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Atherogenic index of plasma is reduced during follow-up among Roux-in-Y gastric bypass patients

El índice aterogénico del plasma se reduce durante el seguimiento de los pacientes sometidos a bypass gástrico en Y de Roux

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ABSTRACT

Atherogenic index of plasma is a marker used to assess risk of cardiovascular diseases. The present study evaluated plasma atherogenic index in individuals before and after bariatric surgery. Individuals were evaluated at three time points: before surgery (T0), in the 2nd (T1) and 6th (T2) months post-surgery. Anthropometric (body mass index, waist circumference, fat and lean mass) and biochemical parameters (lipid profile, glucose and C-reactive protein), and atherogenic index of plasma, calculated by the formula $[\log (\text{serum triglycerides concentration}/\text{HDL cholesterol})]$, were evaluated. Data were analyzed using the repeated measures ANOVA or Friedman test according to data distribution. The level of significance was 5%. Thirty-four patients agreed to participate. A significant reduction was observed in all anthropometric parameters in women and men ($p < 0.05$). Atherogenic index of plasma reduced significantly in all time points in women; there was a significant reduction only between periods T0 and T2 ($p < 0.05$) in men. A reduction in the classification for risk in cardiovascular diseases, with high risk in T0 (0.441 ± 0.13) to moderate risk at T1 (0.204 ± 0.22) and low risk at T2 (0.041 ± 0.16) was observed in men. In women, the risk remained low (< 0.11) in all periods. Bariatric surgery reduced the atherogenic index of plasma during the 6-month follow-up, suggesting a reduction in cardiovascular risk.

Keywords: Bariatric surgery; Cardiovascular diseases; Lipid profile; Obesity; Roux-en-Y gastric bypass.

RESUMEN

El índice aterogénico plasmático es un marcador que se utiliza para evaluar el riesgo de enfermedades cardiovasculares. El presente trabajo evaluó el índice aterogénico plasmático de pacientes antes y después de la cirugía bariátrica. Los individuos fueron evaluados en tres momentos: antes de la cirugía (T0), el segundo (T1) y el sexto (T2) meses después de la cirugía. Se evaluaron parámetros antropométricos (índice de masa corporal, circunferencia de cintura, masa grasa y masa magra), parámetros bioquímicos (perfil lipídico, glucosa y proteína C reactiva) y el índice aterogénico plasmático, calculado mediante la fórmula $[= \log (\text{concentración sérica de triglicéridos} / \text{colesterol HDL})]$. Los datos se analizaron mediante el ANOVA de medidas repetidas o el Test de Friedman según la distribución de los datos. Nivel de significancia adoptado 5%. Treinta y cuatro pacientes aceptaron participar en el estudio. Se observó una reducción significativa en todos los parámetros antropométricos en ambos sexos ($p < 0.05$). En las mujeres, el índice aterogénico plasmático disminuyó significativamente en todos los períodos. En los hombres, hubo una reducción significativa en el índice aterogénico plasmático solo entre T0 y T2 ($p < 0.05$), aunque se observó una reducción en la clasificación de riesgo para enfermedades cardiovasculares de alto riesgo en T0 (0.441 ± 0.13) para moderadas riesgo en T1 (0.204 ± 0.22) y riesgo bajo en T2 (0.041 ± 0.16). En las mujeres, el riesgo se mantuvo bajo (< 0.11) en todos los períodos. La cirugía bariátrica redujo la PIA durante el seguimiento de 6 meses, lo que sugiere una reducción del riesgo cardiovascular.

Palabras clave: Bypass Gástrico en Y de Roux; Cirugía bariátrica; Enfermedades cardiovasculares; Obesidad; Perfil lipídico.

