Diabetes, Metabolic Syndrome and Obesity

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ORIGINAL RESEARCH

An Assessment of the Effect of Bariatric Surgery on Cardiovascular Disease Risk in the Chinese Population Using Multiple Cardiovascular Risk Models

Guangzhong Xu[1,*], Zheng Wang[1,*], Chengyuan Yu[1,*], Buhe Amin[1], Dexiao Du[1], Tianxiong Li[1], Guanyang Chen[2], Liang Wang[2], Zhehong Li[1], Weijian Chen[1], Chenxu Tian[1], Qiqige Wuyun[1], Qing Sang[2], Mingyue Shang[1], Dongbo Lian[1], Nengwei Zhang[1]

[1]Surgery Centre of Diabetes Mellitus, Capital Medical University Affiliated Beijing Shijitan Hospital, Beijing, People's Republic of China; [2]Surgery Centre of Diabetes Mellitus, Peking University Ninth School of Clinical Medicine, Beijing, People's Republic of China

*These authors contributed equally to this work

Correspondence: Nengwei Zhang; Dongbo Lian, Tel +8613801068802; +8613681299755, Email zhangnw1@sohu.com; lian.dongbo@126.com

Background: Many studies have reported that bariatric surgery may reduce postoperative cardiovascular risk in patient with obesity, but few have addressed this risk in the Chinese population.

Objective: To assess the impact of bariatric surgery on cardiovascular disease (CVD) risk in the Chinese population using the World Health Organization (WHO) risk model, the Global risk model, and the Framingham Risk Score.

Methods: We retrospectively analyzed data collected on patient with obesity who underwent bariatric surgery at our institution between March 2009 and January 2021. Their demographic characteristics, anthropometric variables, and glucolipid metabolic parameters were assessed preoperatively and at their 1-year postoperative follow-up. Subgroup analysis compared body mass index (BMI) < 35 kg/m^2 and BMI ≥ 35 kg/m^2, as well as gender. We used the 3 models to calculate their CVD risk.

Results: We evaluated 61 patients, of whom 26 (42.62%) had undergone sleeve gastrectomy (SG) surgery and 35 (57.38%) Roux-en-Y gastric bypass (RYGB) surgery. Of the patients with BMI ≥ 35 kg/m^2, 66.67% underwent SG, while 72.97% with BMI < 35 kg/m^2 underwent RYGB. HDL levels were significantly higher at 12 months postoperatively relative to baseline. When the models were applied to calculate CVD risk in Chinese patients with obesity, the 1-year CVD risk after surgery were reduced lot compared with the preoperative period.

Conclusion: Patient with obesity had significantly lower CVD risks after bariatric surgery. This study also demonstrates that the models are reliable clinical tools for assessing the impact of bariatric surgery on CVD risk in the Chinese population.

Keywords: obesity, bariatric surgery, CVD, World Health Organization risk model, global risk model, Framingham Risk Score

Introduction

Cardiovascular disease (CVD) is one of the leading causes of death worldwide, with more than 400 million CVD cases and 17 million CVD-related deaths occurring worldwide in 2005, and a 21.1% increase in the total number of CVD deaths between 2007 and 2017.[1–3] It is worth noting that obesity is a high-risk factor for developing cardiovascular disease[1,4–6] and is also a risk factor for developing type 2 diabetes, various cancers,[5,7] hip fractures,[8] dyslipidemia, and depression.[9] The prevalence of obesity in the world's population has increased in recent years.[7,10] It doubled in more than 70 countries and regions between 1980 and 2015.[11] In 2015, there were 170.7 million children with obesity and 603.7 million adults with obesity worldwide.[12] China now ranks first in the world in the number of overweight and

Received: 2 November 2022
Accepted: 31 March 2023
Published: 12 April 2023

patient with obesity, and the prevalence and growth rate of overweight and obesity are among the highest in the world.[12,13]

There are many ways to treat obesity, such as lifestyle changes, nutritional therapy, and exercise therapy.[5] Compared with traditional treatments, bariatric surgery can provide long-term stable weight loss and effective blood sugar control.[14] It improves the metabolic syndrome[15] and reduces the CVD mortality rate and improves the quality of life of patients.[16–18] To assess the risk of CVD in patient with obesity, many predictive models have been developed. Commonly used models include Framingham Risk Score (FRS), United Kingdom Prospective Diabetes Study, and Pooled Cohort Equations (PCE). However, most of these models are constructed based on population data from western countries, which may underestimate the CVD risk in the Chinese population.[19–21] In 2019, the WHO CVD Risk Chart Working Group reported the WHO CVD risk charts, which can be adjusted by region when calculating CVD risk.[22] Global risk is the first CVD risk score that predicts 10-year risk of fatal and non-fatal CVD in healthy individuals worldwide. The model, reported in 2017 by Ueda et al, uses the most recent data from 182 countries and can be adjusted by country when calculating CVD risk,[23] which allows the model to predict CVD risk in the Chinese population with considerable accuracy. Several studies have reported that bariatric surgery can reduce CVD risk in patients, but there are few reports using the WHO and Global risk models to assess the change in CVD risk before and after bariatric surgery in the Chinese population.

This study calculated the CVD risk in Chinese patient with obesity before, 3 months after, and 1 year after bariatric surgery using the WHO, Global, and FRS, to assess the effect of bariatric surgery on CVD risk in Chinese patient with obesity.

