

**Cardiometabolic Improvements After Metabolic Surgery and Related Pre-
surgery Factors**

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SUPPLEMENTARY MATERIAL

Supplementary Table 1. Baseline characteristics of study patients by age group

	Median (25 th , 75 th percentile)/ N (%)		<i>P</i> value
	Age ≤ 45 y (n=3855)	Age > 45 y (n=3949)	
Sex			<0.0001
Women	3174 (82.3)	3012 (76.3)	
Men	681 (17.7)	937 (23.7)	
Race/ Ethnicity			<0.0001
White	3001 (77.8)	3340 (84.6)	
Black	748 (19.4)	523 (13.2)	
Other	106 (2.8)	86 (2.2)	
Body mass index, kg/m ²	47.3 (42.8, 53.6)	45.6 (41.3, 51.2)	<0.0001
Procedure			0.004
RYGB	2579 (66.9)	2693 (68.2)	
SG	1089 (28.3)	1014 (25.7)	
AGB	187 (4.8)	242 (6.1)	
Surgery year			<0.0001
1999-2005	680 (17.6)	544 (13.8)	
2006-2010	632 (16.4)	775 (19.6)	
2011-2015	821 (21.3)	966 (24.5)	
2016-2022	1722 (44.7)	1664 (42.1)	
History of diabetes	1348 (35.0)	2030 (51.4)	<0.0001
History of hypertension	2529 (65.6)	3489 (88.4)	<0.0001
History of dyslipidemia	1335 (34.6)	2394 (60.6)	<0.0001
History of cardiovascular disease	145 (3.8)	678 (17.2)	<0.0001

Abbreviation: AGB: adjustable gastric banding; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Supplementary Table 2. Baseline characteristics of study patients by sex

	Median (25 th , 75 th percentile)/ N (%)		<i>P</i> value
	Women (n=6186)	Men (n=1618)	
Age, year	44.6 (36.7, 52.9)	47.2 (39.5, 55.6)	<0.0001
Race/ Ethnicity			<0.0001
White	4957 (80.1)	1384 (85.5)	
Black	1090 (17.6)	181 (11.2)	
Other	139 (2.3)	53 (3.3)	
Body mass index, kg/m ²	46.2 (42.0, 52.0)	47.3 (42.7, 53.7)	<0.0001
Procedure			0.24
RYGB	4187 (67.7)	1085 (67.1)	
SG	1648 (26.6)	455 (28.1)	
AGB	351 (5.7)	78 (4.8)	
Surgery year			<0.0001
1999-2005	981 (15.9)	243 (15.0)	
2006-2010	1088 (17.6)	319 (19.7)	
2011-2015	1365 (22.1)	422 (26.1)	
2016-2022	2752 (44.5)	634 (39.2)	
History of diabetes	2559 (41.4)	819 (50.6)	<0.0001
History of hypertension	4590 (74.2)	1428 (88.3)	<0.0001
History of dyslipidemia	2791 (45.1)	938 (58.0)	<0.0001
History of cardiovascular disease	526 (8.5)	297 (18.4)	<0.0001

Abbreviation: AGB: adjustable gastric banding; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Supplementary Table 3. Baseline characteristics of study patients by race

	Median (25 th , 75 th percentile)/ N (%)		<i>P</i> value
	White (n=6341)	Black (n=1271)	
Age, year	45.8 (37.6, 54.1)	42.4 (35.3, 49.7)	<0.0001
Sex			<0.0001
Women	4957 (78.2)	1090 (85.8)	
Men	1384 (21.8)	181 (14.2)	
Body mass index, kg/m ²	46.2 (42.0, 52.1)	47.7 (42.7, 54.2)	<0.0001
Procedure			<0.0001
RYGB	4450 (70.2)	710 (55.9)	
SG	1521 (24.0)	513 (40.4)	
AGB	370 (5.8)	48 (3.8)	
Surgery year			<0.0001
1999-2005	1074 (16.9)	140 (11.0)	
2006-2010	1232 (19.4)	150 (11.8)	
2011-2015	1448 (22.8)	315 (24.8)	
2016-2022	2587 (40.8)	666 (52.4)	
History of diabetes	2730 (43.1)	580 (45.6)	0.09
History of hypertension	4867 (76.8)	1024 (80.6)	0.003
History of dyslipidemia	3119 (49.2)	529 (41.6)	<0.0001
History of cardiovascular disease	688 (10.9)	121 (9.5)	0.16

Abbreviation: AGB: adjustable gastric banding; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Supplementary Table 4. Baseline characteristics of study patients by procedure type

	Median (25 th , 75 th percentile)/ N (%)		<i>P</i> value
	RYGB (n=5272)	SG (n=2103)	
Age, year	45.3 (37.3, 53.4)	44.5 (36.8, 52.6)	0.13
Sex			0.31
Women	4187 (79.4)	1648 (78.4)	
Men	1085 (20.6)	455 (21.6)	
Race/ Ethnicity			<.0001
White	4450 (84.4)	1521 (72.3)	
Black	710 (13.5)	513 (24.4)	
Other	112 (2.1)	69 (3.3)	
Body mass index, kg/m ²	47.2 (42.6, 53.4)	45.2 (41.5, 50.4)	<.0001
Surgery year			<.0001
1999-2005	1183 (22.4)	0 (0.0)	
2006-2010	963 (18.3)	79 (3.8)	
2011-2015	1181 (22.4)	584 (27.8)	
2016-2022	1945 (36.9)	1440 (68.5)	
History of diabetes	2445 (46.4)	759 (36.1)	<.0001
History of hypertension	4147 (78.7)	1538 (73.1)	<.0001
History of dyslipidemia	2638 (50.0)	834 (40.0)	<.0001
History of cardiovascular disease	571 (10.8)	198 (9.4)	0.07

Abbreviation: RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Supplementary Table 5. Comparison of cardiometabolic profiles between pre- and 2-year post-surgery