INTRODUCTION

Cardiovascular diseases (CVD) are the world's leading cause of death¹. The main risk factors for the development of CVD include arterial hypertension, diabetes mellitus, obesity, and dyslipidemia, the latter represented by high serum levels of total cholesterol (TC), low-density lipoprotein (LDL), and triglycerides (TG), as well as reduced levels of high-density lipoprotein (HDL)². The assessment of risk factors for CVD by methods which are simple, relatively inexpensive, and easy to use in clinical practice, has been proposed^{3,4,5}. The Atherogenic Index of Plasma (AIP), calculated as the logarithm of the molar ratio of plasma TG to HDL, was initially described in 2001 as a marker of atherogenicity⁶. AIP can reflect the balance between atherogenic and anti-atherogenic factors, being superior in assessing the risk for the development of CVD when compared to other isolated indexes or parameters from the lipid profile^{4,7}. AIP has a positive association with molecular biomarkers that predict CVD, such as asymmetric dimethylarginine and fatty acid binding protein 4, and a negative association with the size of LDL particles^{4,8}. An increase in AIP also reflects an increase in the proportion of small dense LDL, which are more vulnerable to oxidative attack and, consequently, favor the occurrence of atherosclerotic lesions^{9,10}. In addition, high AIP values usually indicate a higher risk for obesity¹¹. Obesity is considered an independent risk factor for CVD^{12,13}, as it generates an abnormal metabolic profile and may affect cardiac structure and function^{14,15}. With regards to the treatment of severe obesity, bariatric surgery is considered the most effective method to promote consistent weight loss over time and reduce associated comorbidities^{16,17,18}. The impact of bariatric surgery on atherogenic dyslipidemia has been studied^{19,20,21}, however, in cases where isolated parameters of the lipid profile are within the normal range, it is necessary to use an additional investigation tool³. Considering the relevance and feasibility of AIP, and its

relationship with cardiovascular risk, including among people with obesity, the aim of this study was to evaluate AIP before and after bariatric surgery.

MATERIALS AND METHODS

We conducted a prospective study among adults of both sexes, enrolled in the Bariatric and Metabolic Surgery Program of the Hospital Universitário Cassiano Antônio Moraes (HUCAM) in Vitória, Espírito Santo, Brazil. In order to be enrolled in the program, one must have a medical referral from the public health system in the state of Espírito Santo, and have a Body Mass Index (BMI) greater than 40 kg/m² or greater than 35 kg/m² with one or more comorbidities of clinical importance related to obesity, such as: diabetes mellitus, systemic arterial hypertension, cardiovascular diseases, dyslipidemia, or depression, among others.

All individuals eligible for Roux-en-Y gastric bypass were invited to participate in the study. Participants were personally invited to join the study by nutritionists from the Graduate Program in Nutrition and Health of the Federal University of Espírito Santo. Invitations took place at the last meeting before surgery, foreseen in the schedule of the HUCAM Bariatric Surgery Program.

The sample was assembled by those individuals who agreed to participate in the study and who carried out the three evaluations. The study was carried out from April 15, 2016 to March 12, 2020 and data were collected in three moments: preoperative (approximately one month before surgery-T0), two months (T1) and six months (T2) after surgery. Biochemical and anthropometric evaluations were performed by trained researchers at all three moments, during clinical follow-up consultations.

This study was approved by the HUCAM Research Ethics Committee (CAAE 51519115.7.0000.5071). All procedures were performed in accordance with the Code of Medical

Ethics of the World Medical Association (Declaration of Helsinki).

Anthropometric and body composition parameters

Body weight (kg) and height (m) were measured using standardized techniques^{22,23}. Waist circumference (WC) was measured in centimeters at the level of the umbilical scar²⁴. In people with obesity, WC is usually performed at the level of the umbilical scar, since the identification of the midpoint between the iliac crest and the last rib can be hampered by the accumulation of abdominal fat²⁵.

Body mass index (BMI) was calculated using the equation: body weight (kg) / height² (m). Obesity was classified into three levels: grade I obesity: BMI 30-34, grade II obesity: BMI 35-39.9, and grade III obesity: BMI 40-49.9²⁶.

Body composition was estimated by electrical bioimpedance, using the Biodynamics® model 450 equipment, following the recommendations of the European Society of Clinical Nutrition and Metabolism²⁷. Lean mass (LM) was calculated using the equation for obese people, proposed by Segal and collaborators²⁸, and fat mass (FM) by the equation (FM = body weight - LM), both expressed in kilograms and percentage.