Methods

Patient Data Collection

We retrospectively collected data from patient with obesity who underwent bariatric surgery at our hospital between March 2009 and January 2021. The inclusion criteria were: patient with obesity with a BMI ≥ 32.5 kg/m^2; patients with a BMI ≥ 27.5kg/m^2 whose weight was difficult to control with lifestyle modification and medical therapy and met at least two metabolic syndrome components or had comorbidities in keeping with metabolic syndrome. The age at surgery was between 16 and 65. The enrolled patients met the WHO and Global criteria to calculate the 10-year CVD risk score or the criteria for the FRS to calculate 10-year and 30-year CVD risk scores. All enrolled patients had signed informed consent forms for surgery. The exclusion criteria were as follows: a history of CVD, such as acute myocardial infarction, acute coronary syndrome, or stroke, or patients lost to follow-up. A total of 61 patients were included in the study. The surgical technique was based on a previously published article.[24,25] The Institutional Review Board (IRB) of Beijing Shijitan Hospital approved this study (Approval No. sjtkyll-lx-2019-58). All participants provided informed consent for participation in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Application of Models

The FRS is a multivariate risk function that predicts the 10-year and 30-year risk of developing a cardiovascular disease event (coronary heart disease, stroke, peripheral arterial disease or heart failure). The FRS is the earliest and most widely used prediction model among the cardiovascular risk prediction models. Variables include age, total and HDL cholesterol, systolic blood pressure, hypertension treatment, smoking and diabetes status.[26]

The WHO risk model is based on a robust, extensive, and complementary global correlation dataset that includes prediction models for many low-income and middle-income countries and can be used to calculate CVD risk according to region. And the WHO CVD Risk Graph uses individual participant data from the Emerging Risk Factors Collaboration to derive a 10-year risk prediction model for fatal and non-fatal cardiovascular diseases (ie myocardial infarction and stroke), which includes information on age, smoking status, systolic blood pressure, history of diabetes and total cholesterol.[22]

The Global risk model is a predictive model based on laboratory data and recalibrated with risk assessment tools, which can be adjusted by country when calculating CVD risk. The new version of the Globorisk model (laboratory-based and non-laboratory

-based risk scores and charts) is based on the original laboratory-based predictive model (Globorisk) recalibrated with country-specific average risk factor levels and CVD rates for each sex and age group in each country. The laboratory-based risk score includes age, sex, smoking, blood pressure, diabetes and total cholesterol; for the non-laboratory-based (office) risk score, BMI is used instead of diabetes and total cholesterol.[23]

Definition of Surgical Success

Weight loss was most commonly reported as %EWL, with success defined as ≥ 50% EWL and failure as < 50% EWL.[27]

Definition of Diabetes Remission

According to a recent American Diabetes Association's (ADA)[28] expert consensus, remission is defined as an HbA1c level < 6.5% that occurs spontaneously or after intervention and lasts for at least 3 months without conventional glucose-lowering drug therapy.

Statistical Analysis

Statistical analyses were performed using SPSS version 26.0. (Armonk, NY: IBM Corp, USA) For continuous variables, the mean ± standard deviation was used if the data conformed to a normal distribution, and the median (quartiles) was used to describe the data if they did not conform to a normal distribution; for categorical variables, numbers (%) were used to describe the data. Categorical variable information was tested using the chi-squared test. For paired measures, the paired *t*-test was performed if the data were normally distributed, and if they did not obey a normal distribution, the Wilcoxon signed-ranks test was used for group comparisons. The student (independent sample) *t*-test was used for unpaired measures if the data were normally distributed. The Mann–Whitney *U*-test was performed if they did not obey a normal distribution. The *P*-value of < 0.05 was considered statistically significant.

Result

Patients' Baseline Characteristics

A total of 61 patients were included in this study, as shown in Table 1, aged 35–65 years with a median age of 45 years. Thirty patients (49.18%) were males, and 31 (50.82%) were females. Out of 61 patients, 26 (42.62%) underwent sleeve gastrectomy (SG) surgery, and 35 (57.38%) underwent Roux-en-Y gastric bypass (RYGB) surgery. There were twenty-four (39.34%) patients with BMI ≥ 35 kg/m^2 and 37 (60.66%) with BMI < 35 kg/m^2. Of the patients with a BMI ≥ 35 kg/m^2, 66.67% underwent SG surgery, while 72.97% with BMI < 35 kg/m^2 underwent RYGB surgery. Of the patients with a BMI ≥ 35 kg/m^2, 62.50% were males, and 59.46% of patients with a BMI < 35 kg/m^2 were females. Patients with a BMI ≥ 35 kg/m^2 had significantly higher basal systolic blood pressures compared with patients with a BMI < 35 kg/m^2 (p < 0.01). As shown in Table 2, body weight, glycosylated hemoglobin (HbA1c), total cholesterol (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) levels were higher in males than in females at baseline (*P* < 0.05). There were no significant differences in other indicators.

Table 1 Patient Demographics According to BMI

Characteristic	All (n = 61)	BMI ≥ 35 kg/m^2 (n = 24)	BMI < 35 kg/m^2 (n = 37)	P value
Age, yr	45 (37.5, 52)	44 (37, 52.5)	45.89 ± 7.7	0.615
Male (Female)	30 (31)	15 (9)	15 (22)	0.094
SG/RYGB	26/35	16 (8)	10 (27)	<0.01
Smoking (%)	8 (13.11%)	6 (25%)	2 (5.41%)	0.068
Duration of diabetes, yr	2.00 (1.00, 7.5)	1.00 (1, 5.25)	5 (0.5, 8)	0.143
Weight, kg	90.1 (84, 110)	113.05 ± 14.1	85.53 ± 8.46	<0.01
BMI, kg/m^2	33.06 (30.44, 39.33)	39.24 ± 1.81	30.94 ± 1.99	<0.01
WC, cm	109.07 ± 12.98	119.33 ± 10.67	102.42 ± 9.61	<0.01
SBP, mmHg	130 (120, 150)	142.42 ± 19.72	129 (119.5, 142)	<0.05

(*Continued*)

Table 1 (Continued).

Characteristic	All (n = 61)	BMI ≥ 35 kg/m^2 (n = 24)	BMI < 35 kg/m^2 (n = 37)	P value
DBP, mmHg	80 (78, 91)	84 (80, 98.75)	80 (76.5, 90)	0.082
FPG, mmol/L	7.57 (6.35, 10.95)	7.35 (6.2, 10.98)	7.92 (6.38, 10.96)	0.883
HbA1c,%	6.8 (5.95, 8.95)	6.85 (6, 7.8)	6.8 (5.8, 9)	0.749
TC, mmol/L	5.10 ± 1.02	5.05 ± 0.9	5.14 ± 1.1	0.756
TG, mmol/L	1.78 (1.32, 3.08)	1.89 (1.34, 3.71)	1.77 (1.31, 2.88)	0.488
HDL, mmol/L	1.04 ± 0.23	1.01 ± 0.18	1.06 ± 0.25	0.394
LDL, mmol/L	2.90 ± 0.87	2.91 ± 0.92	2.88 ± 0.84	0.912

