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

A cross-sectional study

Jei Hak Myung, MDa, Bo Ryun Kim, MD, PhDa,* Soo Hoon Yoon, MDb, Yeong Kuen Kwon, MD, PhDb, Sung Soo Park, MD, PhD, FASMBSb, Sung-Bom Pyun, MD, PhDb

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 (VO2peak), 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/m² and 46.2 ± 6.1%, respectively. The VO2peak/kg, METs, REFPpeak, HPpeak, RPPpeak, age-predicted HR percentage, and VO22peak 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), HRpeak (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 VO2peak/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, VO2 = peak values of oxygen consumption

Keywords: cardiopulmonary exercise test, gastrectomy, obesity, quality of Life
1. Introduction

According to the World Health Organization, in adults, a body mass index (BMI) of 25.0 to 29.9 kg/m² indicates overweight, ≥30 kg/m² indicates obesity, and ≥40.0 kg/m² 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/m² for overweight, 25.0–29.9 kg/m² for obesity (first stage), 30.0 to 34.9 kg/m² for obesity (second stage), and >35.0 kg/m² for morbid obesity. 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/m², overall mortality increased by 29.0%, vascular mortality increased by 41.0%, and diabetes-related mortality increased by 210.0%.

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/m² or a BMI ≥35.0 kg/m² and one or more significant comorbidities. Peak oxygen consumption per unit of body weight (VO₂peak/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 recommending that cardiorespiratory fitness, quantified based on VO₂peak/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.

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 VO₂peak/kg values of healthy Korean men and women were 42.0 ± 5.0 and 32.2 ± 4.5 mL/kg·min⁻¹, respectively. Typically, patients with obesity have much lower VO₂peak/kg values than healthy patients owing to deficiencies in aerobic exercise capacity. 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. Previous studies have revealed several factors predicting VO₂peak/kg in healthy Danish adolescents and peri-/postmenopausal women in the United States, focusing only on Western populations. However, only a few studies have investigated the parameters predicting VO₂peak/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 VO₂peak/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/m²;
2. age between 18 and 65 years, and 65 years as the cut-off age for deeming an individual elderly, 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.

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 mmHg during the preoperative evaluation.[12]

**Diabetes mellitus** was defined as having a known diagnosis before enrollment or fulfilling 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, VO2peak/kg with the corresponding peak in metabolic equivalents, peak respiratory exchange ratio, peak and resting heart rates (HRpeak and HRresting, respectively), peak and resting SBP/DBP (SBPpeak/DBPpeak and SBPresting/DBPresting, respectively), peak rate pressure product, anaerobic threshold (VO2 AT), age-predicted percentage of maximum HR, and age-predicted VO2 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). VO2peak/kg was also expressed in a forced expiratory volume (1 s) of the Moseley-Holden protocol by analyzing exhaled gas using the breath-by-breath method and a portable telemetry system (CPET; COSMED Inc., Pavona di Albano, Italy). VO2peak/kg was also expressed as a percentage of the age-predicted maximal HR: [HRpeak/(220 – age)] × 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 VO2peak exhibited the highest VO2 value during the test. A maximal effort was considered if VO2 did not increase by > 150 mL in the final minute of exercise (i.e., a VO2 plateau had been reached).[17] We then divided VO2peak/kg by body weight.

2.4. Anthropometric characteristics

BMI was calculated using the formula: BMI (kg/m²) = weight(kg) / Height(m)²

The following body composition variables were determined using bioimpedance analysis (InBody720, BIOSPACE, Cheon-An, Korea): body fat percentage (%), body fat mass (kg), skeletal muscle mass (kg), and skeletal muscle index (kg/m²):

\[
\text{SBP (SBPpeak/DBPpeak and SBPresting/DBPresting, respectively), peak and resting SBP/DBP (SBPpeak/DBPpeak and SBPresting/DBPresting, respectively), peak rate pressure product, anaerobic threshold (VO2 AT), age-predicted percentage of maximum HR, and age-predicted VO2 peak.}
\]

\[
\text{Sum of muscle mass of all four limbs (kg), and skeletal muscle index (kg/m²):}
\]

\[
\text{Before surgery, patients underwent laboratory tests, including hemoglobin A1c, lipoprotein, inflammatory markers, ESR, and C-reactive protein.}
\]