Biochemical parameters and Atherogenic Index of Plasma

Blood samples were collected and analyzed at the hospital's Clinical Analysis Laboratory after a 10-12 hour overnight fast. Serum concentrations (mg/dL) of total cholesterol (TC), LDL cholesterol (LDL), HDL cholesterol (HDL), triglycerides (TG), glucose (GLUC), and C-reactive protein (CRP) were evaluated by colorimetric enzymatic methods, using commercial kits and an automatic analyzer model CMD801 (Wiener®, Santa Fé, Argentina).

Plasma atherogenic index was calculated as $\log [TG \text{ (mmol/L)} / HDL \text{ (mmol / L)}]$, as previously described⁶. The values were classified into three categories: low cardiovascular risk: <0.11 ; intermediate risk: 0.11 to 0.21 and high risk: >0.21 ^{29,30,31}.

Statistical Analysis

The normality of the variables was tested by the Shapiro-Wilk test. Data were analyzed using the Friedman test or one-way ANOVA for repeated measures followed by Tukey post hoc test, and expressed as median (interquartile range) or mean $\pm$ standard deviation, according to data distribution. Comparison between men and woman was performed by t-test. A significance level of 5% was adopted for all analyses. The Statistical Package for the Social Sciences – SPSS, version 22.0, was used.

RESULTS

Thirty-four patients (28 women and 6 men) agreed to participate in the study and completed the three scheduled evaluations. In this study, patients were evaluated 27 ± 28 days (T0) before surgery, 74 ± 20 days (T1) and 192 ± 15

days (T2) after surgery. Table 1 shows the characteristics of the sample at the beginning of the study (T0). There was a predominance of female participants (82.4%) and a higher proportion of individuals classified as having grade III obesity (66.7% in men and 66.9% in women). Regarding comorbidities and medication use, 50.0% of men and 53.6% of women had arterial hypertension, and 66.0% of men and 53.5% of women used oral antihypertensive drugs. There was no significant difference between groups ($p > 0.05$).

Table 2 shows the anthropometric parameters throughout the evaluation. In both sexes, there was a significant reduction over time in all parameters analyzed ($p < 0.05$).

Table 3 shows AIP values and other biochemical parameters at the evaluation moments. AIP decreased significantly over time in both sexes ($p < 0.05$). In men, there was a reduction in the risk classification for CVD, from high risk at T0 to moderate risk at T1, and low risk at T2. In women, the risk remained low at all times.

Regarding lipid profile parameters, serum TG levels were significantly reduced in both sexes ($p < 0.05$). In men, the reduction was significant at T1 and in women only at T2. Serum levels of TC and LDL decreased significantly only in women, with T1 and T2 values being lower than those at T0 ($p < 0.05$). Serum HDL levels did not change significantly over time in either sex ($p > 0.05$), while serum CRP levels decreased significantly in both sexes ($p < 0.05$). A significant reduction in fasting blood glucose over time was observed only in women ($p < 0.05$).

DISCUSSION

This study showed that AIP values decreased significantly in both sexes over the periods evaluated; however, a reduction in the risk classification for CVD was observed only in men, who were at high risk before bariatric surgery and at low risk 6 months after the surgery.

A reduction in the risk for CVD in patients who underwent bariatric surgery has been previously reported^{21,32}. A complete remission of atherogenic dyslipidemia, defined by serum TG concentrations <148.7 mg/dL and HDL >40 mg/dL, was observed 1 year after bariatric surgery in both men and women²¹. The same study reported a significant reduction in AIP by the 3rd, 6th and 12th month after the surgery. According to the authors, a reduction in the cardiovascular risk indicated by AIP was expected, as serum TG levels decreased significantly and serum HDL levels increased significantly throughout evaluation²¹. In the present study, serum HDL levels did not change significantly in either sex, what could have led to a misinterpretation of the cardiovascular risk if HDL levels had been assessed on their own.

On the other hand, although TG levels have decreased significantly over time in both sexes, it is important to consider that, in men, mean TG levels were above the reference values only at baseline (T0), with no significant reductions having been observed between T1 and T2.