Abbreviations: BMI, body mass index; yr, year; SG, sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1c, glycosylated hemoglobin; TC, serum total cholesterol; TG, serum triglycerides; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Table 2 Patient Demographics According to Gender

Characteristic	All (n=61)	Male (n=30)	Female (n=31)	P value
Age, yr	45 (37.5, 52)	45 (37, 52.5)	45 (39, 52)	0.994
SG/RYGB	26/35	12 (18)	14 (17)	0.684
Smoking (%)	8 (13.11%)	6 (20%)	2 (6.45%)	0.235
Duration of diabetes	2 (1, 7.5)	2 (1, 7)	3 (0, 8)	0.844
Weight, kg	90.1 (84, 110)	105.42 ± 19.05	87.59 ± 9.66	<0.01
BMI, kg/m^2	33.06 (30.44, 39.33)	35.45 (31.04, 39.45)	32.97 (29.74, 36.72)	0.379
WC, cm	109.07 ± 12.98	110.7 ± 15.75	107.5 ± 9.59	0.345
SBP, mmHg	130 (120, 150)	130 (120, 155.25)	135.48 ± 19.67	0.783
DBP, mmHg	80 (78, 91)	82.5 (80, 94)	80 (75, 90)	0.077
FPG, mmol/L	7.57 (6.35, 10.95)	8.95 (6.29, 11.62)	7.34 (6.41, 9.58)	0.184
HbA1C,%	6.8 (5.95, 8.95)	7.55 (6.03, 9.4)	6.7 (5.85, 7)	<0.05
TC, mmol/L	5.1 ± 1.02	5.02 ± 1.07	5.18 ± 0.98	0.550
TG, mmol/L	1.78 (1.32, 3.08)	2.3 (1.38, 4.14)	1.67 (1.31, 2.29)	<0.05
HDL, mmol/L	1.04 ± 0.23	0.92 (0.83, 1.08)	1.13 ± 0.19	<0.05
LDL, mmol/L	2.9 ± 0.87	2.62 ± 0.86	3.17 ± 0.79	<0.05

Abbreviations: BMI, body mass index; yr, year; SG, sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1c, glycosylated hemoglobin; TC, serum total cholesterol; TG, serum triglycerides; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

The baseline data trend is shown in Figure 1, where patients had significantly lower BMI, waist circumference (WC), fasting plasma glucose (FPG), and HbA1c at 3 and 12 months postoperatively compared with baseline values. Figure 2 summarizes the changes in baseline data compared by BMI subgroups. BMI ≥ 35 kg/m^2 BMI levels at 12 months in the patient group decreased from 39.24 ± 1.81 kg/m^2 to 25.30 ± 8.18 kg/m^2. In the BMI < 35 kg/m^2 and BMI ≥ 35 kg/m^2 groups, BMI, WC, FPG, systolic blood pressure (SBP), diastolic blood pressure (DBP), and HbA1c showed similar decline curves. SBP and DBP measurements were significantly lower compared with baseline values in both groups. Total cholesterol levels decreased in both groups at 3 months postoperatively compared with 1 year postoperatively compared with baseline values. The HDL levels were significantly higher in both groups 12 months postoperatively relative to baseline values.

Figure 3 summarizes and compares the changes in baseline data by sex subgroup. BMI, WC, FPG, and HbA1c were significantly lower in both groups 3 and 12 months postoperatively compared with baseline values. In the male patient group, the weight decreased from 105.42 ± 19.05 kg to 78.04 ± 12.24 kg at 12 months. The decline curves of BMI, WC, FPG, SBP, DBP, and HbA1c were similar between the two groups. HDL levels were significantly higher in both groups 12 months postoperatively relative to baseline.

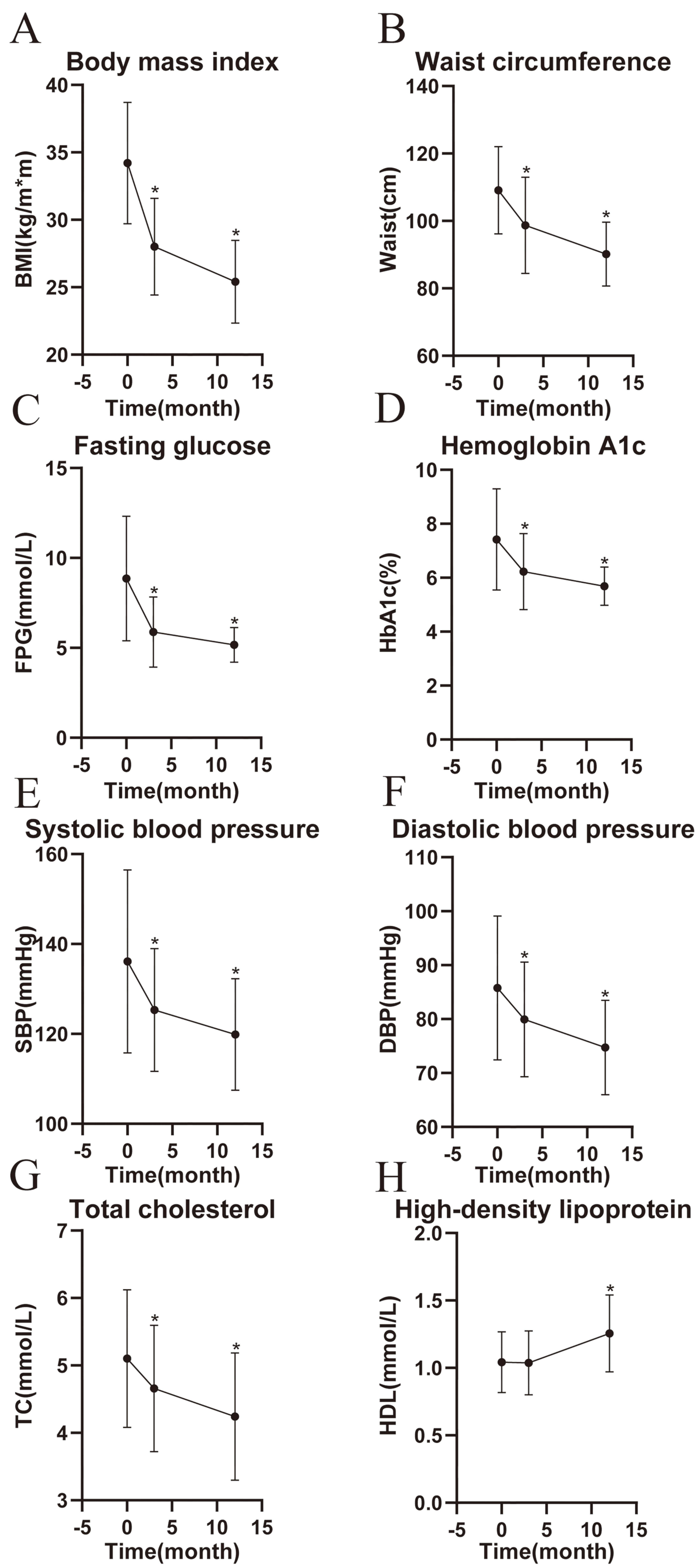

Figure 1 Mean changes in measures of weight loss and glycemic control from baseline to 1 years.

