasting glucose and HbA1c were both lower in the AYA group (86.2 ± 10.1 vs 103.5 ± 35.1 mg/dL, $p < 0.001$; and 5.4 ± 0.4 vs $5.8 \pm 1.0\%$, $p < 0.001$, respectively). ALT levels were slightly higher in AYA patients (39.3 ± 29.5 vs 29.7 ± 22.4 U/L; $p < 0.001$), while no significant differences were observed for gamma-GT ($p = 0.22$). AYA group had higher eGFR (133.8 ± 13.4 vs 105.8 ± 16.9 mL/min/1.73 m²; $p < 0.001$), and no significant differences regarding urinary albumin excretion ($p = 0.70$).

Baseline characteristics of AYA and adult patients are shown in **Table 1**.

After propensity score matching, baseline covariates between AYA and older adult patients were well balanced, with standardized mean differences below 0.1 for all variables (**Table 1**). Outcome analyses were subsequently conducted using outcome-specific propensity score matching procedures, as described in the Methods. Matched sample sizes varied depending on outcome availability, ranging from **31 to 57 AYA patients and from 92 to 159 adult controls**.

Table 1. Baseline characteristics of AYA and adult patients before and after propensity score matching.

Variable	AYA Cohort (n=65)	Adult Cohort (n=3082)	p value	AYA Matched	Adult Matched	Std Diff
Demographics						
Age at surgery (years)	18.2 ± 1.6	44.3 ± 10.6	< 0.001	-	-	-
Female sex	39 (60.0%)	2600 (84.4%)	< 0.001	36.4	35.8	0.014
Anthropometric characteristics						
BMI (kg/m ²)	44.6 ± 8.0	35.1 ± 18.1	< 0.001	44.5 ± 8.0	44.2 ± 9.4	0.018
Type of Surgery						
Sleeve Gastrectomy	55 (84.6%)	1042 (33.8%)	< 0.001	89.1	90.3	0.030
Obesity-related conditions						
Diabetes	0 (0%)	602 (19.5%)	< 0.001	-	-	-
Pre-diabetes	14 (21.7%)	1390 (45.1%)	0.003	23.6	23.0	0.013
HTN	17 (25.8%)	1861 (60.4%)	< 0.001	27.3	29.1	-0.039
Dyslipidemia	35 (53.2%)	1810 (58.7%)	0.37	54.5	54.8	-0.006
Medication						
GLP-1RAs	7 (10.2%)	31 (1.0%)	< 0.001	-	-	-
Metformin	21(32.8%)	638 (20.7%)	0.018	-	-	-
Statins	0 (0%)	644 (20.9%)	< 0.001	-	-	-

Antihypertensive	9 (14.1%)	1224 (39.7%)	< 0.001	-	-	-
Laboratory parameters						
Fasting glucose (mg/dL)	86.2 ± 10.1	103.5 ± 35.1	< 0.001	-	-	-
HbA1c (%)	5.4 ± 0.4	5.8 ± 1.0	<0.001	-	-	-
LDL-C (mg/dL)	106.5 ± 28.6	119.2 ± 32.7	0.003	-	-	-
HDL-C (mg/dL)	44.4 ± 10.4	49.9 ± 12.4	<0.001	-	-	-
eGFR (mL/min/1.73m ²)	133.8 ± 13.4	105.8 ± 16.9	<0.001	-	-	-

Values are presented as mean ± standard deviation (SD) or number (%).

Matched values are presented as percentages or mean ± SD.

Std Diff: standardized mean difference. _AYA: adolescents and young adults

Propensity score matching shown in this table was performed for descriptive purposes to illustrate covariate balance between groups. Outcome analyses were conducted using outcome-specific propensity score matching procedures as described in the Methods.

Weight loss outcomes

Both AYA and adult patients experienced clinically meaningful weight reduction after MBS. Longitudinal changes are illustrated in **Figure 1**. After propensity score matching, 57 AYA patients were compared with 159 adult controls at 1 year. The %TWL was significantly lower in AYA compared with adults at 1 year, with mean values of 21.2% versus 32.5% (ATT -11.2%; 95% CI -14.2 to -8.3; p<0.001). At 2 years, 46 AYA patients were compared with 128 matched adults. Mean %TWL remained lower in the AYA group (25.9% vs 31.7%; ATT -5.8%; 95% CI -9.9 to -1.7; p=0.006). At 3 years, 41 AYA patients were compared with 111 matched adults. Mean %TWL was 29.8% in the AYA group and 31.5% in adults, with no statistically significant difference between groups (ATT -1.7%; 95% CI -5.2 to 1.7; p=0.324).