Table 1. Baseline characteristics of participants.

Characteristics	Men	Women	p-value* (Men vs Women)
Distribution	17.6% (n=6)	82.4% (n=28)	-
Age, years Mean±SD	43.2±8,3	40.6±9.4	0.547
	%	%	-
Level of obesity			
Grade III	66.7	67.9	0.334
Grade II	33.3	32.1	0.671
Comorbidities			
Arterial hypertension	50.0	53.6	-
Dyslipidemia	50.0	46.4	-
Diabetes	33.3	39.3	-
Joint diseases	-	10.7	-
Depression	-	7.1	-
Cardiovascular diseases	-	3.6	-
Medication			
Antihypertensive agents	66,0	53.6	-
Hypoglycemic drugs	66.0	46.4	-
Hypolipidemic drugs	33.0	35.7	-
Diuretics	17.0	10.7	-
Antidepressants	17.0	-	-
Insulin	-	3.6	-

* t-test.

Table 2. Anthropometric parameters of participants who underwent bariatric surgery at the three evaluation points.

Parameter	Men				Women			
	T0	T1	T2	p value	T0	T1	T2	p-value
Weight (kg)	138.0±18.5 ^a	114.4±17.2 ^{a,b}	101.9±14.0 ^b	0.006	107.6 (96.8-123.9) ^a	91.6 (82.6-103,5) ^b	80.5 (71.6-90.3) ^c	<0.001
BMI (kg/m ²)	45.6±7.7 ^a	37.8±6.9 ^{a,b}	33.8±5.5 ^b	0.026	43.5 (39.1-46.9) ^a	35.8 (32.8-40.5) ^b	31.7 (28.8-34.6) ^c	<0.001
WC (cm)	139.2 (127.8-155.0) ^a	120.6 (115.0-136.5) ^{a,b}	109.5 (104.8-123.1) ^b	0.007	118.8 (110.4-126.3) ^a	104.5 (100.0-116.8) ^b	92.2 (87.2-107.3) ^c	<0.001
LM (kg)	86.7±8.8 ^a	75.0±7.7 ^b	69.9±6.2 ^b	0.005	55.4 (51.7-61.4) ^a	50.7 (47.1-54.4) ^b	46.3 (43.8-50.8) ^b	<0.001
LM (%)	63.0±2.7 ^a	66.0±3.6 ^{a,b}	69.0±4.1 ^b	0.029	51.6 (49.6-53.5) ^a	55.1 (53.1-57.4) ^b	58.3 (55.5-61.1) ^c	<0.001
FM (kg)	49.2 (42.6-58.0) ^a	36.4 (30.5-51.2) ^{a,b}	31.6 (23.5-38.2) ^b	0.029	53.3 (45.9-62.2) ^a	41.8 (35.3-48.3) ^b	33.6 (27.7-38.7) ^c	<0.001
FM (%)	36.9±2.4 ^a	34.0±3.6 ^{a,b}	31.0±4.1 ^b	0.030	48.4 (46.5-50.4) ^a	44.9 (42.6-46.9) ^b	41.7 (38.9-44.5) ^c	<0.001

BMI: body mass index; WC: waist circumference; LM: lean mass; FM: fat mass. N= 6 (men), N= 28 (women) for all moments. T0: 27.1±28.4 days before surgery; T1: 73.6±20.4 days after surgery; T2: 192.4±14.8 days after surgery. Values expressed as median (interquartile range): analyzed using the Friedman test and Tukey post hoc test. Values expressed as mean±standard deviation: analyzed with ANOVA for repeated measures and Tukey post hoc test. Different letters on the same line represent significantly different values between T0, T1 e T2 for men and women separately (p<0.05).

Table 3. Atherogenic Index of Plasma and biochemical parameters of participants who underwent bariatric surgery at the three evaluation points.