Notes: (**A–H**) Represents the change curves of BMI, Waist, FPG, HbA1c, SBP, DBP, TC, and HDL before surgery, 3 months and 12 months after surgery, respectively.

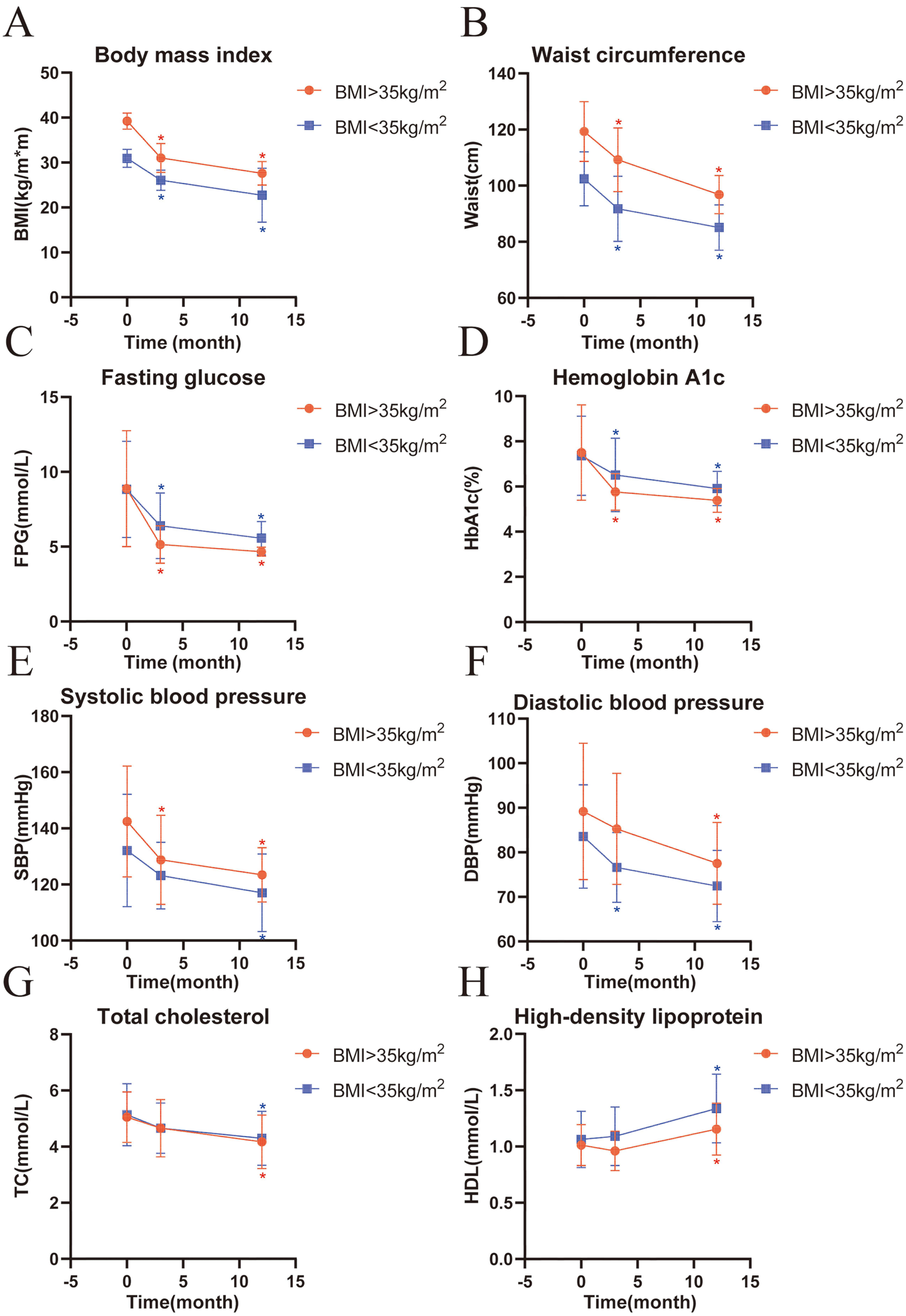

Figure 2 Mean changes in measures of weight loss and glycemic control from baseline to 1 years between the 2 groups. (BMI ≥ 35kg/m^2 versus BMI < 35kg/m^2).
Notes: (**A**–**H**) Represents the change curves of BMI, Waist, FPG, HbA1c, SBP, DBP, TC, and HDL before surgery, 3 months and 12 months after surgery in BMI≥35 kg/m^2 and BMI<35 kg/m^2 groups, respectively.