	Pre-surgery ^a		2-year post-surgery		Difference (95% CI)		
	Number of patients	Median (IQR)	Number of patients	Median (IQR)	Pairs	Absolute reduction ^b	Relative reduction ^c , %
Body weight (kg)	7550	130.9 (115.6, 150.5)	3477	88.0 (75.1, 104.3)	3452	42.5 (41.9, 43.1)	31.5 (31.2, 31.9)
SBP (mmHg)	7197	134.0 (126.0, 143.0)	3128	124.0 (114.0, 134.0)	2998	9.6 (9.0, 10.1)	6.7 (6.3, 7.1)
DBP (mmHg)	7201	79.0 (72.0, 86.0)	3129	74.0 (67.0, 81.0)	3001	4.8 (4.4, 5.2)	5.1 (4.6, 5.7)
PP (mmHg)	7190	54.0 (48.0, 62.0)	3121	49.0 (42.0, 57.5)	2991	4.8 (4.4, 5.3)	6.7 (5.9, 7.5)
TC (mg/dL)	1099	183.0 (159.5, 208.0)	523	171.0 (149.0, 194.0)	246	10.6 (6.3, 14.9)	4.4 (1.9, 6.9)
LDL (mg/dL)	1083	100.0 (80.5, 122.0)	523	87.0 (68.0, 110.0)	242	11.6 (7.3, 15.9)	4.9 (-0.7, 10.4)
HDL (mg/dL)	1095	46.0 (39.0, 55.0)	520	60.0 (50.0, 70.3)	239	-12.8 (-14.4, -11.2)	-30.3 (-34.3, -26.2)
TG (mg/dL)	1069	149.0 (106.0, 213.0)	495	83.0 (63.0, 112.0)	225	63.4 (54.5, 72.4)	32.8 (28.7, 36.9)
Glucose (mg/dL)	6218	99.5 (91.0, 115.0)	2243	92.4 (86.0, 103.0)	1910	10.7 (9.5, 11.8)	7.3 (6.3, 8.3)
HbA1c (%)	1681	6.50 (5.80, 7.50)	684	5.60 (5.20, 6.30)	451	0.93 (0.83, 1.03)	12.2 (11.0, 13.4)
10-year ASCVD risk (%)	1214	2.43 (1.04, 5.53)	365	1.79 (0.51, 4.96)	139	0.54 (-0.03, 1.11)	22.6 (12.6, 32.7)

Abbreviation: ASCVD, atherosclerotic cardiovascular disease; DBP, diastolic blood pressure; HDL, high-density lipoprotein; IQR, interquartile range; LDL, low-density lipoprotein; PP, pulse pressure; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

^a Among patients who had at least one post-surgery value during follow-up period.

^b Absolute reduction = pre-surgery – 2-year post-surgery.

^c Relative reduction = (pre-surgery – 2-year post-surgery)/ pre-surgery*100.

Supplementary Table 6. The number of patients with missing outcomes at pre- and post-surgery

	Number of missing patients		
	Pre-surgery	1-year post-surgery	2-year post-surgery
Body weight (kg)	126	2257	4327
SBP (mmHg)	599	2603	4676
DBP (mmHg)	595	2587	4675
PP (mmHg)	606	2608	4683
TC (mg/dL)	6120	6754	7281
LDL (mg/dL)	6140	6769	7281
HDL (mg/dL)	6133	6758	7284
TG (mg/dL)	6160	6802	7309
Glucose (mg/dL)	1349	3570	5561
HbA1c (%)	4959	6696	7120
10-year ASCVD risk (%)	6590	7015	7439

Abbreviation: ASCVD, atherosclerotic cardiovascular disease; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; PP, pulse pressure; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

Supplementary Table 7. Pre-surgery factors associated with cardiometabolic improvements at 2-year post-surgery