Parameter	Men				Women				*
	T0	T1	T2	p	T0	T1	T2	p	
AIP	0.441±0.13 ^a	0.204±0.22 ^{a,b}	0.041±0.16 ^b	0.004	0.042 (-0.02-0.21) ^a	-0.033 (-0.12-0.17) ^a	-0.161 (-0.26-0.01) ^b	<0.001	<0.11
TG (mg/dL)	230.3±69.9 ^a	128.2±46.3 ^b	108.7±46.8 ^b	0.004	115.0 (81.0-160.0) ^a	80.5 (69.5-121.0) ^{a,b}	72.0 (55.5-99.0) ^b	<0.001	150
TC (mg/dl)	179.3±51.2 ^a	150.2±24.4 ^a	143.3±46.2 ^a	0.321	183.5±42.0 ^a	151.2±40.9 ^b	149.7±41.1 ^b	0.004	<190
LDL (mg/dL)	104.2±36.9 ^a	90.5±17.4 ^a	81.4±33.5 ^a	0.449	115.1 (96.8-142.5) ^a	88.6 (69.8-110.2) ^b	88.3 (68.8-117.9) ^b	0.006	<130
HDL (mg/dl)	34.5 (33.0-39.0) ^a	29.5 (29.0-36.0) ^a	37.5 (36.0-48.0) ^a	0.133	39.5 (34.0-51.0) ^a	36.0 (31.5-43.0) ^a	41.0 (36.5-46.0) ^a	0.085	>40
CRP (mg/L)	5.4 (4.0-7.0) ^a	4.2 (2.1-6.0) ^{a,b}	0.9 (0.8-3.2) ^b	0.020	12.4 (2.6-18.5) ^a	4.2 (1.0-6.6) ^{a,b}	2.2 (0.8-3.5) ^b	<0.001	<5.0
GLUC (mg/dL)	94.0 (88.0-108.8) ^a	92.5 (90.0-97.0) ^a	88.5 (87.0-91.0) ^a	0.457	96.0 (91.0-108.5) ^a	88.5 (79.0-96.0) ^b	86.5 (82.0-92.0) ^b	0.004	70-99

*Reference values. AIP: atherogenic index of plasma; TC: total cholesterol; LDL: low-density lipoprotein; HDL: high-density lipoprotein; TG: triglycerides; GLUC: glucose; CRP: C-reactive protein.

N=6 (men), N=28 (women) for all moments.

T0: 27.1±28.4 days before surgery; T1: 73.6±20.4 days after surgery; T2: 192.4±14.8 days after surgery.

Values expressed as median (interquartile range): analyzed using the Friedman test and Tukey post hoc test.

Values expressed as mean±standard deviation: analyzed with ANOVA for repeated measures and Tukey post hoc test.

Different letters on the same line represent significantly different values between T0, T1 e T2 for men and women separately (p<0.05).

Nevertheless, the cardiovascular risk indicated by AIP decreased from moderate at T1 to low at T2, suggesting AIP might be considered a better indicator for assessing the risk of CVD when compared to isolated parameters of the lipid profile in these patients.

In an individualized analysis, 100.0% of men were at high cardiovascular risk according to AIP at T0, and only 33.0% at T2 (data not shown). In women, serum TG levels were within the reference values at all times, and HDL values—which were below reference values at T0 and T1—were not sufficiently low to alter the classification of cardiovascular risk by AIP, although a significant reduction was observed over time. It is worthy of note that, while at baseline 25.0% of women were at high risk for CVD, those numbers decreased to only 3.0% at T2 (data not shown).

The differences in AIP found between sexes can be partly explained by men having more preoperative risk factors, including higher BMI and an increased burden of comorbidities^{33,34}. In addition, differences in metabolic states, which include sex hormones, may also influence AIP values³⁵.

Different indices have been proposed to assess the risk for CVD, but none specific for people with obesity. The

Framingham risk score assesses the 10-year risk for CVD, according to the presence or absence of certain risk factors⁷. Bariatric surgery was proved to be efficient at significantly reducing this score in men and women, from moderate to low risk in men, and maintenance at low risk in women³². A study carried out with 1989 bariatric patients of both sexes revealed significantly reduced Framingham scores 1 year after bariatric surgery (p<0.001); however, men had a significantly lower risk reduction than women (35.6% and 41.0% for men and women, respectively)³⁶.