Weight loss outcomes are shown in **Table 2**.

Table 2. Weight loss outcomes in AYA and adult patients following metabolic and bariatric surgery.

Follow-up	AYA	%TWL	Adults %TWL	ATT (% difference)	95% CI	p-value
1 year	21.2 ± 1.3		32.5 ± 0.8	-11.2	-14.2 to -8.3	<0.001
2 years	25.9 ± 1.9		31.7 ± 0.9	-5.8	-9.9 to -1.7	0.006
3 years	29.8 ± 1.4		31.5 ± 1.0	-1.7	-5.2 to 1.7	0.324

Values are presented as mean ± standard deviation (SD).

AYA: adolescents and young adults.

%TWL: percentage of total weight loss relative to preoperative weight.

ATT: average treatment effect on the treated estimated using propensity score matching.

CI: confidence interval.

Metabolic outcomes

Both cohorts showed improvements in glycemic control, lipid profile, and BP over follow-up. Compared with baseline, the prevalence of prediabetes, hypertension, and dyslipidemia decreased in both groups.

For prediabetes, 37 AYA patients were compared with 111 matched adults at 1 year. Prediabetes prevalence was identical in both groups (8.1% vs 8.1%; ATT 0.0 percentage points; 95% CI -10.2 to 10.2; p=1.000). Similar results were observed at 2 years (6.5% vs 6.5%; ATT 0.0; 95% CI -10.0 to 10.0; p=1.000) and 3 years (16.7% vs 9.3%; ATT 7.4; 95% CI -6.0 to 20.8; p=0.278).

For hypertension, prevalence did not differ between groups at any follow-up time point: 11.8% vs 14.4% at 1 year (ATT -2.6; 95% CI -13.1 to 7.9; p=0.625), 6.7% vs 11.9% at 2 years (ATT -5.2; 95% CI -14.3 to 4.0; p=0.266), and 13.5% vs 11.7% at 3 years (ATT 1.8; 95% CI -10.8 to 14.4; p=0.779).

For dyslipidemia, prevalence was lower in AYA patients but reached statistical significance only at later follow-up. At 1 year, dyslipidemia was observed in 26.4% of AYA patients and 37.7% of adults (ATT -11.3; 95% CI -25.6 to 3.0; p=0.121). At 2 years, prevalence was significantly lower in AYA patients (20.5% vs 36.4%; ATT -15.9; 95% CI -30.8 to -1.0; p=0.037), and this difference persisted at 3 years (18.9% vs 35.1%; ATT -16.2; 95% CI -32.1 to -0.4; p=0.045).

Changes in obesity-related conditions are summarized in **Table 3**.

Table 3. Changes in obesity-related conditions after metabolic and bariatric surgery.

Outcome	Follow-up	AYA (%)	Adults (%)	ATT (percentage points)	95% CI	p-value
Prediabetes	1 year	8.1	8.1	0.0	-10.2 to 10.2	1.000
	2 years	6.5	6.5	0.0	-10.0 to 10.0	1.000
	3 years	16.7	9.3	7.4	-6.0 to 20.8	0.278
Hypertension	1 year	11.8	14.4	-2.6	-13.1 to 7.9	0.625
	2 years	6.7	11.9	-5.2	-14.3 to 4.0	0.266
	3 years	13.5	11.7	1.8	-10.8 to 14.4	0.779
Dyslipidemia	1 year	26.4	37.7	-11.3	-25.6 to 3.0	0.121
	2 years	20.5	36.4	-15.9	-30.8 to -1.0	0.037
	3 years	18.9	35.1	-16.2	-32.1 to -0.4	0.045

Values are presented as percentages.

AYA: adolescents and young adults.

ATT: average treatment effect on the treated estimated using propensity score matching.