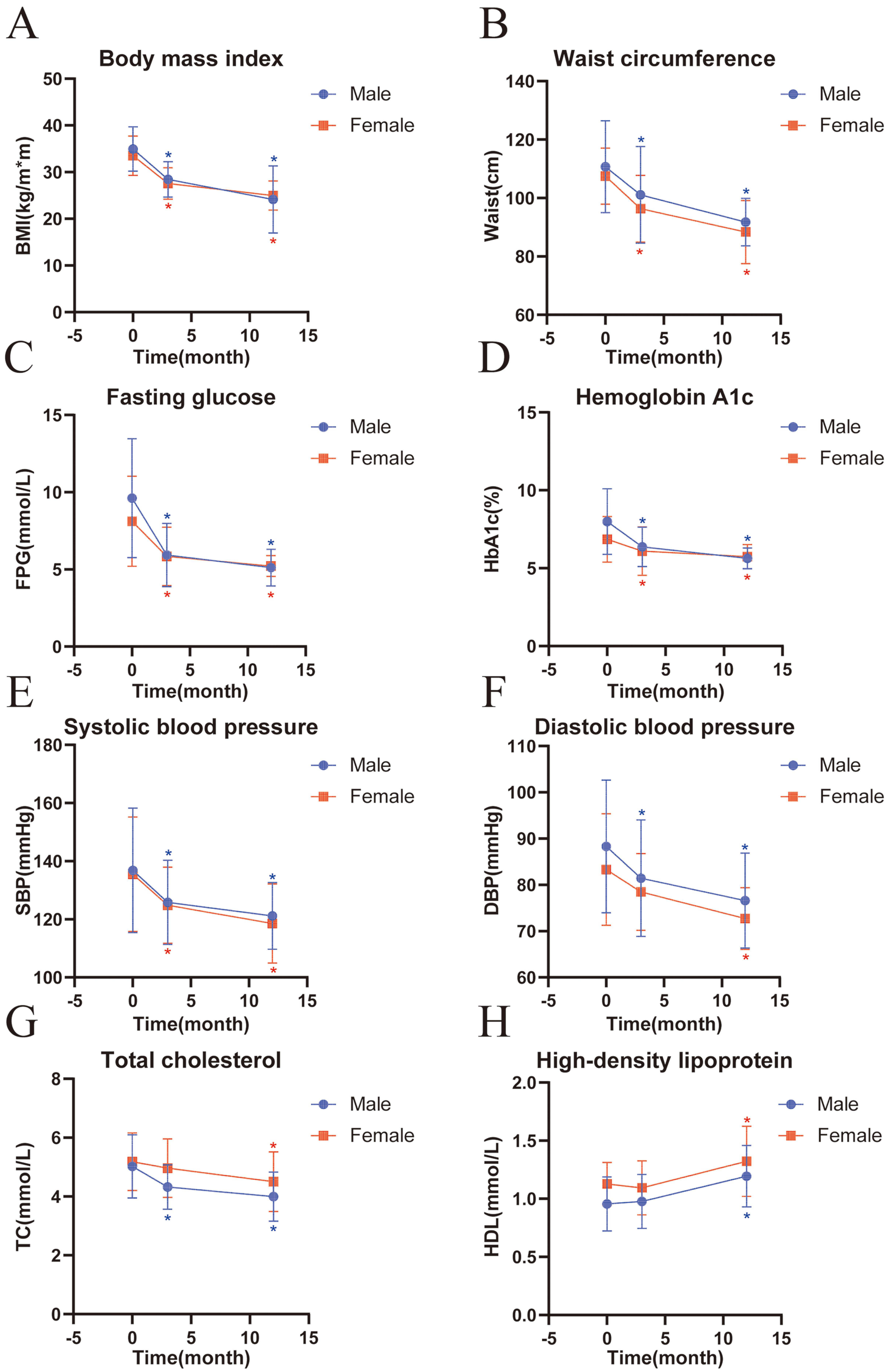

Figure 3 Mean changes in measures of weight loss and glycemic control from baseline to 1 years between the 2 groups. (Male versus Female).
Notes: (**A–H**) Represents the change curves of BMI, Waist, FPG, HbA1c, SBP, DBP, TC, and HDL before surgery, 3 months and 12 months after surgery in Male and Female groups, respectively.

Ten-Year Cardiovascular Risk Assessment

As shown in Table 3 for subgroups by BMI, the WHO and Global risk models were used to assess the 10-year CVD risk of patients based on laboratory and non-laboratory data. At baseline, the 10-year CVD risk was higher in the group of patients with BMI ≥ 35 kg/m^2 than in those with a BMI < 35 kg/m^2. At 3 months and 1 year postoperatively, the overall CVD risk values calculated by the WHO risk model based on laboratory data were significantly lower compared with baseline values, and overall CVD risk values calculated by the Global risk model were significantly lower compared with baseline values. In the BMI ≥ 35 kg/m^2 patient group, the 10-year CVD risk calculated based on laboratory data at 3 months and 1 year postoperatively was significantly lower than preoperative values.

As shown in Table 3 by BMI subgroups, the 10-year risk of CVD for patients assessed using the FRS was higher in the preoperative BMI ≥ 35 kg/m^2 patient group than in the BMI < 35 kg/m^2 group. The 10-year risk of CVD calculated based on laboratory and non-laboratory data decreased significantly ($P < 0.05$) in both patient groups at 12 months of follow-up.

As shown in Table 4 for subgroups by sex, using the WHO and Global risk models to assess the 10-year CVD risk of patients at baseline, only the Global risk model yielded a greater CVD risk for females than for males based on laboratory data, whereas several other models yielded a higher CVD risk for males than for females. At 3 months and 1 year postoperatively, the WHO and Global risk models calculated significantly lower CVD risk values based on laboratory data