Despite the importance and relevance of the Framingham risk score as an indicator of cardiovascular risk for population studies, being present even in the guidelines of the National Cholesterol Education Program Adult Treatment Panel III, it appears to be of little use in clinical practice⁷. A recent study evaluated the association of anthropometric parameters, lipid profile, and cardiovascular risk indices (Framingham risk score, Castelli index, and AIP) with the predictive CVD biomarkers asymmetric dimethylarginine and fatty acid binding protein 4, and found that only AIP had a significant association with these markers (p<0.05)⁴. Asymmetric dimethylarginine, a non-proteinogenic amino acid generated by post-translational modifications of

arginine, inhibits the nitric oxide synthase enzyme³⁷, and its levels have an important association with cardiovascular risk³⁸. The fatty acid binding protein 4 regulates adipocyte metabolism³⁹ and epidemiological studies have shown its association with several diseases, including obesity and type 2 diabetes⁴⁰.

Regarding the other biochemical parameters evaluated here, the significant reductions observed in TC, LDL, and glucose levels in women might have less clinical significance, as the values were within the reference range at all times.

The effectiveness of bariatric surgery, especially the Roux-en-Y gastric bypass, for the treatment of severe obesity is well documented in the literature^{16,18}. As expected, the patients presented a significant reduction in body weight, BMI, LM, and FM by the 2nd month, what persisted until the 6th month. The reduction of excess FM can lead to a reduction in the inflammatory state⁴⁰, and the significant reduction in CRP serum levels over time is an indicator of this attenuation. In addition, it is important to highlight the positive association between inflammatory biomarkers-particularly CRP-and cardiovascular events⁵.

The results of the present study showed that the cardiovascular risk, assessed by AIP, decreased during the first 6 months after bariatric surgery. Due to its practicality and relative low cost, this index could be an auxiliary tool for monitoring the cardiovascular risk of patients during surgical treatment of obesity. This study has some limitations: the difficulty in carrying out evaluations at established times resulted in some patients having been evaluated at different periods; the small sample size that occurred due to participant dropouts between assessments; differences in sample size between men and women may have affected the statistical power of some analyses; the absence of data on factors that impact the course of treatment of the disease, especially those related to lifestyle, such as diet and physical activity, should be considered and will be evaluated in future studies.

CONCLUSION

Bariatric Surgery reduced IAP as well as body and biochemical parameters 6 months post-surgery. The reduction in IAP may indicate a reduction in cardiovascular risk.