Reduction of outcomes	Model	N ^d	β coefficient (95% CI) ^a							
			Age	Sex	Race	Procedure	Diabetes	Hypertension	Dyslipidemia	CVD
			(Per 5 years)	(Men vs. Women)	(Black vs. White)	(SG vs. RYGB)	(Yes vs. No)	(Yes vs. No)	(Yes vs. No)	(Yes vs. No)
Body weight (kg)	M1 ^b	3452	-0.40 (-0.63, -0.17)*	-5.42 (-6.70, -4.13)*	-5.38 (-6.61, -4.15)*	-7.33 (-8.43, -6.23)*	-4.58 (-5.52, -3.63)*	-0.25 (-1.46, 0.95)	-1.47 (-2.47, -0.47)*	0.78 (-0.56, 2.12)
SBP (mmHg)	M1	2998	-0.59 (-0.83, -0.35)*	-3.06 (-4.27, -1.86)*	-5.34 (-6.62, -4.06)*	-2.08 (-3.23, -0.92)*	-1.66 (-2.66, -0.66)*	-5.87 (-7.22, -4.52)*	0.29 (-0.77, 1.34)	-0.18 (-1.56, 1.21)
	M2 ^c	2912	-0.50 (-0.74, -0.25)*	-3.58 (-4.82, -2.33)*	-5.10 (-6.40, -3.80)*	-1.33 (-2.51, -0.15)^	-1.42 (-2.43, -0.41)*	-6.24 (-7.59, -4.88)*	0.78 (-0.28, 1.85)	-0.33 (-1.73, 1.06)
LDL (mg/dL)	M1	242	1.26 (-0.63, 3.14)	7.36 (-0.43, 15.15)	5.74 (-3.03, 14.51)	-20.48 (-30.79, -10.18)*	-8.10 (-15.71, -0.48)^	6.30 (-3.42, 16.02)	-15.65 (-25.81, -5.48)*	4.23 (-3.25, 11.7)
	M2	236	1.60 (-0.34, 3.55)	6.45 (-1.56, 14.46)	5.61 (-3.37, 14.59)	-19.35 (-29.85, -8.86)*	-7.51 (-15.30, 0.29)	4.33 (-5.70, 14.36)	-15.11 (-25.53, -4.69)*	3.53 (-4.14, 11.19)
HDL (mg/dL)	M1	239	-0.29 (-1.23, 0.66)	4.51 (0.54, 8.48)^	-5.47 (-9.81, -1.14)^	3.53 (-1.58, 8.63)	4.73 (1.14, 8.33)^	0.05 (-4.78, 4.87)	3.06 (-2.19, 8.30)	-0.77 (-4.48, 2.93)
	M2	234	-0.36 (-1.34, 0.61)	4.90 (0.80, 8.99)^	-5.37 (-9.80, -0.93)^	2.97 (-2.24, 8.17)	4.41 (0.72, 8.10)^	0.73 (-4.24, 5.69)	3.44 (-1.90, 8.78)	-0.75 (-4.51, 3.01)
TG (mg/dL)	M1	225	0.42 (-2.48, 3.31)	8.49 (-3.37, 20.34)	6.75 (-6.21, 19.71)	-23.04 (-38.72, -7.37)*	-15.96 (-26.95, -4.97)*	-0.49 (-15.24, 14.26)	0.10 (-14.38, 14.57)	-3.53 (-14.91, 7.84)
	M2	219	1.11 (-1.85, 4.06)	7.30 (-4.70, 19.29)	7.93 (-5.14, 20.99)	-21.17 (-36.85, -5.49)^	-14.90 (-25.99, -3.81)^	-4.12 (-19.14, 10.90)	0.40 (-14.26, 15.05)	-4.25 (-15.79, 7.30)
Glucose (mg/dL)	M1	1910	-0.55 (-1.01, -0.09)^	-3.51 (-5.82, -1.21)*	-0.16 (-2.59, 2.27)	0.80 (-1.40, 3.00)	-6.69 (-8.72, -4.67)*	-0.62 (-3.05, 1.81)	-2.60 (-4.59, -0.61)^	-1.06 (-3.62, 1.49)
	M2	1846	-0.47 (-0.94, -0.01)^	-4.41 (-6.80, -2.02)*	0.79 (-1.68, 3.25)	1.55 (-0.71, 3.82)	-6.45 (-8.50, -4.41)*	-0.75 (-3.19, 1.70)	-1.99 (-4.02, 0.04)	-1.16 (-3.74, 1.42)
HbA1c (%)	M1	451	-0.07 (-0.11, -0.03)*	-0.11 (-0.28, 0.06)	-0.15 (-0.34, 0.03)	-0.05 (-0.27, 0.16)	-0.06 (-0.32, 0.19)	0.14 (-0.12, 0.40)	-0.22 (-0.41, -0.02)^	0.05 (-0.12, 0.22)
	M2	438	-0.06 (-0.10, -0.02)*	-0.17 (-0.35, -0.01)^	-0.11 (-0.30, 0.07)	0.03 (-0.19, 0.26)	-0.01 (-0.27, 0.24)	0.10 (-0.16, 0.35)	-0.19 (-0.39, 0.01)	0.03 (-0.14, 0.20)
10-year ASCVD	M1	139	-12.08 (-19.40, -4.75)*	-13.74 (-42.94, 15.45)	-40.55 (-71.45, -9.64)^	-22.70 (-50.82, 5.42)	-23.87 (-45.63, -2.11)^	23.70 (-3.73, 51.12)	-3.75 (-31.11, 23.61)	/
relative risk (%)	M2	136	-11.47 (-19.16, -3.77)*	-13.00 (-43.57, 17.56)	-39.56 (-71.29, -7.82)^	-21.74 (-50.78, 7.30)	-22.90 (-45.89, 0.10)	22.05 (-6.25, 50.35)	-2.85 (-30.87, 25.17)	/

Note: ^ *P*<0.05; * *P*<0.005.

Abbreviation: ASCVD, atherosclerotic cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; M1, model 1; M2, model 2; RYGB, Roux-en-Y gastric bypass; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; SG, sleeve gastrectomy.

^a β coefficients (95%CI) from multivariate linear regression models; the reference groups were women, White, RYGB, and those without comorbidities.

^b Model 1 adjusted for pre-surgery values (weight/ SBP/ LDL/ HDL /TG/ glucose/ HbA1c/ 10-year ASCVD risk), age at surgery, sex, race, procedure type, surgery year, status of diabetes, hypertension, dyslipidemia, and CVD.

^c Model 2 adjusted for covariates in model 1 and weight loss.

^d N indicated the number of patients used in each analysis.

Supplementary Table 8. Pre-surgery factors associated with remissions of metabolic diseases at 2-year post-surgery

Remission of diseases	Model	N ^d	Odds Ratio (95% Confidence Interval) ^a							
			Age (Per 5 years)	Sex (Men vs. Women)	Race (Black vs. White)	Procedure (SG vs. RYGB)	Diabetes (Yes vs. No)	Hypertension (Yes vs. No)	Dyslipidemia (Yes vs. No)	CVD (Yes vs. No)
Diabetes	M1 ^b	2737	0.90 (0.86, 0.94)	0.58 (0.46, 0.73)	0.96 (0.76, 1.22)	1.46 (1.16, 1.83)	/	0.67 (0.51, 0.88)	0.72 (0.59, 0.87)	0.75 (0.57, 0.99)
	M2 ^c	1388	0.89 (0.84, 0.96)	0.54 (0.37, 0.79)	1.13 (0.81, 1.58)	1.33 (0.95, 1.86)	/	0.73 (0.49, 1.08)	0.74 (0.55, 0.99)	0.83 (0.58, 1.19)
Hypertension	M1	5623	0.83 (0.80, 0.85)	0.60 (0.52, 0.70)	0.52 (0.44, 0.61)	1.01 (0.88, 1.16)	0.69 (0.61, 0.78)	/	0.82 (0.72, 0.93)	0.62 (0.50, 0.76)
	M2	2648	0.82 (0.78, 0.86)	0.56 (0.44, 0.73)	0.42 (0.32, 0.56)	0.92 (0.73, 1.16)	0.64 (0.53, 0.78)	/	0.85 (0.70, 1.04)	0.45 (0.33, 0.63)
Dyslipidemia	M1	1339	0.72 (0.67, 0.78)	0.71 (0.52, 0.96)	0.90 (0.61, 1.32)	0.84 (0.55, 1.26)	0.44 (0.33, 0.58)	0.65 (0.42, 1.01)	/	0.36 (0.25, 0.50)
	M2	738	0.73 (0.66, 0.81)	0.62 (0.40, 0.96)	0.69 (0.42, 1.11)	0.85 (0.49, 1.47)	0.46 (0.32, 0.67)	0.95 (0.55, 1.63)	/	0.28 (0.18, 0.44)

Abbreviation: CVD, cardiovascular disease; M1, model 1; M2, model 2; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

^a Odds ratios (95% CI) were obtained from multivariate logistic regression models; the reference groups were younger age, women, White, RYGB, and those without comorbidities.