CI: confidence interval.

Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or use of antihypertensive medication.

Dyslipidemia was defined as LDL-C ≥ 130 mg/dL, triglycerides ≥ 150 mg/dL, HDL-C < 40 mg/dL, or use of lipid-lowering medication.

Prediabetes was defined as fasting plasma glucose between 100–125 mg/dL and/or HbA1c between 5.7–6.4%.

Discussion

This study compared weight loss and metabolic outcomes after MBS between AYA and adults. Overall, MBS was associated with significant improvements in metabolic parameters in both groups, including BMI, glycemic control, BP, and lipid profile. However, after propensity score matching, adults achieved a higher %TWL during the first two postoperative years ($p < 0.001$). Notably, differences in weight loss

outcomes between groups decreased over time, although % TWL remained statistically significant compared to baseline in both groups.

The lower %TWL observed in AYA patients in the first two years may be explained by ongoing growth during adolescence, which influences body composition and postoperative weight trajectories. In addition, AYA patients presented with a higher baseline BMI, which may also have influenced relative weight loss outcomes (11). This finding likely reflects differences in clinical practice, as indications for bariatric surgery in younger populations are often more restrictive, with referral typically occurring at more advanced stages of obesity (12). Consequently, relative weight loss measures such as %TWL may appear lower despite meaningful improvements in body composition. Behavioral and lifestyle factors may also contribute, such as differences in adherence to diet and postoperative follow-up between AYA and adults have been reported in previous studies (13, 14). Notably, the difference in %TWL between groups decreased over time and was no longer statistically significant by the third postoperative year, suggesting that weight loss trajectories in younger patients may progressively approach those observed in adults.

Despite early differences in weight loss, no statistically significant differences were found between AYA and adults regarding the prevalence of prediabetes, dyslipidemia, and hypertension at one year following surgery. Interestingly, dyslipidemia became significantly less prevalent among younger patients at 3 years. This finding may reflect the shorter duration of obesity, and the lower baseline metabolic burden typically observed in younger patients, which may allow for greater reversibility of lipid abnormalities after MBS. Moreover, because obesity is a chronic disease with cumulative adverse effects over time (15), earlier intervention may help mitigate its long-term physiological consequences. Indeed, prolonged exposure to obesity has been associated with increased overall mortality (16).

This study is strengthened by the direct comparison between AYA and adult patients undergoing MBS within the same tertiary care center, allowing for meaningful evaluation of age-related differences in outcomes. Propensity score matching improved comparability between groups by balancing key baseline characteristics (see Methods).

This study has several limitations. First, the AYA cohort was relatively small, which may limit statistical power and external validity. Second, the retrospective design and use of EHR may introduce potential measurement inconsistencies, as many variables were recorded in open-text fields. Consequently, the quality of information could vary depending on the clinical context. Finally, follow-up was limited to 3 years, preventing the assessment of longer-term outcomes, particularly in the younger group.

Conclusion

MBS was effective in both groups, leading to substantial improvements in weight and obesity-related conditions during the first three years after surgery. Despite achieving earlier lower relative weight loss, AYA patients experienced comparable metabolic benefits to adults, highlighting the potential value of early intervention in younger patients with severe obesity.

Declarations

Ethics approval

This study was approved by the Local Institutional Ethics Committee.

Consent

Due to the retrospective design, informed consent was waived.

Conflict of interest

The authors declare no conflict of interest.

Funding

This study received no external funding.

Data Availability

The data from the merged cohort is not publicly available due to privacy or ethical restrictions.

Author Contribution

A.L.M. contributed to data collection, statistical analysis, and drafted the main manuscript. M.V.H. and J.S.N. designed and supervised the study. J.S.N. contributed to the statistical analysis. M.V.H., T.T., and M.C. contributed to the development and maintenance of the database used in this study. J.C. contributed to long-term data collection. S.C., H.S.S., E.L.C., and P.F. critically reviewed the manuscript. All authors reviewed and approved the final manuscript.