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REFERENCES

- Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019: Update from the GBD 2019 Study. *J Am Coll Cardiol*. 2020; 76: 2982-3021.
- Peng J, Luo F, Ruan G, Peng R, Li X. Hypertriglyceridemia and atherosclerosis. *Lipids Health Dis*. 2017; 16: 233-241.
- Anandkumar MH, Chandrashekhara DM, Jayalakshmi MK, Prashanth BG. Anthropometric measures of obesity as correlates of atherogenic index of plasma in young adult females. *Natl J Physiol Pharm*. 2020; 10: 85-88.
- Fernandez-Macias JC, Martínez ACO, Varela-silva JÁ, Perez-Maldonado IN. Atherogenic index of plasma: novel predictive biomarker for cardiovascular illnesses. *Arch Med Res*. 2019; 50: 285-294.
- Piccardi B, Giralt D, Bustamante A, Liombart V, Garcia-Berrococo T, Inzitari D, et al. Blood markers of inflammation and endothelial dysfunction in cardioembolic stroke: Systematic review and meta-analysis. *Biomarkers*. 2017; 22: 200-209.
- Dobiasova M, Frohlich J. The plasma parameter log (TG/HDL-C) as an atherogenic index: Correlation with lipoprotein particle size and esterification rate in apo B-lipoprotein-depleted plasma (FERHDL). *Clin Biochem*. 2001; 34: 583-588.
- Khazaa MS. Atherogenic index of plasma (AIP) as a parameter in predicting cardiovascular risk in males compared to the conventional dyslipidemic indices (cholesterol ratios). *Karbala J Med*. 2013; 6: 1506-1513.
- Dobiasova M, Frohlich J, Sedova M, Cheung MC, Brown BG. Cholesterol esterification and atherogenic index of plasma correlate with lipoprotein size and findings on coronary angiography. *J Lipid Res*. 2011; 52: 566-571.
- Dobiasova M. AIP-Atherogenic index of plasma as a significant predictor of cardiovascular risk: From research to practice. *Vnitr Lek*. 2006; 52: 64-71.
- Shen SW, Lu Y, Li F, Yang CJ, Feng YB, Li HW, et al. Atherogenic index of plasma is an effective index for estimating abdominal obesity. *Lipids Health Dis*. 2018; 17: 1-6.
- Zhu X, Yu L, Zhou H, MA Q, Zhou X, Lei T, et al. Atherogenic index of plasma is a novel and better biomarker associated with obesity: A population-based cross-sectional study in China. *Lipids Health Dis*. 2018; 5: 1-6.
- Kotsis V, Tsioufis K, Antza C, Seravalle G, Coca A, Sierra C, et al. Obesity and cardiovascular risk: A call for action from the Hypertension Working Group of Obesity, Diabetes and the High-risk Patient and European Association for the Study of Obesity: Part B: Obesity-induced cardiovascular disease, early prevention strategies and future research directions. *J Hypertens*. 2018; 36: 1441-1455.
- Piché ME, Poirier P, Lemieux I, Després JP. Overview of epidemiology and contribution of obesity and body fat distribution to cardiovascular disease: An update. *Progr Cardiovasc Dis*. 2018; 61: 103-113.
- Leiva A, Martínez M, Durán E, Labraña A, Diaz X, Salas C, Campillo RR, et al. Higher adiposity levels are associated with detrimental metabolic health in Chilean adults. *Rev Chil Nutr*. 2017; 44: 262-269.
- Oliveira-Junior AS, Muzili NA, De Carvalho MR, Ota GE, Morais CS, Vieira LFC, et al. AT1 receptor blockade improves myocardial functional performance in obesity. *Arq Bras Cardiol*. 2020; 115: 17-27.
- Gero D, Favre L, Allemann P, Fournier P, Demartines N, Suter M. Laparoscopic Roux-en-Y gastric bypass improves lipid profile and decreases cardiovascular risk: A 5-year longitudinal cohort study of 1048 patients. *Obes Surg*. 2018; 28: 805-811.
- Kuno T, Tanimoto E, Morita S, Shimada YJ. Effects of bariatric surgery on cardiovascular disease: A concise update of recent advances. *Front Cardiovasc Med*. 2019; 6: 1-10.
- Witte D, Wijngaarden LH. Houten VAAV, Van-Den-Dorpel