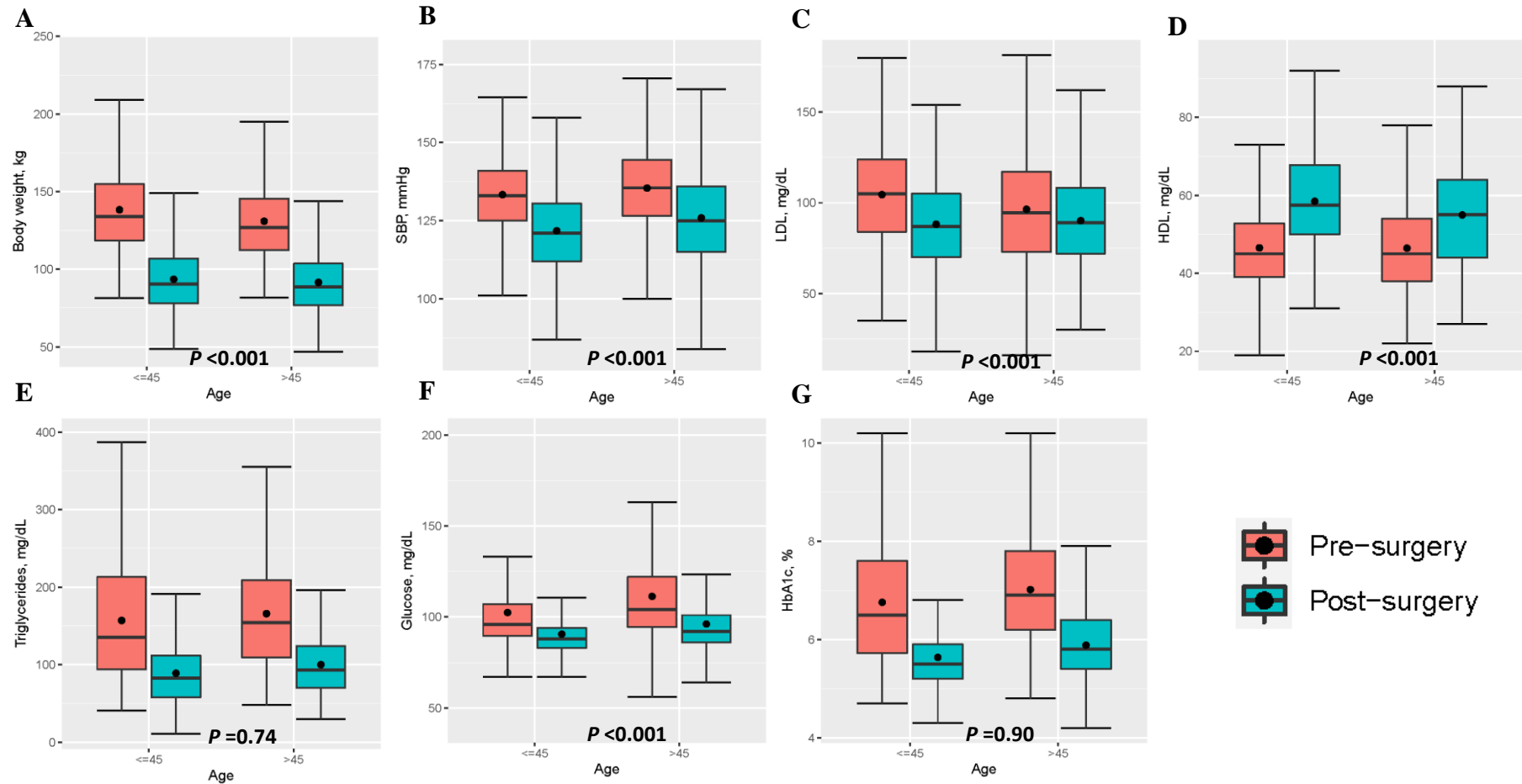
^b Model 1 adjusted for pre-surgery biomarkers related to diseases (glucose/ SBP/ LDL), age at surgery, sex, race, procedure type, surgery year, and pre-surgery status of other comorbidities.

^c Model 2 adjusted for covariates in model 1 and weight loss at 2-year post-surgery.

^d N indicated the number of patients used in each analysis.

