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Relationship between cardiorespiratory fitness and preoperative evaluation findings in patients with morbid obesity undergoing sleeve gastrectomy

A cross-sectional study

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Abstract

Evaluating various parameters, including preoperative cardiorespiratory fitness markers, is critical for patients with morbid obesity. Also, clinicians should prescribe suitable exercise and lifestyle guideline based on the tested parameters. Therefore, we investigated cardiorespiratory fitness and its correlation with preoperative evaluation in patients with morbid obesity scheduled for laparoscopic sleeve gastrectomy.

A retrospective cross-sectional study was conducted with 38 patients (13 men and 25 women; mean age, 34.9 ± 10.9 years) scheduled for laparoscopic sleeve gastrectomy. Cardiopulmonary exercise stress tests were also performed. Measured cardiopulmonary responses included peak values of oxygen consumption (VO_2), metabolic equivalents (METs), respiratory exchange ratio, heart rate (HR), and rate pressure product. Body composition variables were analyzed using bioimpedance analysis, laboratory parameters (hemoglobin A1c, lipid profile, inflammatory markers), and comorbidities. In addition, self-reported questionnaires were administered, including the Beck Depression Inventory (BDI), Hamilton Depression Rating Scale (HDRS), Short-Form Health Survey (SF-36), and Moorehead-Ardelt Quality of Life Questionnaire (MAQOL).

The average body mass index (BMI) and percent body fat were 39.8 ± 5.7 kg/m^{-2} and 46.2 ± 6.1%, respectively. The VO_{2peak}/kg, METs, RER_{peak}, HR_{peak}, RPP_{peak}, age-predicted HR percentage, and VO_{2peak} percentage were 18.6 ± 3.8 mL/min^{-1}/kg^{-1}, 5.3 ± 1.1, 1.1 ± 0.1, 158.5 ± 19.8, 32,414.4 ± 6,695.8 mm Hg/min^{-1}, 85.2 ± 8.8%, and 76.1 ± 14.8%, respectively. BMI (P = .026), percent body fat (P = .001), HR_{peak} (P = .018), erythrocyte sedimentation rate (P = .007), total BDI (P = .043), HDRS (P = .025), SF-36 (P = .006), and MAQOL (P = .007) scores were significantly associated with VO_{2peak}/kg. Body fat percentage (P < .001) and total SF-36 score (P < .001) remained significant in the multiple linear regression analysis.

Various cardiorespiratory fitness markers were investigated in patients with morbid obesity who underwent the sleeve gastrectomy. Peak aerobic exercise capacity was significantly associated with preoperative parameters such as body fat composition and self-reported quality of life in these patients. These results could be utilized for preoperative and/or postoperative exercise strategies in patients with morbid obesity scheduled for laparoscopic sleeve gastrectomy.

Abbreviations: BDI = beck depression inventory, BMI = body mass index, DBP = diastolic blood pressure, ESR = erythrocyte sediment rate, HDRS = Hamilton depression rating scale, HR = heart rate, MAQOL = moorehead-ardelt quality of life questionnaire, METs = metabolic equivalents, SBP = systolic blood pressure, SF-36 = short-form health survey, VO_2 = peak values of oxygen consumption.

Keywords: cardiopulmonary exercise test, gastrectomy, obesity, quality of Life

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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1. Introduction

According to the World Health Organization, in adults, a body mass index (BMI) of 25.0 to 29.9 kg/m^2 indicates overweight, ≥30 kg/m^2 indicates obesity, and ≥40.0 kg/m^2 indicates morbid obesity. Alternatively, according to the Korean Society for the Study of Obesity and Health, the previously defined ranges of BMI are considered broad, and the following definitions of BMI are proposed: 23.0 to 24.9 kg/m^2 for overweight, 25.0–29.9 kg/m^2 for obesity (first stage), 30.0 to 34.9 kg/m^2 for obesity (second stage), and >35.0 kg/m^2 for morbid obesity.[1] The prevalence of obesity continues to increase worldwide. Obesity is associated with multiple comorbidities, including cardiovascular disease. For every 5-unit increase in BMI above 25.0 kg/m^2, overall mortality increased by 29.0%, vascular mortality increased by 41.0%, and diabetes-related mortality increased by 210.0%.[2] Occasionally, conservative or medical treatments for obesity are often insufficient, and surgical treatments are often adopted for patients with obesity with a BMI >40.0 kg/m^2 or a BMI >35.0 kg/m^2 and one or more significant comorbidities.[3]