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 for assessing 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-
form results from 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 1
| Characteristic | Value |
|----------------|-------|
| Age (yr)       | 34.9 ± 10.9 |
| Sex            |       |
| Male (%)       | 13 (34.2) |
| Female (%)     | 25 (65.8) |
| Co-morbidity   |       |
| Hypertension   | 30 (79.0) |
| Diabetes       | 19 (50.0) |
| Dyslipidemia   | 28 (73.7) |
| Chronic pain   | 16 (42.1) |
| Metabolic syndrome | 31 (81.6) |
| SBPresting, mmHg | 133.1 ± 46.2 |
| DBPresting, mmHg | 87.3 ± 14.8 |
| HRresting, /min | 86.2 ± 8.8 |
| HRpeak, /min   | 18.5 ± 3.8 |
| RERpeak        | 1.1 ± 0.1 |
| VO$_2$peak/kg  | 18.6 ± 3.8 |
| HRpeak, % of age-predicted | 85.2 ± 8.8 |
| SBPpeak, mmHg  | 158.5 ± 19.8 |
| DBPpeak, mmHg  | 86.2 ± 18.5 |
| SBPresting, mmHg | 225.7 ± 31.4 |
| DBPresting, mmHg | 133.1 ± 16.2 |
| DBPpeak, mmHg  | 81.6 ± 21.4 |
| RPPpeak, mmHg/min | 87.3 ± 11.7 |
| CRP, mg/dL      |       |
| Values are presented as mean ± standard deviation or number (%). |
| All patients underwent preoperative evaluation, including a symptom-limited cardiopulmonary 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$_2$peak/kg and METspeak were 18.6 ± 3.8 mL/min/kg and 3.3 ± 1.1, respectively, with the percentage of predicted VO$_2$peak/kg being 76.1 ± 14.8%.

### Table 2
| Cardiorespiratory fitness indices | Value |
|----------------------------------|-------|
| Peak aerobic capacity (VO$_2$peak/kg), mL/min-kg | 18.6 ± 3.8 |
| Peak aerobic capacity (METspeak) | 5.3 ± 1.1 |
| Percentage of predicted VO$_2$peak/kg, % | 76.1 ± 14.8 |
| Anaerobic threshold (VO$_2$AT), mL/min | 1,666.9 ± 469.7 |
| RERpeak | 1.1 ± 0.1 |
| VO$_2$peak/ min | 1,666.9 ± 469.7 |
| HRpeak, % of age-predicted | 85.2 ± 8.8 |
| SBPpeak, mmHg | 158.5 ± 19.8 |
| DBPpeak, mmHg | 81.6 ± 21.4 |
| RPPpeak, mmHg/min | 87.3 ± 11.7 |
| Values are presented as mean ± standard deviation or number (%). |

### Table 3
| Anthropometric characteristics and laboratory findings of the patients (N = 38). |
|----------------------------------|-------|
| Blood composition and related indices | Value |
| Height, cm | 165.6 ± 11.1 |
| Body weight, kg | 112.7 ± 23.0 |
| BMI, kg/m² | 35.0 ± 16.2 |
| Percent body fat | 42.1 ± 6.1 |
| Skeletal muscle, kg | 32.9 ± 5.4 |
| Skeletal muscle index, kg/m² | 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 |

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 4

Simple linear regression analysis of preoperative parameters with peak aerobic exercise capacity (VO2peak) (N = 22).

| Factors                                      | Standardized (B) | P value | Adjusted R² |
|----------------------------------------------|------------------|---------|-------------|
| 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           |                  |         |             |
| HRpeak (% of age-predicted)                 | 0.499            | .018    | 0.211       |
| SBPpeak                                      | 0.250            | .262    | 0.016       |
| SBPresting                                   | 0.159            | .480    | -0.024      |
| DBPpeak                                      | -0.033           | .884    | -0.049      |
| DBPresting                                   | 0.177            | .430    | -0.017      |
| RPPpeak                                      | 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           | .860    | -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       |
| HDRS                                         | -0.478           | .023    | 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, HRSD = Hamilton depression rating scale, LDL-C = low-density lipoprotein cholesterol, MAQOL = Moorehead–Arlert quality of life questionnaire, RPP = rate pressure product, SBP = systolic blood pressure, SF-36 = short form health survey.