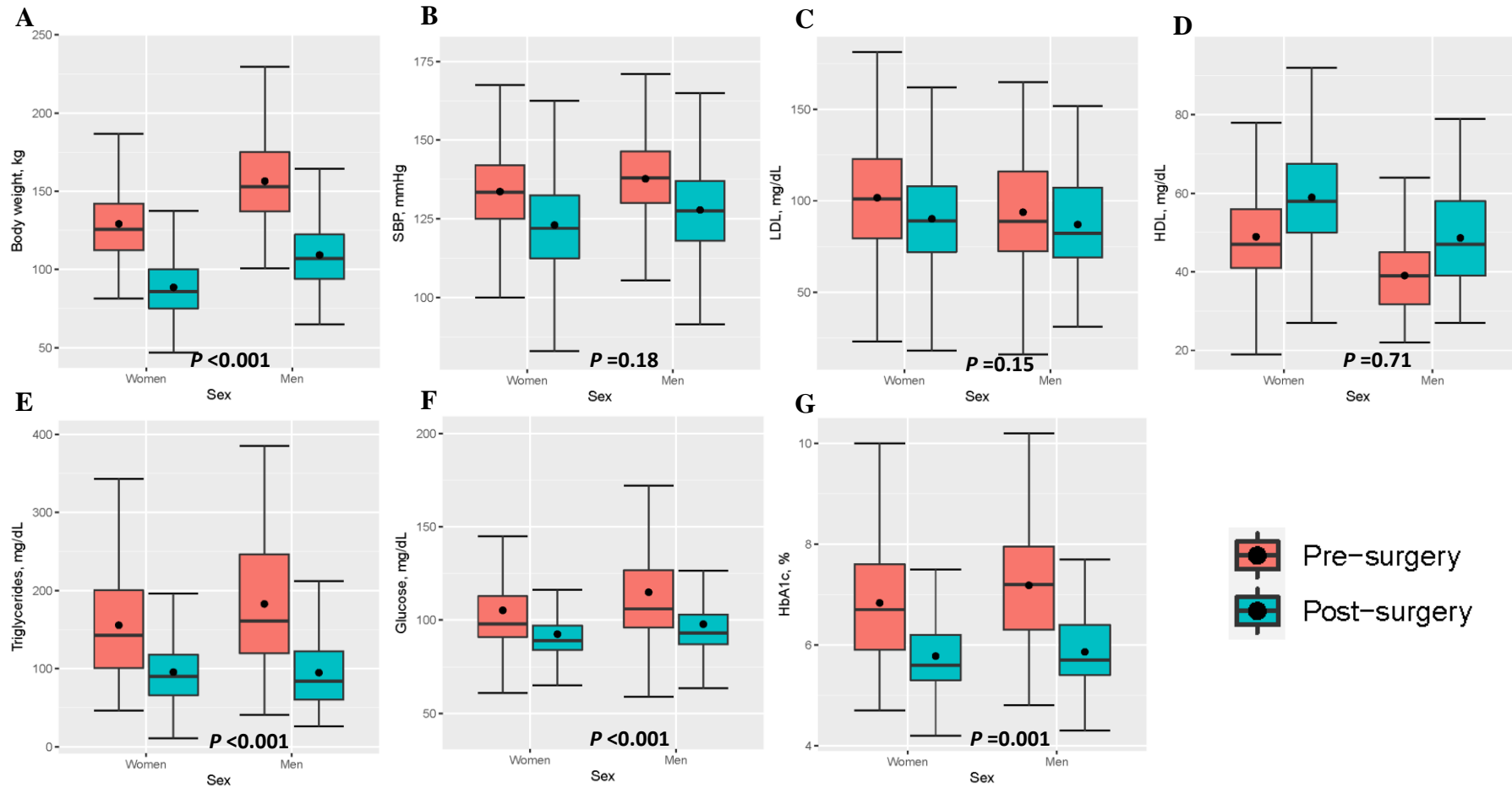
Supplementary Fig. 1 Cardiometabolic improvements between pre- and 1-year post-surgery by age group

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* values were for comparisons of cardiometabolic improvements after surgery between patients ≤ 45 y and patients > 45 y.



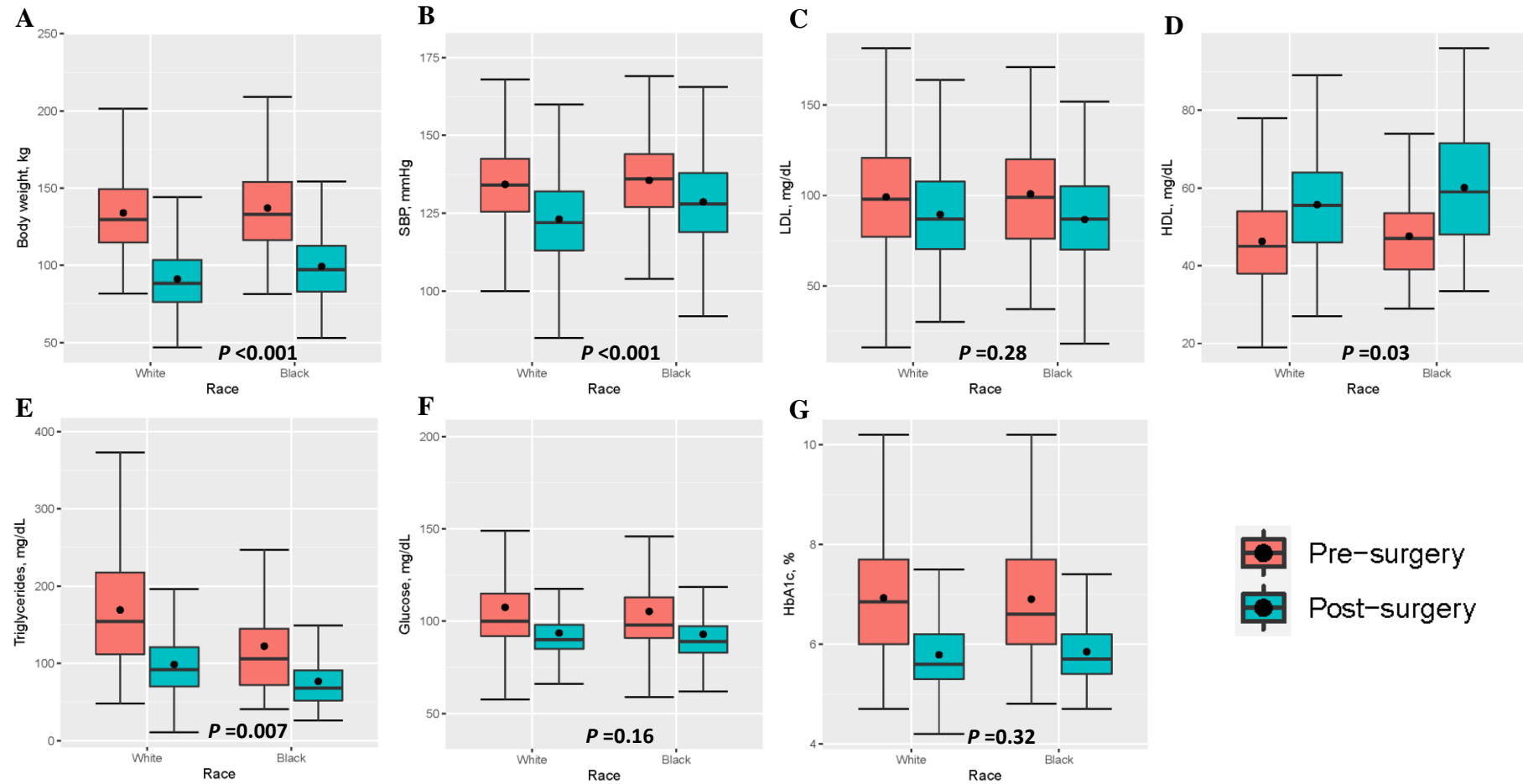
Supplementary Fig. 2 Cardiometabolic improvements between pre- and 1-year post-surgery by sex