Peak oxygen consumption per unit of body weight (VO_{2peak}/kg) represents the peak amount of oxygen an individual utilizes during intense or maximal exercise. It is generally considered the best indicator of cardiovascular fitness and aerobic exercise endurance. In 2016, the American Heart Association published a statement[4] recommending that cardiorespiratory fitness, quantified based on VO_{2peak}/kg, was assessed regularly and used as a vital clinical sign. This statement was based on mounting evidence that lower fitness levels are associated with a high risk of cardiovascular disease, all-cause mortality, and mortality from various types of cancers.[5] In addition to risk assessment, the American Heart Association recommendation cited the value of measuring fitness for validating exercise prescription, conducting physical activity counseling, and improving both patient management and health. According to Jang et al, the average VO_{2peak}/kg values of healthy Korean men and women were 42.0 ± 5.0 and 32.2 ± 4.5 mL/kg^{-1}/min^{-1}, respectively.[6] Typically, patients with obesity have much lower VO_{2peak}/kg values than healthy patients owing to deficiencies in aerobic exercise capacity.[7] Additionally, many physiological parameters, including percent body fat, erythrocyte sedimentation rate (ESR), C-reactive protein levels, and mental health status, are also worse in obese patients.[8] Previous studies have revealed several factors predicting VO_{2peak}/kg in healthy Danish adolescents and peri-/postmenopausal women in the United States,[9] focusing only on Western populations. However, only a few studies have investigated the parameters predicting VO_{2peak}/kg in patients with morbid obesity scheduled for sleeve gastrectomy.

From these previous studies, we could infer that assessing various parameters, including preoperative cardiorespiratory fitness markers, is vital in patients with morbid obesity. Subsequently, clinicians can prescribe suitable exercises and provide both mental and physical health counseling to enhance general health and reduce cardiorespiratory risk in these patients.

Therefore, we hypothesized that VO_{2peak}/kg could be correlated with various parameters (including physical and mental factors) in patients with morbid obesity, particularly those scheduled to undergo surgical treatment.

2. Methods

2.1. Subjects

We retrospectively collected data from 38 patients with morbid obesity scheduled for bariatric surgery from January 2019 to June 2020 at OO Medical Center (Fig. 1). The inclusion criteria were as follows:

1. BMI >30 kg/m^2;
2. age between 18 and 65 years, and 65 years as the cut-off age for deeming an individual elderly,[10] and performance of a symptom-limited cardiopulmonary exercise stress test.

The exclusion criteria were as follows:

1. no preoperative evaluation;
2. severe cognitive impairment; and
3. significant orthopedic or pain conditions that limited participation in exercise testing or contraindications to exercise testing, as identified using the American College of Sports Medicine criteria.[11]

This study was approved by the Institutional Review Board of OO Medical Center (IRB no. 2020AN0363) and conducted in