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Figures

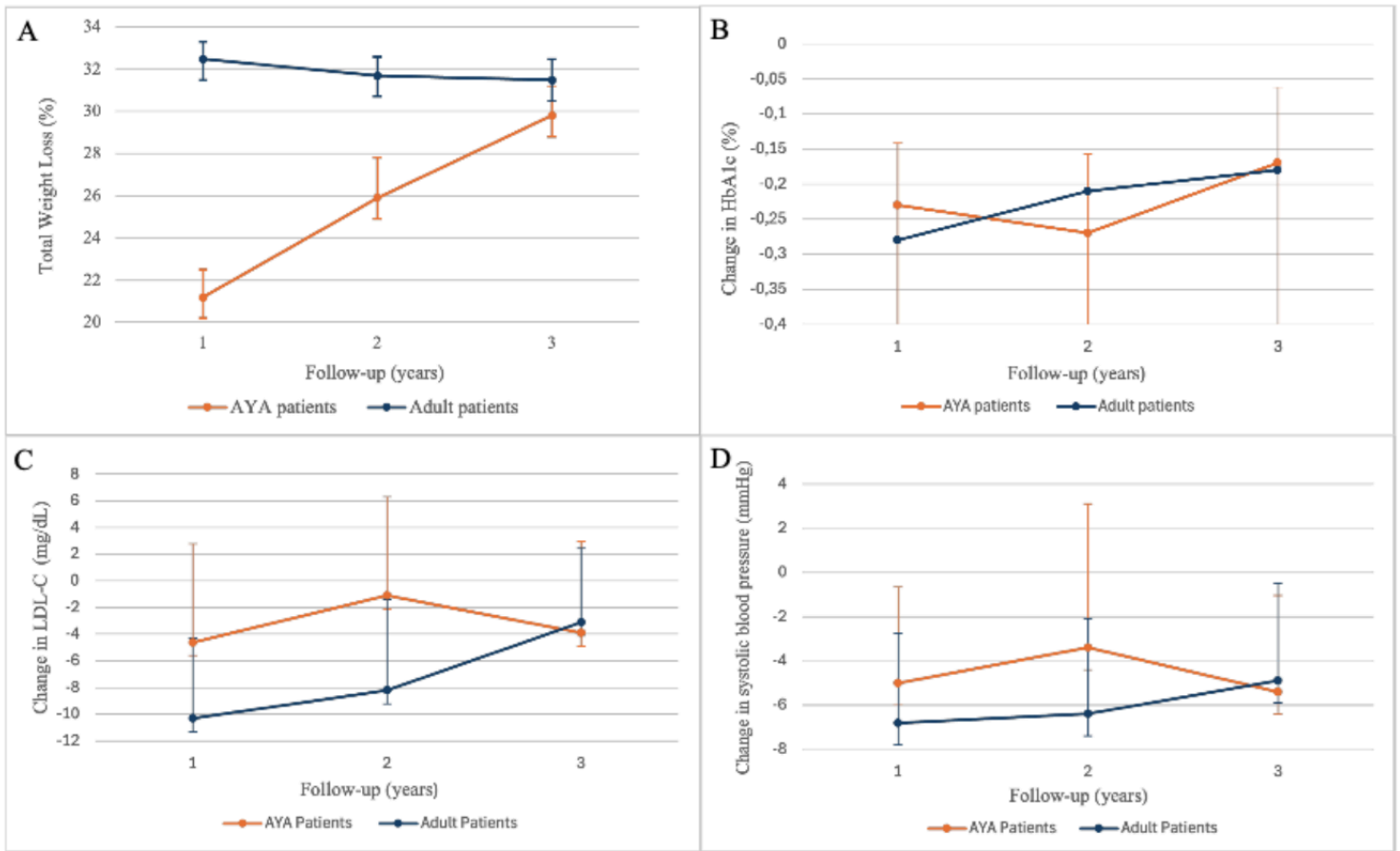


Figure 1

Changes in weight and metabolic parameters after metabolic and bariatric surgery according to age group.

(A) Percentage of total weight loss (%TWL), (B) change in HbA1c, (C) change in LDL-cholesterol, and (D) change in systolic blood pressure over 3 years of follow-up. Orange lines indicate Adolescent and young adults' patients (≤ 21 years) and blue lines indicate adult patients (> 21 years). Error bars represent variability around the estimated mean values. AYA: adolescents and young adults.