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* values were for comparisons of cardiometabolic improvements after surgery between women and men.



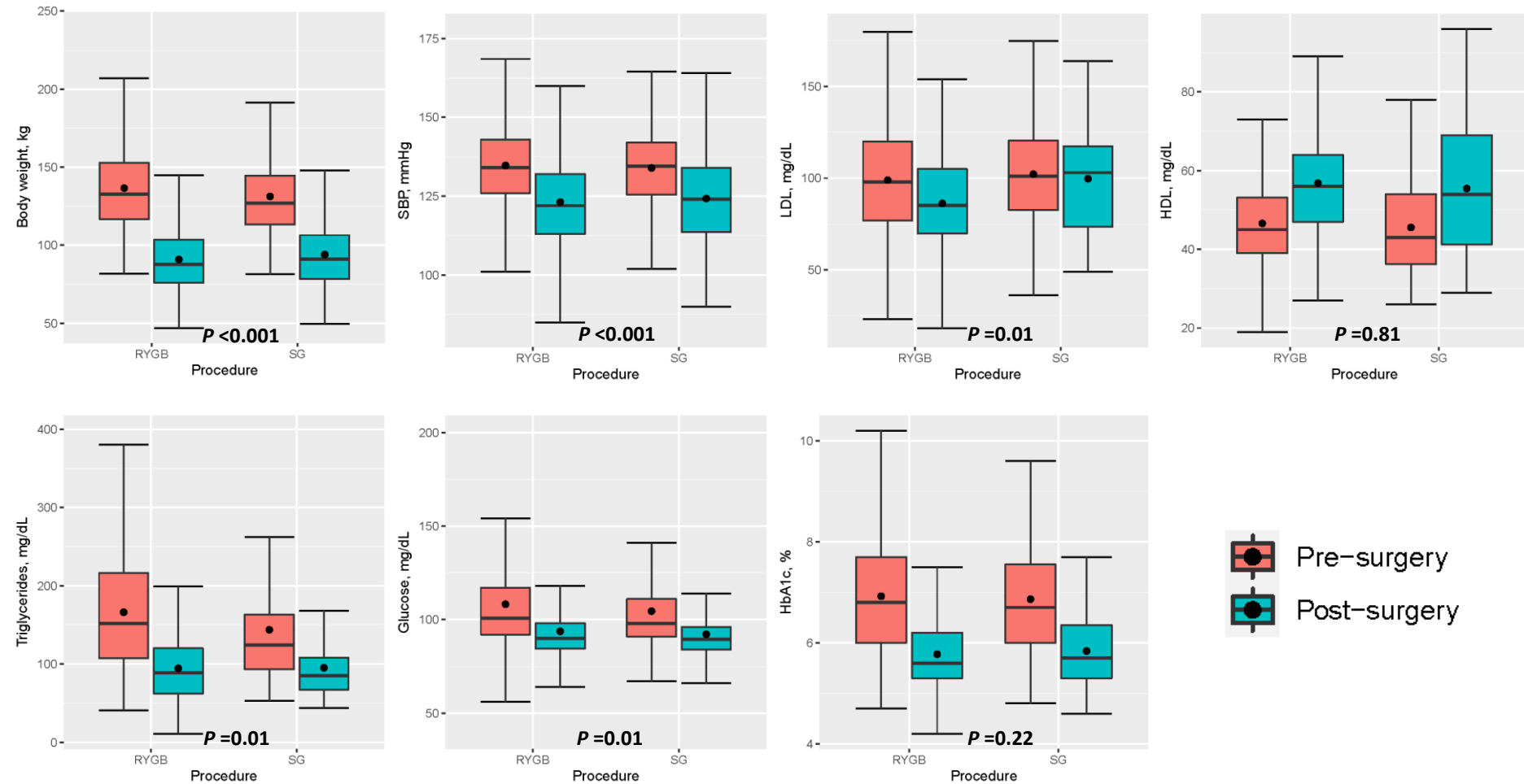
Supplementary Fig. 3 Cardiometabolic improvements between pre- and 1-year post-surgery by race

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* values were for comparisons of cardiometabolic improvements after surgery between Whites and Blacks.