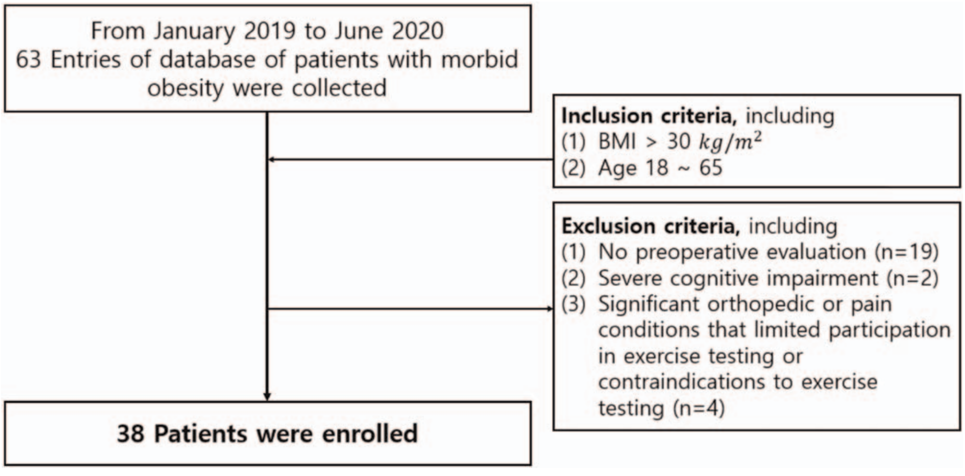

Figure 1. Flow chart for patients enrollment.

accordance with the principles of the Declaration of Helsinki. The requirement for obtaining informed consent was waived owing to the retrospective nature of the study.

2.2. Comorbidities

Comorbidities such as hypertension, diabetes mellitus, dyslipidemia, chronic musculoskeletal pain, and metabolic syndrome were also analyzed.

Hypertension was defined as having a known diagnosis before enrollment or systolic blood pressure (SBP) >140 mmHg and diastolic blood pressure (DBP) >90 mm Hg during the preoperative evaluation.[12]

Diabetes mellitus was defined as having a known diagnosis before enrollment or fulfillment of the criteria for diabetes diagnosis during the preoperative evaluation, such as abnormal hemoglobin A1c or plasma glucose levels, including fasting plasma glucose or 2-hour plasma glucose levels after a 75-g oral glucose tolerance test.[13]

Dyslipidemia was defined as having a known diagnosis before enrollment or having a total cholesterol level >240 mg/dL, low-density lipoprotein cholesterol level >160 mg/dL, high-density lipoprotein cholesterol level <40 mg/dL, or triglyceride level >200 mg/dL during preoperative evaluation.[14]

Chronic musculoskeletal pain was defined as a "persistent (>3–6 months) or recurrent pain that arises as part of a disease process directly affecting the bone(s), joint(s), muscle(s), or related soft tissue(s)".[15]

Metabolic syndrome was defined as central obesity (waist circumference >90 cm for men and >85 cm for women), plus 2 or more of the following 4 factors: serum triglyceride >150 mg/dL, high-density lipoprotein cholesterol <40 mg/dL for men and <50 mg/dL for women, SBP >130 mmHg or DBP >85 mm Hg, and fasting plasma glucose >100 mg/dL during the preoperative evaluation.[16]

2.3. Assessment of cardiorespiratory fitness markers

Study outcome measures included total exercise duration, VO_{2peak}/kg with the corresponding peak in metabolic equivalents, peak respiratory exchange ratio, peak and resting heart rates (HR_{peak} and $HR_{resting}$, respectively), peak and resting SBP/DBP (SBP_{peak}/DBP_{peak} and $SBP_{resting}/DBP_{resting}$, respectively), peak rate pressure product, anaerobic threshold ($VO_{2\ AT}$), age-predicted percentage of maximum HR, and age-predicted $VO_{2\ peak}$.