Table 3 10-Yr Cardiovascular Risk Between BMI ≥ 35 kg/m^2 and BMI < 35 kg/m^2

	Baseline	**3 Mo**	**12 Mo**
WHO risk model (TC)			
Overall	8.00 (5.00, 13.50)	5.00 (3.00, 7.00)*	4.00 (2.00, 6.00)*
BMI ≥ 35 kg/m^2	9.00 (7.25, 14.00)	5.00 (3.00, 7.00)*	4.00 (2.50, 5.00)*
BMI < 35 kg/m^2	8.00 (5.00, 12.50)	5.00 (3.00, 9.00)*	4.00 (2.00, 6.75)*
p value	> 0.05	> 0.05	> 0.05
WHO risk model (BMI)			
Overall	5.00 (3.00, 9.50)	4.00 (3.00, 7.00)	4.00 (3.00, 6.00)
BMI ≥ 35 kg/m^2	8.00 (4.00, 10.75)	5.00 (4.00, 8.50)	5.00 (3.00, 6.00)
BMI < 35 kg/m^2	4.00 (3.00, 8.00)	4.00 (3.00, 6.00)	4.75 ± 2.65
p value	< 0.01	< 0.05	> 0.05
Global risk model (TC)			
Overall	12.00 (6.50, 18.00)	5.00 (3.00, 10.00)*	3.00 (2.00, 7.50)*
BMI ≥ 35 kg/m^2	14.00 (7.25, 18.00)	4.50 (3.00, 8.00)*	3.00 (2.00, 5.00)*
BMI < 35 kg/m^2	11.00 (5.50, 17.50)	6.20 (3.70, 10.50)*	4.00 (3.00, 8.00)*
p value	> 0.05	>0.05	> 0.05
Global risk model (BMI)			
Overall	7.00 (4.00, 11.00)	4.00 (3.00, 8.00)*	4.00 (2.00, 7.00)*
BMI ≥ 35 kg/m^2	9.00 (6.00, 13.00)	6.00 (4.00, 10.50)*	4.00 (2.50, 7.50)*
BMI < 35 kg/m^2	5.00 (3.00, 9.50)	3.00 (2.00, 6.25)*	4.00 (2.00, 7.00)
p value	< 0.01	< 0.05	> 0.05
Framingham Risk score (lipid)			
Overall	11.80 (6.75, 19.35)	6.85 (4.05, 11.03)*	4.20 (1.35, 6.73)*
BMI ≥ 35 kg/m^2	14.75 (9.53, 20.75)	8.25 ± 4.15*	4.35 (1.20, 6.15)*
BMI < 35 kg/m^2	10.70 (5.10, 17.00)	6.20 (3.70, 10.50)*	3.85 (1.35, 7.58)*
p value	< 0.05	> 0.05	> 0.05
Framingham Risk score (BMI)			
Overall	14.50 (8.05, 24.00)	8.20 (4.00, 12.00)*	6.50 (3.20, 9.90)*
BMI ≥ 35 kg/m^2	16.90 (12.43, 27.80)	9.05 ± 4.04*	6.88 ± 3.05*
BMI < 35 kg/m^2	11.30 (5.95, 19.15)	7.25 (3.48, 13.38)*	5.55 (1.98, 13.50)*
p value	< 0.01	> 0.05	> 0.05

Note: *P< 0.05 compared with baseline in patients.

Abbreviations: BMI, body mass index; yr, year; TC, serum total cholesterol; mo, month.

than baseline values. In the WHO risk model based on non-laboratory data, only males had a significantly lower CVD risk at 12 months postoperatively compared with the baseline. Notably, the risk values calculated by the Global risk model based on non-laboratory data were slightly higher at 12 months postoperatively in comparison with 3 months postoperatively.

As shown in Table 4 for subgroups by sex, the 10-year risk of CVD was significantly higher in males than in females at baseline when the FRS was applied to assess patients' 10-year risk of CVD. The 10-year CVD risk calculated based on laboratory and non-laboratory data decreased significantly ($P < 0.05$) in both patient groups at 12 months of follow-up.

Thirty-Year Cardiovascular Risk Assessment

As shown in Table 5, in the calculation of 30-year CVD risk based on non-laboratory data using the FRS, the risk was significantly higher in both the BMI ≥ 35 kg/m^2 patient group than in the BMI < 35 kg/m^2 group at baseline values ($P < 0.05$) and was significantly lower in both groups compared with baseline values at 3 and 12 months of follow-up ($P < 0.05$).

In Table 6, the FRS was used to assess the 30-year CVD risk between males and females. At baseline, the CVD risk was higher in males than in females, and at 3 and 12 months after bariatric surgery, the 30-year CVD risk was significantly lower in both groups compared with the baseline value ($P < 0.05$).

Table 4 10-Yr Cardiovascular Risk Between Male and Female

	Baseline	3 Mo	12 Mo
WHO risk model (TC)			
Overall	8.00 (5.00, 13.50)	5.00 (3.00, 7.00)*	4.00 (2.00, 6.00)*
Male	10.00 (6.00, 13.25)	5.00 (4.00, 8.50)*	4.00 (3.00, 7.00)*
Female	8.00 (5.00, 14.00)	5.00 (2.00, 7.00)*	4.00 (2.00, 6.00)*
p value	> 0.05	> 0.05	> 0.05
WHO risk model (BMI)			
Overall	5.00 (3.00, 9.50)	4.00 (3.00, 7.00)	4.00 (3.00, 6.00)
Male	7.63 ± 4.06	5.00 (4.00, 8.00)	5.27 ± 2.34*
Female	4.00 (3.00, 8.00)	3.50 (3.00, 6.50)	3.50 (2.75, 6.25)
p value	> 0.05	> 0.05	> 0.05
Global risk model (TC)			
Overall	12.00 (6.50, 18.00)	5.00 (3.00, 10.00)*	3.00 (2.00, 7.50)*
Male	10.50 (5.75, 16.00)	4.00 (3.00, 8.50)*	3.00 (2.00, 6.00)*
Female	16.00 (8.00, 21.00)	6.00 (3.00, 13.25)*	3.50 (2.00, 8.00)*
p value	> 0.05	> 0.05	> 0.05
Global risk model (BMI)			
Overall	7.00 (4.00, 11.00)	4.00 (3.00, 8.00)*	4.00 (2.00, 7.00)*
Male	8.23 ± 4.58	5.00 (3.00, 8.00)*	4.00 (2.00, 6.00)*
Female	6.00 (3.00, 10.00)	3.00 (3.00, 6.75)*	3.50 (2.00, 8.00)
p value	> 0.05	> 0.05	> 0.05
Framingham risk score (lipid)			
Overall	11.80 (6.75, 19.35)	6.85 (4.05, 11.03)*	4.20 (1.35, 6.73)*
Male	16.40 (9.45, 22.23)	7.50 (5.90, 13.15)*	4.80 (3.28, 8.45)*
Female	10.10 (4.90, 15.70)	4.40 (3.00, 10.00)*	2.40 (0.95, 5.78)*
p value	< 0.01	< 0.01	> 0.05
Framingham risk score (BMI)			
Overall	14.50 (8.05, 24.00)	8.20 (4.00, 12.00)*	6.50 (3.20, 9.90)*
Male	16.90 (11.80, 26.18)	10.00 (6.70, 16.20)*	9.16 ± 4.90*
Female	10.70 (4.80, 15.80)	4.60 (3.00, 9.35)*	3.65 (1.80, 6.83)*
p value	< 0.01	< 0.01	< 0.01