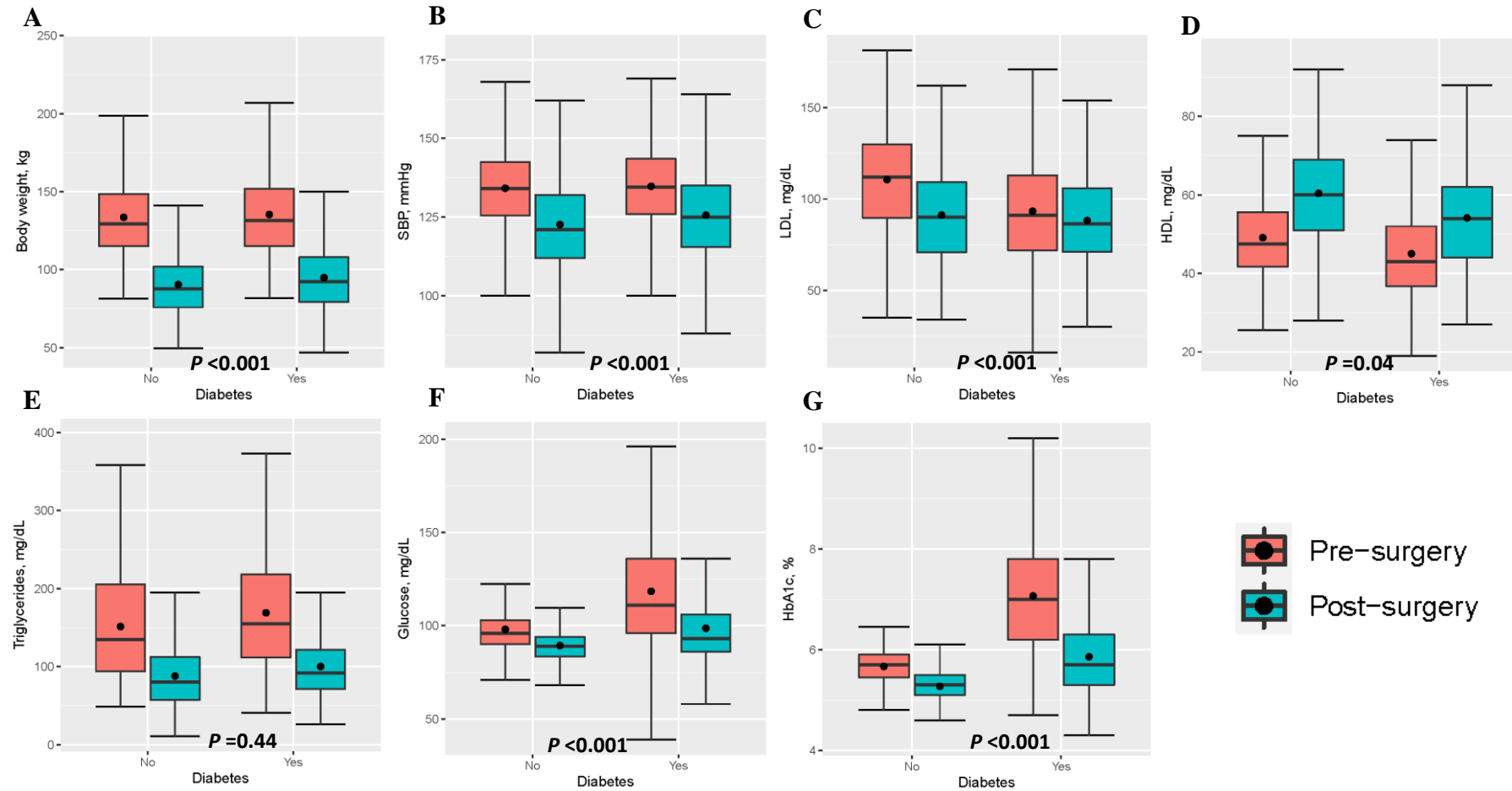
Supplementary Fig. 4 Cardiometabolic improvements between pre- and 1-year post-surgery by procedure type

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* values were for comparisons of cardiometabolic improvements after surgery between RYGB and SG.



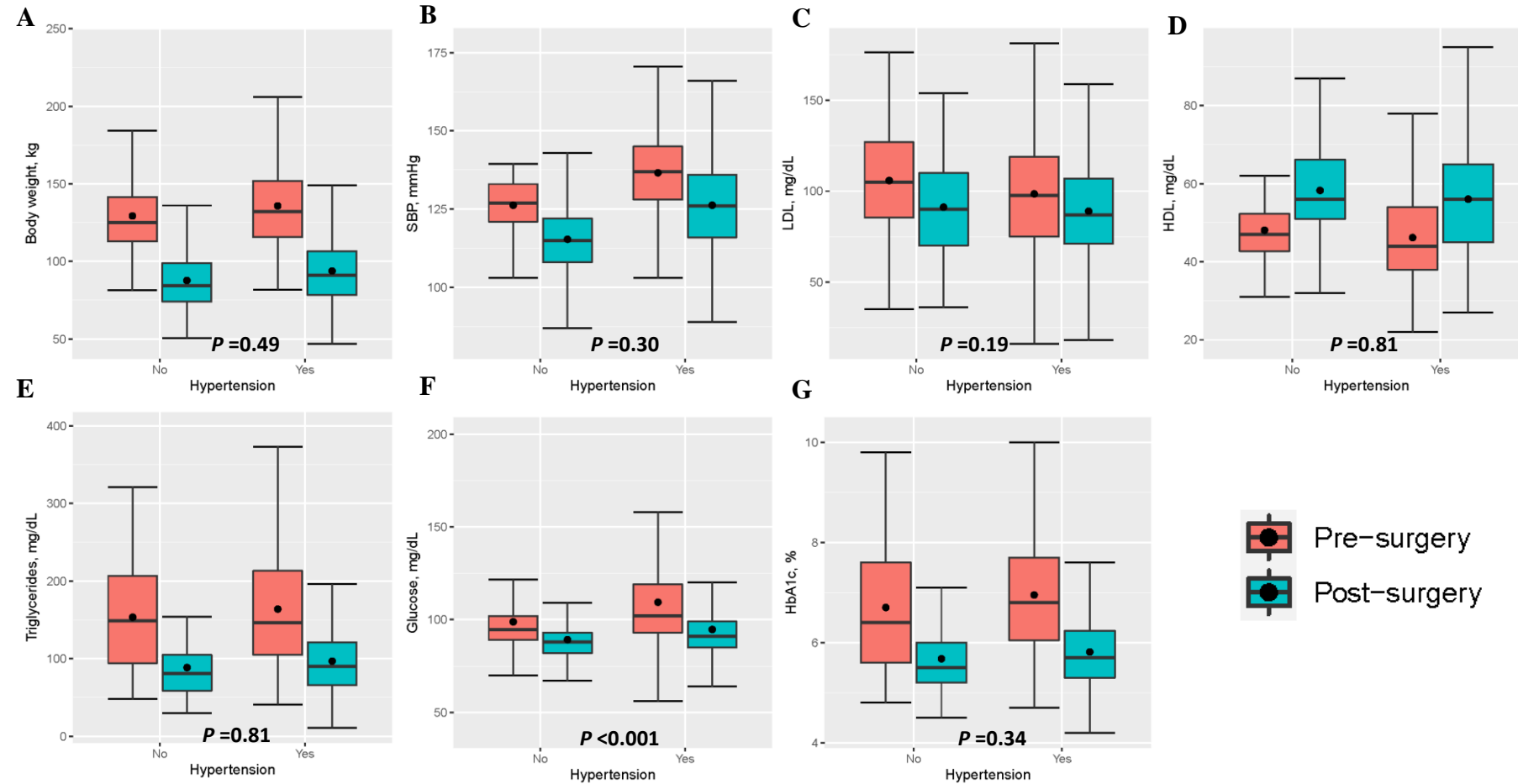
Supplementary Fig. 5 Cardiometabolic improvements between pre- and 1-year post-surgery by history of diabetes