These parameters were measured during the modified Bruce protocol by analyzing exhaled gas using the breath-by-breath method and a portable telemetry system (CPET; COSMED Inc., Pavona di Albano, Italy). VO_{2peak}/kg was also expressed in metabolic equivalents to describe peak exercise intensity. The peak values of the exercise variables were defined as the mean of the values recorded during the last 30 second of the test. The HR_{peak} was a predetermined study outcome measure, defined as the mean HR during the last 30 second of exercise, and was expressed as a percentage of the age-predicted maximal HR: $[HR_{peak}/(220-\text{age})]\times 100$ (%). SBP and DBP were measured using a Finometer BP monitor (SunTech, Incheon, Korea) during the last 30 second of the test. The peak rate pressure product was calculated as (HR × SBP) and expressed as the average of the values recorded during the last 30 second of the test. The VO_{2peak} exhibited the highest VO_2 value during the test. A maximal effort was considered if VO_2 did not increase by >150 mL in the final minute of exercise (i.e., a VO_2 plateau had been reached).[17] We then divided VO_{2peak} by body weight.

2.4. Anthropometric characteristics

BMI was calculated using the formula: BMI $(kg/m^2) = \frac{\text{Bodyweight(kg)}}{\text{Height(m)}^2}$.

The following body composition variables were determined using bioimpedance analysis (InBody720, BIOSPACE, Cheon-An, Korea): body fat percentage (%), $\frac{\text{Body fat mass(kg)}}{\text{Total body mass(kg)}}$, skeletal muscle mass (kg), and skeletal muscle index (kg/m^2): $\frac{\text{Sum of muscle mass of all four limbs(kg)}}{\text{Height}(m)^2}$.[11]

Before surgery, patients underwent laboratory tests, including hemoglobin A1c, lipid profile, inflammatory markers, ESR, and C-reactive protein.

2.5. Patient questionnaires

Twenty two of the 38 patients completed the self-reported questionnaires, including the following 4 questionnaires.

2.5.1. Beck depression inventory. The BDI is a widely used tool for assessing depression. The BDI is a 21-item self-report inventory that assesses major depressive symptoms according to the diagnostic criteria listed in the Diagnostic and Statistical Manual for Mental Disorders. Items are summed to generate a total score, with higher scores indicating higher levels of depression.[18]

2.5.2. Hamilton depression rating scale. The HDRS has been referred to as the gold standard for measuring depression severity; however, the tool is limited by scoring difficulties and psychometric weaknesses. The 17-item HDRS has evolved over the past 50 years into 11 modified versions that have been administered to various patient populations in psychiatric, medical, and other research settings.[19]

2.5.3. Short-form health survey. The SF-36 is based on 8 scales: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. Component analyzes have shown 2 distinct dimensions measured with the SF-36: a physical dimension, represented by the physical component summary, and a mental dimension, represented by the mental component summary. All scales contributed in different proportions to the mental and physical component summary scores. The summation of all scores to a single score was validated in a previous study.[20]

2.5.4. Moorehead–ardelt quality of life questionnaire. The MAQOL questionnaire is widely used because it is simple and has been validated in several languages. It comprises 6 items: feeling, physical activity, social contact, working, sex, and eating. The Korean version of the MA-II is a valid instrument for measuring the obesity-specific quality of life.[21]

2.6. Statistical analysis

The Statistical Package for the Social Sciences for Windows, version 24.0 (IBM, Armonk, NY) was used for all statistical calculations. Descriptive means and standard deviations (SDs) were calculated. The Shapiro–Wilk test was used to test the normal distribution of the data, which revealed normal distribution. First, simple linear regression analysis was per-

Table 1

Patient demographics (N=38) and self-reported questionnaires (N=22).

Characteristic	Value
Age (yr)	34.9±10.9
Sex	
Male (n) (%)	13 (34.2)
Female (n) (%)	25 (65.8)
Co-morbidity	
Hypertension (n) (%)	30 (79.0)
Diabetes mellitus (n) (%)	19 (50.0)
Dyslipidemia (n) (%)	28 (73.7)
Chronic musculoskeletal pain (n) (%)	16 (42.1)
Metabolic syndrome (n) (%)	31 (81.6)
BDI, points	16.1±8.5
HDRS, points	12.0±6.5
SF-36 total score, points	393.9±146.0
MAQOL total score, points	−0.4±0.7

Values are presented as mean±standard deviation or number (%).
BDI = beck depression inventory, HDRS = hamilton depression rating scale, MAQOL = moorehead–ardelt quality of life questionnaire, SF-36 = short form health survey.

formed using preoperative parameters (anthropometric data, cardiopulmonary fitness markers, and self-reported questionnaire scores) $VO_{2\ peak}$. We then extracted the parameters with *P* values <.10, which were used as input into multiple stepwise regression analysis. Multiple stepwise regression analysis was used to determine whether the remaining parameters could predict the $VO_{2\ peak}$. Statistical significance was set at $P<.05$.