Note: *P< 0.05 compared with baseline in patients.
Abbreviations: BMI, body mass index; yr, year; TC, serum total cholesterol; mo, month.

https://doi.org/10.2147/DMSO.S389346

Table 5 30-Yr Cardiovascular Risk Between BMI ≥ 35 kg/m^2 and BMI < 35 kg/m^2

	Baseline	3 Mo	12 Mo
30-year Full CVD (Lipid)			
Overall	51.41 ± 20.81	35.04 ± 16.36*	20.00 (10.00, 39.00)*
BMI ≥ 35 kg/m^2	57.25 ± 18.22	35.89 ± 15.76*	22.00 (9.00, 51.50)*
BMI < 35 kg/m^2	47.62 ± 21.73	34.47 ± 16.99*	25.31 ± 20.43*
P value	> 0.05	> 0.05	> 0.05
30-year Hard CVD (Lipid)			
Overall	37.41 ± 19.86	19.00 (11.25, 29.50)*	12.00 (4.00, 19.50)*
BMI ≥ 35 kg/m^2	42.79 ± 17.78	21.48 ± 11.77*	12.00 (4.50, 31.50)*
BMI < 35 kg/m^2	33.92 ± 20.58	19.00 (11.00, 30.00)*	10.50 (3.50, 19.75)*
P value	> 0.05	> 0.05	> 0.05
30-year Full CVD (BMI)			
Overall	60.00 (40.50, 78.00)	37.40 ± 17.10*	29.00 ± 15.24*
BMI ≥ 35 kg/m^2	69.29 ± 16.84	38.52 ± 14.84*	29.38 ± 9.63*
BMI < 35 kg/m^2	51.19 ± 21.62	36.71 ± 18.53*	28.69 ± 18.95*
P value	< 0.01	> 0.05	> 0.05
30-year Hard CVD (BMI)			
Overall	46.05 ± 22.09	24.00 (14.00, 33.00)*	17.00 (8.50, 24.50)*
BMI ≥ 35 kg/m^2	57.25 ± 18.83	25.33 ± 12.66*	18.23 ± 6.98*
BMI < 35 kg/m^2	38.78 ± 21.19	24.50 (9.75, 33.25)*	13.50 (6.00, 28.00)*
P value	< 0.01	> 0.05	> 0.05

Note: *P< 0.05 compared with baseline in patients.
Abbreviations: BMI, body mass index; yr, year; TC, serum total cholesterol; mo, month CVD, Cardiovascular disease.

As shown in Table 7, comparison of different models for calculating CVD risk preoperatively and at 12 months postoperatively, in the calculation of CVD risk based on laboratory data, the FRS calculated a higher CVD risk than the other models and had a higher relative risk reduction rate at 12 months postoperatively; in the calculation of CVD risk based on non-laboratory data, the Global risk model calculated a higher CVD risk than the other models and had a higher relative risk reduction rate at 12 months postoperatively than the other risks.

Table 6 30-Yr Cardiovascular Risk Between Male and Female

	Baseline	3 Mo	12 Mo
30-year Full CVD (Lipid)			
Overall	51.41 ± 20.81	35.04 ± 16.36*	20.00 (10.00, 39.00)*
Male	56.36 ± 18.01	37.88 ± 14.71*	22.00 (16.00, 34.00)*
Female	47.00 (23.00, 67.00)	32.41 ± 17.62*	14.50 (5.50, 44.50)*
P value	> 0.05	> 0.05	> 0.05
30-year Hard CVD (Lipid)			
Overall	37.41 ± 19.86	19.00 (11.25, 29.50)*	12.00 (4.00, 19.50)*
Male	44.00 ± 18.69	23.00 (15.00, 32.00)*	13.00 (9.00, 19.00)*
Female	31.00 (13.00, 46.00)	13.00 (9.00, 28.00)*	6.50 (1.75, 20.25)*
P value	< 0.05	> 0.05	> 0.05
30-year Full CVD (BMI)			
Overall	60.00 (40.50, 78.00)	37.40 ± 17.10*	29.00 ± 15.24*
Male	65.67 ± 16.31	44.41 ± 14.29*	33.93 ± 14.53*
Female	51.19 ± 23.95	26.00 (17.25, 42.50)*	19.00 (11.00, 36.00)*
P value	< 0.01	< 0.01	> 0.05

(*Continued*)

Table 6 (Continued).

	Baseline	3 Mo	12 Mo
30-year Hard CVD (BMI)			
Overall	46.05 ± 22.09	24.00 (14.00, 33.00)*	17.00 (8.50, 24.50)*
Male	55.27 ± 18.00	29.00 (21.00, 45.00)*	22.00 (15.00, 28.00)*
Female	37.13 ± 22.26	14.50 (8.25, 28.50)*	9.50 (5.75, 19.50)*
P value	< 0.01	< 0.01	< 0.05

Note: *P< 0.05 compared with baseline in patients.
Abbreviations: BMI, body mass index; yr, year; mo, month; CVD, Cardiovascular disease.

Table 7 10-Year Cardiovascular Risk of Different Modal Before and 1 Year After Surgery

	Baseline	12 Mo	Relative Risk Reduction
WHO risk model (TC)	8.00 (5.00, 13.50)	4.00 (2.00, 6.00)*	50%
WHO risk model (BMI)	5.00 (3.00, 9.50)	4.00 (3.00, 6.00)	20%
Global risk model (TC)	12.00 (6.50, 18.00)	3.00 (2.00, 7.50)*	75%
Global risk model (BMI)	7.00 (4.00, 11.00)	4.00 (2.00, 7.00)*	42.86%
Framingham Risk score (lipid)	11.80 (6.75, 19.35)	4.20 (1.35, 6.73)*	64.41%
Framingham Risk score (BMI)	14.50 (8.05, 24.00)	6.50 (3.20, 9.90)*	55.17%

Note: *P< 0.05 compared with baseline in patients.
Abbreviations: BMI, body mass index; yr, year; TC, serum total cholesterol; mo, month.

Discussion

Numerous recent studies have shown that bariatric surgery can reduce CVD risk in patient with obesity. In 2019 the WHO organization updated the WHO risk prediction model, which calculates CVD risk with the ability to adjusted by region,[22] and in 2017, Harvard University updated the Global risk model, which can be adjusted by country when calculating CVD risk.[23] However, no studies have evaluated the change in CVD risk in Chinese patient with obesity after bariatric surgery using CVD risk models, such as FRS, WHO risk model, and Global risk model.