Table 5

Multiple linear regression analysis of preoperative parameters with peak aerobic exercise capacity (VO2peak) (N = 22).

| Outcome/independent predictor | Standardized (B) | P value | Adjusted R² |
|-------------------------------|------------------|---------|-------------|
| VO2peak                       | 0.704            |         |             |
| Body fat percentage           | -0.639           | <.001   |             |
| SF-36 – Total                 | 0.524            | <.001   |             |

B = beta coefficient, SF-36 = short form health survey, VO2peak = peak oxygen consumption.
percent HR reserve and percent VO2 reserve with a mean intercept of –6.1, a mean slope of 1.10, and a mean r of 0.990.\textsuperscript{[29]} Their results indicated that if HR increased during treadmill exercise, the percent VO2 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 VO2 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.\textsuperscript{[30]} Additionally, an S-shaped relationship between physical activity and physical fitness (VO2 peak/kg) was shown in a previous study.\textsuperscript{[31]} Therefore, we inferred that the prevalence of obesity and 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 VO2 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.\textsuperscript{[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.\textsuperscript{[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 Lattar et al regarding the correlation between the BDI score and VO2 peak/kg.\textsuperscript{[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 VO2 peak. Therefore, we performed both simple linear regression and multiple stepwise regression analyses 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.\textsuperscript{[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.

Acknowledgments
We would like to thank Editage (www.editage.co.kr) for English language editing.

Author contributions
Conceptualization: Bo Ryun Kim, Yeong Kuen Kwon, Sung Soo Park, Sung-Bom Pyun.
Data curation: Jei Hak Myung, Yeong Kuen Kwon.
Formal analysis: Jei Hak Myung, Bo Ryun Kim.
Methodology: Jei Hak Myung, Bo Ryun Kim, Sung Soo Park, Sung-Bom Pyun.
Project administration: Bo Ryun Kim, Sung-Bom Pyun.
Supervision: Bo Ryun Kim, Sung Soo Park, Sung-Bom Pyun.
Validation: Bo Ryun Kim, Yeong Kuen Kwon, Sung Soo Park.
Writing – original draft: Jei Hak Myung.
Writing – review & editing: Jei Hak Myung, Bo Ryun Kim, Soo Hoon Yoon, Sung-Bom Pyun.

References
[1] Seo MH, Lee WY, Kim SS, et al. 2018 Korean Society for the Study of Obesity Guideline for the Management of Obesity in Korea. J Obes Metab Syndr 2019;28:40–5.
[2] Apovian CM. Obesity: definition, comorbidities, causes, and burden. Am J Manag Care 2016;22:e176–185.
[3] Kouvelioti R, Vagenas G, Langley-Evans S. Effects of exercise and diet on weight loss maintenance in overweight and obese adults: a systematic review. J Sports Med Phys Fitness 2014;54:456–74.
[4] Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. Circulation 2016;134:e653–99.
[5] Berry JD, Pandey A, Gao A, et al. Physical fitness and risk for heart failure and coronary artery disease. Circ Heart Fail 2013;6:627–34.
[6] Jiang WY, Kim W, Kang DO, et al. Reference values for cardiorespiratory fitness in healthy Koreans. J Clin Med 2019;8:2191.
[7] Capoccia D, Coccia F, Guarisco G, et al. Long-term metabolic effects of laparoscopic sleeve gastrectomy. Obes Surg 2018;28:2289–96.
[8] Deforche BL, De Bourdeaudhuij IM, Tanghe AP. Attitude toward physical activity in normal-weight, overweight and obese adolescents. J Adolesc Health 2006;38:560–8.
[9] Andersen LB. Blood pressure, physical fitness and physical activity in 17-year-old Danish adolescents. J Intern Med 1994;236:323–9.
[10] Sieber CC. The elderly patient—who is that. Internist (Berl) 2007;48:11901192–1194.
[11] Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, muscular, bone mass, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334–59.
[12] Greenland P, Peterson E. The new 2017 ACC/AHA guidelines “up the pressure” on diagnosis and treatment of hypertension. JAMA 2017;318:2083–4.
[13] American Diabetes A2 classification and diagnosis of diabetes: standards of medical care in diabetes-2019. Diabetes Care 2019;42: S13–28.

[14] Teramoto T, Sasaki J, Ishibashi S, et al. Diagnostic criteria for dyslipidemia. J Atheroscler Thromb 2013;20:653–60.