3. Results

In total, 38 patients (13 men and 25 women) with a mean age of 34.9±10.9 years were included. Table 1 shows the baseline demographic characteristics of the participants. The prevalence rates of hypertension, diabetes, dyslipidemia, chronic musculoskeletal pain, and metabolic syndrome were 79.0% (30/38), 50.0% (19/38), 73.7% (28/38), 42.1% (16/38), and 81.6% (31/38), respectively.

Table 2

Cardiorespiratory fitness indices of the patients (N=38).

Cardiorespiratory fitness indices	Value
Peak aerobic capacity ($VO_{2,peak}$/kg), mL/min·kg	18.6±3.8
Peak aerobic capacity ($METs_{peak}$)	5.3±1.1
Percentage of predicted VO_{2peak}/kg, %	76.1±14.8
Anaerobic threshold (VO_{2AT}), mL/min	1,666.9±469.7
RER_{peak}	1.1±0.1
HR_{peak},/min	158.5±19.8
HR_{peak}, % of age-predicted	85.2±8.8
$HR_{resting}$,/min	86.2±18.5
SBP_{peak}, mmHg	225.7±31.4
$SBP_{resting}$, mmHg	133.1±16.2
DBP_{peak}, mmHg	81.6±21.4
$DBP_{resting}$, mmHg	87.3±11.7
RPP_{peak},mmHg/min	32,414.4±6695.8
Anaerobic threshold of predicted $VO_{2,peak}$, %	63.4±16.3
Anaerobic threshold of measured $VO_{2,peak}$, %	82.5±11.9
Total exercise time, s	543.4±127.1

Values are presented as mean±standard deviation or numbed (%).
DBP = diastolic blood pressure, HR = heart rate, MET = metabolic equivalents, RER = respiratory exchange ratio, RPP = rate pressure product, SBP = systolic blood pressure.

All patients underwent preoperative evaluation, including a symptom-limited cardiorespiratory exercise stress test. However, only 22 of 38 patients completed the self-reported questionnaire, and the scores are presented in Table 1.

Various markers of cardiorespiratory responses are listed in Table 2. The VO_{2peak}/kg and $METs_{peak}$ were 18.6±3.8 mL/min/kg and 5.3±1.1, respectively, with the percentage of predicted VO_{2peak}/kg being 76.1±14.8%.

Anthropometric characteristics and laboratory findings are shown in Table 3. The average body mass index (BMI) and percent body fat were 39.8±5.7 kg/m^2 and 46.2%±6.1%, respectively. The average BMI corresponded with the morbid obesity range (>35.0 kg/m^2). The average skeletal muscle mass and skeletal muscle index were 32.9±5.4 kg and 9.0±1.1 kg/m^2, respectively.

Blood testing revealed that the levels of high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, and total cholesterol were 43.9.2 mg/dL, 116.1±34.0 mg/dL, 165.4±74.3 mg/dL, and 182.9±40.7 mg/dL, respectively.

3.1. Correlation of preoperative parameters and peak aerobic exercise capacity ($VO_{2\ peak}$)

A simple linear regression analysis revealed numerous parameters with *P* values <.05. Table 4 shows that BMI (*P*=.026), body fat percentage (*P*=.001), HR_{peak} (*P*=.018), ESR (*P*=.007), and total scores on the BDI (*P*=.043), HDRS (*P*=.025), SF-36 (*P*=.006), and MAQOL (*P*=.007) were significantly associated with VO_{2peak}/kg. Percent body fat ($P<.001$) and total SF-36 score ($P<.001$) remained significant in the multiple linear regression analysis (Table 5).