- MA, Bruning TA, Harst EV. et al. Improvement of cardiac function after Roux-en-Y gastric bypass in morbidly obese patients without cardiac history measured by cardiac MRI. *Obes Surg*. 2020; 30: 2475-2481.
19. Piché ME, Tardif I, Auclair A, Poirier P. Effects of bariatric surgery on lipid-lipoprotein profile. *Metabolism*. 2021; 115: 154441.
 20. Zhang R, Lin B, Parikh M, Fisher EA, Berger JS, Aleman JO, Heffron SP. Lipoprotein insulin resistance score in nondiabetic patients with obesity after bariatric surgery. *Surg Obes Relat Dis*. 2020; 16: 1554-1560.
 21. Climent E, Benaiges D, Pedro-Botet J, Roux JAF, Ramón JM, Villatoro M, et al. Atherogenic dyslipidemia remission 1 year after bariatric surgery. *Obes Surg*. 2017; 27: 1548-1553.
 22. Waitzberg DL, Ferrini MT. Physical examination and anthropometry: Atheneu, São Paulo; 2002.
 23. Marfell JM, Olds T, Stewart A, Carter JL. International standards for anthropometric assessment: Isak, Potchefstroom; 2006.
 24. Han TS, Van Leer EM, Seidell JC, Lean MEJ. Waist circumference action levels in the identification of cardiovascular risk factors: Prevalence study in a random sample. *BMJ*. 1995; 311: 1401-1405.
 25. Melo ATT, Alegre FAM, Merhi VAL, Garcia RWD. Additional abdominal measurements are a useful tool to evaluate body composition in obese women. *Arq Gastroenterol*. 2019; 56: 294-299.
 26. Lorenzo A, Soldati L, Sarlo F, Calvani M, Lorenzo N, Renzo L. New obesity classification criteria as a tool for bariatric surgery indication. *World J Gastroenterol*. 2016; 22: 681-703.
 27. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Manuel Gomez J, et al. Bioelectrical impedance analysis-part II: Utilization in clinical practice. *Clin Nutr*. 2004; 23: 1430-1453.
 28. Segal KR, Gutin B, Presta E, Wang J, Van Itallie TB. Estimation of human body composition by electrical impedance methods: a comparative study. *J Appl Physiol*. 1985; 58: 1565-1571.
 29. Wang Q, Zheng D, Liu J, Fang L, Li Q. Atherogenic index of plasma is a novel predictor of non-alcoholic fatty liver disease in obese participants: A cross-sectional study. *Lipids Health Dis*. 2018; 17: 1-6.
 30. Akbas EM, Timuroglu A, Ozcicek A, Ozcicek F, Demirtas L, Gungor A, et al. Association of uric acid, atherogenic index of plasma and albuminuria in diabetes mellitus. *Int J Clin Exp Med*. 2014; 7: 5737-5743.
 31. Ahn SS, Lee LE, Pyo JY, Song JJ, Park YB, Lee SW. Atherogenic index of plasma predicts cerebrovascular accident occurrence in antineutrophil cytoplasmic antibody-associated vasculitis. *Lipids Health Dis*. 2020; 19: 1-11.
 32. Vogel JA, Franklin BA, Zalesin KC, Trivax JE, Krause KR, Chengelis DL et al. Reduction in predicted coronary heart disease risk after substantial weight reduction after bariatric surgery. *Am J Cardiol*. 2007; 99: 222-226.
 33. Kochkodan J, Telem DA, Amir AG. Physiologic and psychological gender differences in bariatric surgery. *Surg Endosc*. 2018; 32: 1382-1388.
 34. Ni W, Zhenyu Z, Liu T, Wang H, Deng J, Liu X, et al. Gender- and lesion number-dependent difference in "atherogenic index of plasma" in Chinese people with coronary heart disease. *Sci Rep*. 2017; 7: 1-6.
 35. Nwagha, UI, Ikekpeazu EJ, Ejezie FE, Neboh EE, Maduka IC. Atherogenic index of plasma as useful predictor of cardiovascular risk among postmenopausal women in Enugu, Nigeria. *Afr Health Sci*. 2010; 10: 248-252.
 36. Agrawal P, Volter L, Wulfovich S, Dwinal R, Rivas H, Morton J. Are there gender disparities in cardiac outcomes following bariatric surgery? *Surg Obes Relat Dis*. 2016; 12: S29-S32.
 37. Nemeth B, Ajtay Z, Hejfel L, Ferenci T, Abram Z, Muranyi E, et al. The issue of plasma asymmetric dimethylarginine reference range-A systematic review and meta-analysis. *Plos One*. 2017; 12: 1-12.
 38. Leong T, Zylberstein D, Graham I, Lissner L, Ward D, Fogarty J, et al. Asymmetric dimethylarginine independently predicts fatal and nonfatal myocardial infarction and stroke in women: 24-year follow-up of the population study of women in Gothenburg. *Arterioscler Thromb Vasc Biol*. 2008; 28: 961-967.
 39. Chow WS, Tso AWK, Xu A, Yuen MMA, Fong CHY, Lam TH, et al. Elevated circulating adipocyte fatty acid binding protein levels predict incident cardiovascular events in a community-based cohort: A 12-year prospective study. *J Am Heart Assoc*. 2013; 2: 1-9.
 40. Xu A, Wang Y, Xu JY, Stejskal D, Tam S, Zhang J, et al. Adipocyte fatty acid-binding protein is a plasma biomarker closely associated with obesity and metabolic syndrome. *Clin Chem*. 2006; 52: 405-413.