[15] Coster L, Kendall S, Gerdl B, Henriksson C, Henriksson KG, Bengtsson A. Chronic widespread musculoskeletal pain - a comparison of those who meet criteria for fibromyalgia and those who do not. Eur J Pain 2008;12:600–10.

[16] Hong AR, Lim S. Clinical characteristics of metabolic syndrome in Korea, and its comparison with other Asian countries. J Diabetes Invest 2015;6:508–15.

[17] Howley ET, Bassett DR, Welch HG. Criteria for maximal oxygen uptake. Med Sci Sports Exercise 1995;27:1292–301.

[18] Garcia-Batista ZE, Guerra-Pena K, Cano-Vindel A, Herrera-Martinez SX, Medrano LA. Validity and reliability of the Beck Depression Inventory (BDI-II) in general and hospital population of Dominican Republic. PLoS One 2018;13:e0199730.

[19] Rohan KJ, Rough JN, Evans M, et al. A protocol for the Hamilton Rating Scale for Depression: item scoring rules, Rater training, and outcome accuracy with data on its application in a clinical trial. J Affect Disord 2016;200:111–8.

[20] Lins L, Carvalho FM. SF-36 total score as a single measure of health-related quality of life: Scoping review. SAGE Open Med 2016;4: 2050312116671725.

[21] Lee YJ, Song HJ, Heo Y, et al. Validation of the Korean version Moorehead-Ardelt quality of life questionnaire II. Ann Surg Treat Res 2014;87:265–72.

[22] Guazzi M, Bandera F, Ozemek C, Systrom D, Arena R. Cardiopulmonary exercise testing: what is its value? J Am Coll Cardiol 2017;70: 1618–36.

[23] Jette M, Sidney K, Blumchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol 1990;13:555–65.

[24] Steele T, Cuthbertson DJ, Wilding JP. Impact of bariatric surgery on physical functioning in obese adults. Obes Rev 2015;16:248–58.

[25] Goran M, Fields DA, Hunter GR, Herd SL, Weinsier RL. Total body fat does not influence maximal aerobic capacity. Int J Obes Relat Metab Disord 2000;24:841–8.

[26] Kang SJ, Ko KJ. Association between resting heart rate, VO2max and carotid intima-media thickness in middle-aged men. Int J Cardiol Heart Vasc 2019;23:100347.

[27] Blundell JE, Dulloo AG, Salvador J, Fruhbeck G. BMI ESWMbeyond BMI—phenotyping the obesities. Obes Facts 2014;7:322–8.

[28] Black NE, Vehrs PR, Fellingham GW, George JD, Hager R. Prediction of VO2max in children and adolescents using exercise testing and physical activity questionnaire data. Res Q Exerc Sport 2016;87:89–100.

[29] Swain DP, Leutholtz BC, King ME, Haas LA, Branch JD. Relationship between % heart rate reserve and % VO2 reserve in treadmill exercise. Med Sci Sports Exerc 1998;30:318–21.

[30] Karelis AD, Lavoie ME, Messier V, et al. Relationship between the metabolic syndrome and physical activity energy expenditure: a MONET study. Appl Physiol Nutr Metab 2008;33:309–14.

[31] Hong S, Lee J, Park J, et al. Association between cardiorespiratory fitness and the prevalence of metabolic syndrome among Korean adults: a cross sectional study. BMC Public Health 2014;14:481.

[32] Kullo IJ, Khaleghi M, Hensrud DD. Markers of inflammation are inversely associated with VO2 max in asymptomatic men. J Appl Physiol (1985) 2007;102:1374–9.

[33] Rodríguez A, Becerril S, Ezquerro S, Mendez-Gimenez L, Fruhbeck G. Crosstalk between adipokines and myokines in fat browning. Acta Physiol (Oxf) 2017;219:362–81.

[34] Lattari E, Budde H, Paes F, et al. Effects of aerobic exercise on anxiety symptoms and cortical activity in patients with panic disorder: a pilot study. Clin Pract Epidemiol Ment Health 2018;14:11–25.

[35] Poulim-Godefroy O, Lecoeur C, Pattou F, Fruhbeck G, Froguel P. Inflammation is associated with a decrease of lipogenic factors in omental fat in women. Am J Physiol Regul Integr Comp Physiol 2008;295:R1–7.