4. Discussion

This study found varying levels of cardiorespiratory fitness in patients with morbid obesity. Moreover, this study revealed that peak aerobic exercise capacity per kilogram was significantly

Table 3

Anthropometric characteristics and laboratory findings of the patients (N=38).

Anthropometrics	Value
Body composition and related indices	
Height, cm	165.6±11.1
Body weight, kg	112.7±23.0
BMI, kg/m^2	39.8±5.7
Percent body fat	46.2±6.1
Skeletal muscle, kg	32.9±5.4
Skeletal muscle index, kg/m^2	9.0±1.1
Laboratory parameters	
Hemoglobin A1c, %	6.8±1.5
Lipid profile	
HDL-C, mg/dL	43.4±9.2
LDL-C, mg/dL	116.1±34.0
Triglycerides, mg/dL	165.4±74.3
Total cholesterol, mg/dL	182.9±40.7
Inflammatory markers	
ESR, mg/h	31.8±19.5
CRP, mg/dL	9.0±9.2

Values are presented as mean±standard deviation or number (%).
BMI = body mass index, CRP = C-reactive protein, ESR = erythrocyte sedimentation rate, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol.

Table 4

Simple linear regression analysis of preoperative parameters with peak aerobic exercise capacity ($VO_{2\ peak}$) (N=22).

Factors	Standardized (B)	*P* value	Adjusted R^2
Age, years	0.166	.462	−0.021
Sex (male)	−0.233	.296	0.007
Body composition and related indices			
BMI	−0.474	.026	0.186
Percent body fat	−0.678	.001	0.432
Skeletal muscle	0.176	.434	−0.018
Skeletal muscle index	0.118	.602	−0.035
Cardiorespiratory fitness indices			
HR_{peak} (% of age-predicted)	0.499	.018	0.211
SBP_{peak}	0.250	.262	0.016
$SBP_{resting}$	0.159	.480	−0.024
DBP_{peak}	−0.033	.884	−0.049
$DBP_{resting}$	0.177	.430	−0.017
RPP_{peak}	0.397	.067	0.116
Comorbidities			
Hypertension	−0.149	.507	−0.027
Diabetes mellitus	−0.168	.454	−0.020
Dyslipidemia	−0.041	.856	−0.048
Chronic musculoskeletal pain	−0.127	.574	−0.033
Metabolic syndrome	−0.364	.096	0.089
Blood test parameters			
HDL-C	−0.170	.450	−0.020
LDL-C	−0.034	.880	−0.049
Triglycerides	0.401	.065	0.119
Total cholesterol	−0.031	.891	−0.049
Hemoglobin A1c	0.205	.361	−0.006
ESR	−0.555	.007	0.273
CRP	−0.294	.184	0.041
Self-reported questionnaire scores			
BDI	−0.436	.043	0.149
HRDS	−0.478	.025	0.190
SF36 total score	0.571	.006	0.292
MAQOL total score	0.560	.007	0.279

B = Beta coefficient.

BDI = beck depression inventory, BMI = body mass index, CRP = C-reactive protein, DBP = diastolic blood pressure, ESR = erythrocyte sedimentation rate, HDL-C = high-density lipoprotein cholesterol, HR = heart rate, HRDS = Hamilton depression rating scale, LDL-C = low-density lipoprotein cholesterol, MAQOL = moorehead–ardelt quality of life questionnaire, RPP = rate pressure product, SBP = systolic blood pressure, SF-36 = short form health survey.

associated with several preoperative parameters in these patients. Specifically, simple linear regression analysis revealed that BMI, percent body fat, HR_{peak}, ESR, and total scores of the BDI, HDRS, SF-36, and MAQOL were significantly associated with the $VO_{2\ peak}$. Percent body fat and the SF-36 total score remained significant in the multiple linear regression analysis.