Compared with the preoperative period, patients' weight and BMI decreased significantly at 3 and 12 months after bariatric surgery. This suggests that bariatric surgery improved abdominal obesity, which was shown to be an independent risk factor for coronary heart disease in males in a study by Lakka et al.[29] In this study, the %TWL and %EWL of patients continued to rise, with %EWL > 50% as the cut-off value, and the percentage of patients with successful weight loss at 3 and 12 months postoperatively was 63.46% and 96.49%, respectively, with a more favorable weight loss outcome, consistent with previous reports.[30] Patients' blood glucose decreased significantly at 3 and 12 months postoperatively as compared with preoperative levels. According to the definition of T2DM remission, the rate of diabetes remission in patient with obesity in this study was 60% at 1 year. Similarly, in 2021, Sarma et al reported a remission rate of 75% and 95% for T2DM at two years after RYGB and BPD, respectively,[31] which is consistent with the present study. Also, blood pressure was significantly lower in patients after bariatric surgery; we also observed increased HDL levels and decreased TC levels in both subgroups, Osto et al reported that bariatric surgery could rapidly reverse obesity-induced endothelial dysfunction and restore the endothelial protective properties of HDL.[32] Our study suggests that bariatric surgery not only reduces patients' weight but also improves their blood glucose levels, hypertension and hyperlipidemia, these metabolic benefits may help to reduce the risk of cardiovascular occurrence after bariatric surgery.

In this study, three models were used to determine cardiovascular risk after bariatric surgery in the Chinese population. First, when the WHO risk prediction model was used to calculate the 10-year CVD risk in Chinese patient with obesity, the 1-year CVD risk based on laboratory data was reduced by 50% compared with the preoperative risk, whereas the 1-year CVD risk after bariatric surgery based on non-laboratory data was reduced by 20% compared with the preoperative risk. In the global risk model, the CVD risk value at 1 year calculated based on laboratory data was 75.00%

lower than preoperatively, whereas the CVD risk value at 1 year was calculated based on non-laboratory data was 42.86% lower than preoperatively. When the 10-year CVD risk was calculated using the FRS, the CVD risk at 1 year based on laboratory data was 64.41% lower than preoperatively, whereas the CVD risk at 1 year based on non-laboratory data was 55.17% lower than preoperatively. Similarly, several studies assessing the effect of bariatric surgery on cardiovascular risk using the FRS model showed a significant reduction in CVD in patient with obesity after bariatric surgery.[33–35] Arterburn et al used the FRS to calculate a reduction in 10-year cardiovascular risk from 6.7% at baseline to 5.2% at 6 months and 5.4% at 12 months.[34] The 10-year risk of coronary heart disease and fatal coronary heart disease calculated by Ke et al using the UKPDS risk engine was reduced by 48.1% and 53.1%, respectively after surgery.[36] Wei et al found that bariatric surgery reduced the overall 10-year risk of coronary heart disease and fatal coronary heart disease by 50% at 1-year postoperatively.[37]

Then, we performed subgroup analyses on the BMI ≥ 35 kg/m^2 and BMI < 35 kg/m^2 group. The results of the three models suggested a reduced risk value for CVD at 3 months postoperatively and 12 months postoperatively compared with preoperatively. Notably, in the both subgroups, the 10-year and 30-year CVD risk at 3 and 12 months calculated using the WHO risk prediction model (based on non-laboratory data) was decreased compared with baseline, but the difference was not significant; when the FRS was applied to assess the 30-year CVD risk, BMI < 35 kg/m^2 and BMI ≥ 35 kg/m^2 CVD risk was reduced at 3 months postoperatively and 12 months postoperatively in both subgroups relative to preoperatively, but there was no statistical difference in CVD risk at 1 year postoperatively relative to preoperatively in both subgroups ($P > 0.05$), which may be related to the limited volume of specimens at 1 year postoperatively. Additionally, we performed subgroup analyses by gender. The results of all three models suggested that patients had a reduced 10-year CVD risk at 3 and 12 months postoperatively compared with preoperatively; preoperatively, the CVD risk was essentially greater in male than in females, which is consistent with the relevant literature.[38] The risk of CVD at 3 and 12 months using the WHO risk prediction model (based on non-laboratory data) was reduced relative to the preoperative period, but only the males showed a statistically significant difference in CVD risk values at 12 months after surgery relative to the preoperative period.

One of the more striking innovations of this study is the use of the WHO risk model and the Global risk model to assess the change in CVD risk in the Chinese population after bariatric surgery. To our knowledge, we are the first research team to use the WHO and Globorisk models to assess the impact of weight loss surgery on CVD risk in the Chinese population with obesity. Our results showed that the cardiovascular risk calculated by non-laboratory data was consistent with that based on laboratory data for both the global risk model and the WHO risk model, which affirms the feasibility of predicting the risk of cardiovascular occurrence based on non-laboratory data. In this study, the risks calculated by the WHO risk model, Global risk model, and FRS were similar at 1 year after bariatric surgery, ie, the WHO risk model and the Global risk model can be used as reliable and concise clinical tools to assess the change in risk of cardiovascular disease occurrence in Chinese patients after bariatric surgery. Also, when comparing the CVD risk values calculated by different models in this study, the CVD risk values calculated by FRS were higher than the other two models, which is also consistent with other related studies.[39,40]

At the same time, this study has some limitations. It is a retrospective study with a relatively small sample size, a relatively low follow-up rate, and a lack of follow-up data beyond 1 year, which will undoubtedly affect the 10-year cardiovascular risk assessment outcome. Further follow-ups and studies are needed.

Conclusion

The 10-year and 30-year cardiovascular risks were significantly reduced at 3 and 12 months after bariatric surgery in patient with obesity. Our study also showed that WHO risk model and Global risk model are reliable clinical tools to assess the impact of bariatric surgery on CVD risk in the Chinese population.

Acknowledgments

The authors would like to thank all the reviewers who participated in the article. Guangzhong Xu, Zheng Wang, Chengyuan Yu are co-first authors.

Funding

Funding for this study was not applicable.

Disclosure

The authors report no conflicts of interest in this work.

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