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* value were for comparisons of cardiometabolic improvements after surgery between patients without diabetes and patients with diabetes.



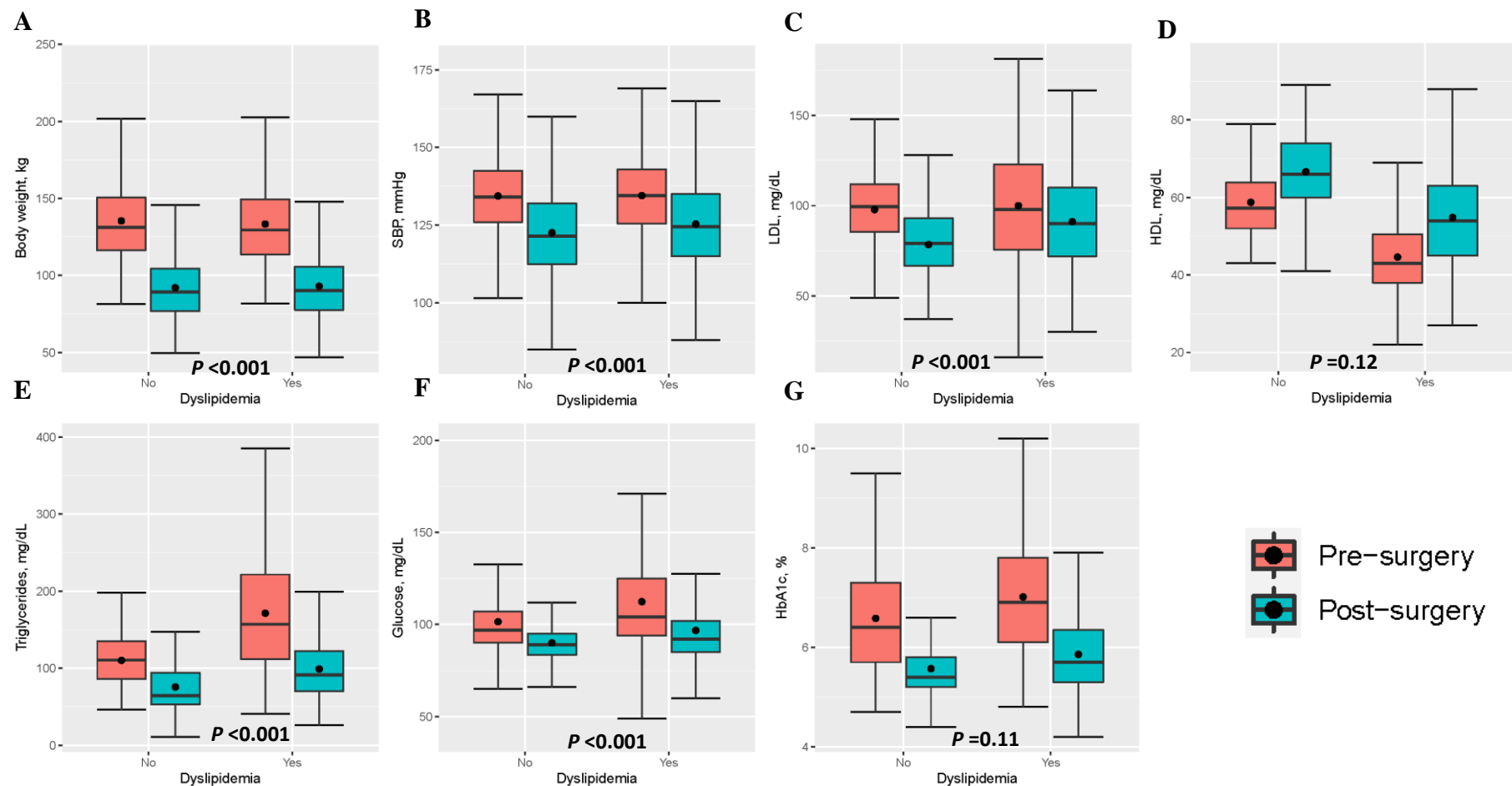
Supplementary Fig. 6 Cardiometabolic improvements between pre- and 1-year post-surgery by history of hypertension

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* value were for comparisons of cardiometabolic improvements after surgery between patients without hypertension and patients with hypertension.



Supplementary Fig. 7 Cardiometabolic improvements between pre- and 1-year post-surgery by history of dyslipidemia

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* value were for comparisons of cardiometabolic improvements after surgery between patients without dyslipidemia and patients with dyslipidemia.



Supplementary Fig. 8 Cardiometabolic improvements between pre- and 1-year post-surgery by history of cardiovascular disease

A: body weight; B: systolic blood pressure (SBP); C: low-density lipoprotein (LDL); D: high-density lipoprotein (HDL); E: triglycerides; F: glucose; G: HbA1c. *P* value were for comparisons of cardiometabolic improvements after surgery between patients without CVD and patients with CVD.