The validity and reliability of the test results were examined. Table 2 shows the baseline cardiorespiratory fitness parameters

Table 5

Multiple linear regression analysis of preoperative parameters with peak aerobic exercise capacity (VO_{2peak}) (N=22).

Outcome/independent predictor	Standardized (B)	*P* value	Adjusted R^2
$VO_{2,peak}$			0.704
Body fat percentage	−0.639	<.001	
SF-36 – Total	0.524	<.001	

B = beta coefficient, SF-36 = short form health survey, VO_{2peak} = peak oxygen consumption.

of patients with morbid obesity. First, the average total exercise time of 543.4±127.1 second is appropriate, falling within the range of 480 to 720 second.[22] Second, the mean respiratory exchange ratio was 1.1, which means that the participants performed the exercise with near-maximum effort.[22] Third, the percentages of the anaerobic threshold ($VO_{2\ AT}$) of measured $VO_{2\ peak}$/kg, and peak predicted kg/m^2 (HR_{peak}) were 82.5±11.9% and 85.2±8.8%, respectively, which indicates sufficient intensity to validate the test (i.e., both more than 80%).[22]

The $VO_{2\ peak}$/kg was 18.6±3.8 mL/min/kg, much lower than that in healthy Korean men and women (42.0±5.0 and 32.2±4.5 mL/min/kg, respectively).[6] A $VO_{2\ peak}$/kg of 18.6±3.8 mL/min/kg corresponds to a mean metabolic equivalent value of 5.3, which corresponds to the activity intensity of active housework such as grocery shopping, painting, and washing the floor.[23] Vigorous housework corresponded to the upper limit of activity in these patients, indicating low physical activity levels. Additionally, this $VO_{2\ peak}$/kg value is similar to that of patients with morbid obesity in previous studies conducted in Chile (20.9±3.2 mL/min/kg)[24] and Italy (20.0±3.7 mL/min/kg).[24] The main reason for the prevalence of low $VO_{2\ peak}$/kg values in these patients were revealed by Goran et al, who reported that patients with high body weight use most of their energy to bear weight; thus, only a small amount remains as aerobic exercise capacity.[25] The low $VO_{2\ peak}$/kg population showed a 3.56-fold higher relative risk of carotid atherosclerosis than the high $VO_{2\ peak}$/kg population; thus, low $VO_{2\ peak}$/kg could be the cause of various cardiovascular diseases.[26]

Simple and multiple linear regression analyses revealed that the final 2 variables significantly related to $VO_{2\ peak}$/kg were percent body fat and the total SF-36 score. As previously mentioned, Goran et al stated that patients with high body weight use most of their aerobic exercise capacity for weight-bearing, leaving little exercise capacity for other physical activities.[25] Therefore, a high percentage of body fat is a critical factor for low cardiorespiratory fitness ($VO_{2\ peak}$/kg). Therefore, we could speculate that body fat composition is correlated with aerobic exercise capacity ($VO_{2\ peak}$), as proven by simple linear regression (Table 4) and multiple stepwise regression analyses (Table 5). Another interesting point is that the body's traditional obesity markers, such as BMI, were not included in the second multiple stepwise regression analysis. This means that BMI actually serves as a marker of body fat measures, as in the study by Blundell et al[27] Therefore, there is a definite discrepancy between actual body fat measures and BMI values. With this point, we thought that the body fat percentage, not BMI, remained meaningful in the multiple stepwise regression analysis.

Table 5 also shows that the total SF-36 score was associated with $VO_{2\ peak}$. As described earlier, the SF-36 is composed of 8 scales: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. All scales contribute differently to the physical and mental component summary scores.[20] Black et al[28] showed that $VO_{2\ peak}$/kg can be accurately predicted using physical activity questionnaire data (including perceived functional ability and level of physical activity). Our study showed comparable results, and we found that obesity, lower aerobic exercise capacity, and poor physical and mental health status create a vicious cycle.

Additionally, other variables were found to be significant in simple linear aggression analysis; peak HR, metabolic syndrome, high BMI, high ESR, and high BDI score were significantly related to $VO_{2\ peak}$/kg. Swain et al. found a relationship between the percent HR reserve and percent VO_2 reserve with a mean intercept of −6.1, a mean slope of 1.10, and a mean r of 0.990.[29] Their results indicated that if HR increased during treadmill exercise, the percent VO_2 reserve also increased. We focused on the peak values of the HR and oxygen consumption during the tests. We collected data on peak HR and oxygen consumption during the exercise stress test, which could be converted to the values of percent HR reserve and percent VO_2 reserve with the sex and age data of those patients to calculate the original values.

Antony et al revealed that obesity and metabolic syndrome were significantly associated with lower levels of physical activity expenditure.[30] Additionally, an S-shaped relationship between physical activity and physical fitness ($VO_{2\ peak}$/kg) was shown in a previous study.[9] Therefore, we inferred that the prevalence of obesity and metabolic syndrome might be associated with a lower $VO_{2\ peak}$/kg. Hong et al found that a low level of cardiorespiratory fitness was a predictor of metabolic syndrome in a Korean population.[31] When the combined impact of BMI and cardiorespiratory fitness on the prevalence of metabolic syndrome was analyzed, a significant increase in the prevalence of metabolic syndrome was found in both men (odds ratio: 18.8, 95% confidence interval: 5.0–70.5) and women (odds ratio: 8.1, 95% confidence interval: 2.8–23.9) who had a high BMI and low cardiorespiratory fitness.

Additionally, the inverse correlation between inflammatory markers and $VO_{2\ peak}$/kg was studied by Kullo et al. Adipose tissue is an important source of inflammatory markers, and increased adiposity is associated with reduced cardiorespiratory fitness.[32] Additionally, according to Rodríguez et al, the co-modulation of adipokines and myokines contributes significantly to the control of inflammation and body weight control.[33] Suitable cardiorespiratory fitness could encourage and enhance the co-functioning of myokines and adipokines to regulate inflammation and energy expenditure.

Moreover, our results correspond to those of Lattari et al regarding the correlation between the BDI score and $VO_{2\ peak}$/kg.[34] This study revealed that regular aerobic exercise significantly reduces the degree of depressive mood, as assessed using the BDI.

4.1. Limitations

This study has several limitations. First, the number of participants who completed the self-reported questionnaires was insufficient to deduce the factors correlated with the $VO_{2\ peak}$. Therefore, we performed both simple linear regression and multiple stepwise regression analyzes to enhance the statistical power. Second, since the effect of morbid obesity itself is very significant, the impact of other factors such as age and sex might have been underestimated. However, there are some sex-related factors. In our study, testing for inflammatory markers showed an ESR and C-reactive protein are 31.8 ± 19.5 mg/h and 9.0 ± 9.2 mg/dL which were elevated. In detail, the ESR and C-reactive protein of women were 33.08 mg/dL and 9.06 mg/dL, which were higher than the total average. These may be associated with the decrease in lipogenic factors in omental fat in obesity, according to Poulain-Godefroy et al.[35] Finally, no follow-up data were collected postoperatively; however, further prospective postoperative studies with larger samples are being conducted in our cohort. In the near future, we expect additional meaningful postoperative follow-up data from our current efforts.

4.2. Conclusions

We found variable levels of cardiorespiratory fitness in patients with morbid obesity scheduled for laparoscopic sleeve gastrectomy. Moreover, our study revealed that peak aerobic exercise capacity was significantly associated with several preoperative parameters such as body fat composition and self-reported quality of life in these patients. Thus, these results may aid in decision-making with respect to preoperative evaluation and preoperative and/or postoperative exercise strategies in patients with morbid obesity scheduled for laparoscopic sleeve gastrectomy.

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