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Research Article



# Comparison of Pulmonary Function, Respiratory Muscle Strength, and Diaphragm Thickness between Underweight and Normal Adults

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**| Abstract |**

**PURPOSE:** This study aimed to investigate the relationship between being underweight and respiratory function indicators such as pulmonary function, respiratory muscle strength, and diaphragm thickness in normal adults without lung disease.

**METHODS:** The participants in this experiment were thirty young adults. To compare the respiratory function between the underweight and normal weight individuals, 15 participants were selected from each of the underweight and normal weight groups based on body mass index. Respiratory function tests were conducted through pulmonary function tests and respiratory muscle strength tests. Diaphragm thickness was measure with ultrasonography, and physical characteristics were obtained from grip strength and waist circumference. An independent t-test was used to compare the averages of the parameters measured in the two groups.

**RESULTS:** In the respiratory function tests between the two groups, statistically significant differences ($p < .05$) emerged in the ratio of the predicted forced vital capacity (%FVC), the ratio of the predicted forced expiratory volume in one second (%FEV1), maximal expiratory pressure (MEP), and diaphragm thickness at the functional residual capacity (FRC). There was no statistically significant difference in the forced vital capacity, forced expiratory volume in one second, maximal inspiratory pressure, diaphragm thickness at the total lung capacity, and thickening ratio ($p > .05$).

**CONCLUSION:** Decreases in some variables of respiratory function, such as the %FVC, %FEV1, MEP, and diaphragm thickness at the FRC were observed in underweight subjects. However, it is difficult to determine whether it affected the overall respiratory function. Future studies are needed to clearly identify the relationship between being underweight and respiratory function.

**Key Words:** Body mass index, Diaphragm, Respiratory function tests, Respiratory muscles

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## Ⅰ. Introduction

Being underweight is one of the factors contributing to the mortality of acute and chronic respiratory diseases

[1]. According to a previous study, underweight patients with acute respiratory distress syndrome (ARDS) and acute lung injury (ALI) showed high mortality [2]. It has been reported that asthma [3], a chronic respiratory disease, has an association with underweight, and that underweight patients with chronic obstructive pulmonary disease (COPD) have a high risk of mortality [4]. Based on the criteria of the Global Initiative for Chronic Obstructive Lung Disease (GOLD), the severity of dyspnea in COPD is higher in underweight patients than in normal-weight patients [5]. Many studies have investigated relationships between being underweight and the mortality in respiratory diseases. However, few studies have investigated the effects of being underweight on respiratory function in normal adults.

Most previous studies on the association between weight and respiratory function in normal adults have focused on obesity. It is known that due to obesity, fat accumulation in the chest and abdominal regions restricts lung inflation and diaphragm movement, negatively affecting respiratory function [6]. It has been reported that weight loss in obesity is associated with improved respiratory function [7]. On the other hand, although it is difficult to elucidate the mechanisms of underweight that affect respiratory function in normal people, a previous study reported that it is associated with a lower forced vital capacity (FVC) measured by the pulmonary function test (PFT) [8].

Respiratory function is measured by lung capacity and respiratory muscle strength. Using the PFT, lung capacity is measured with FVC and forced expiratory volume in one second ($FEV_1$); and respiratory muscle strength is measured with maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). Tuinman et al. [9] evaluated respiratory function of critically ill patients by measuring the thickness of the diaphragm, a major respiratory muscle, using ultrasonography. Likewise, Jung et al. [10] evaluated respiratory function by measuring diaphragm thickness in patients with chronic.

As the diaphragm contracts, the chest cavity expands and lung pressure decreases, pulling in air. When the diaphragm relaxes, exhaling occurs. The contraction and relaxation of the diaphragm affects lung capacity and inspiratory and expiratory pressure; and the contractibility of the diaphragm is essential for maintaining normal breathing. Respiratory muscle strength is known to be associated with changes in the length and thickness of the respiratory muscle [11]. Thus, changes in the length and thickness of the diaphragm are useful indicators of respiratory function [9-11].

However, studies on the relationship between diaphragm thickness and respiratory function in underweight participants are insufficient. A comparison of respiratory function between underweight and normal adults is crucial as a preliminary study to determine whether underweight is a potential cause of acute and chronic respiratory disease and high severity. Therefore, this study compared pulmonary function, respiratory muscle strength, and diaphragm thickness between underweight and normal adults.

## Ⅱ. Methods

### 1. Participants

The participants were 30 healthy male and female adults in their 20s who were attending P University in B city and had no musculoskeletal disorders or respiratory diseases. According to the body mass index (BMI), 15 subjects were assigned to the underweight and normal groups. BMI was obtained by dividing body weight (kg) by height squared ($m^2$). According to the World Health Organization (WHO) Asian criteria, the subjects were assigned to an underweight group (< 18.5 $kg/m^2$) or a normal group (18.5 to < 25 $kg/m^2$) [12].

To obtain the sample size in this study, G-power software ver. 3.1(G-power, University of Kiel, Germany) was used with a test power of .7, effect size of .5, and significance level (α) of .05. As a result, the number of participants was

30. Accordingly, 15 participants were assigned to two groups.

The inclusion criteria were those with a BMI of less than 25kg/m$^2$, those who understood the study purpose and voluntarily agreed to participate, and those who had no difficulty with communication and physical movement during the experiment. Those who exhibited respiratory diseases or respiratory symptoms, those who had musculoskeletal disorders, and women who were pregnant, were excluded. According to the inclusion and exclusion criteria, 30 individuals participated in the study.

The experiment was explained to all the participants and their voluntary agreement was obtained before the commencement of the study. Written consent was obtained for an informed consent form. This study was conducted in compliance with the Declaration of Helsinki.

### 2. Measurement Methods and Tools

The physical characteristics were measured in order of grip strength and waist circumference. Respiratory function was measured in the order of pulmonary function and respiratory muscle strength, and then diaphragm thickness. A three-minute rest was given between the respiratory tests. After all the tests were finished, the smoking status of the subjects was examined.

Grip strength is used as an indicator of overall muscular strength, and a digital grip dynamometer (TKK 5401, Takei, Japan) was used. The participants were asked to stand straight, spread their feet at shoulder width, straighten and lower their arms, and grip the handle of the dynamometer. The strength of the dominant hand was measured three times, and the highest value was used [13].

To measure waist circumference, the standardized waist circumference measurement method by WHO was used. [14]. After the participants were asked to stand straight, spread their feet at shoulder width, and breathe out comfortably, waist circumference was measured up to one decimal point, three times at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, and the mean value was recorded.

Lung capacity was measured using a portable digital spirometer device (Pony Fx, COSMED, Italy). For the accurate measurement of lung capacity, the test was explained to the participants who were asked to sit with their hips at 90 degrees. The maximal effort expiratory spirogram was measured at least three times, and the highest value among the reproducible values of FVC and $FEV_1$ was recorded [15,16].

Respiratory muscle strength was measured using a portable digital spirometer device (Pony Fx, COSMED, Italy). The participants were asked to remain in the same position as with the PFT, and the MIP and MEP were measured. After measuring at least three times, the highest reproducible value was recorded.

To measure diaphragm thickness, using a B-mode ultrasound diagnostic system (MicrUs EXT-1H, Telemed UAB, Lithuania) with 7.5 MHz or above Linear probe, the participants in a supine position were observed (Fig. 1A). With the participants standing upright, the axillary line between the 8$^{th}$ and 9$^{th}$ ribs were marked. Then, with the participants sitting straight, a linear probe was located perpendicular to the intercostal spaces, according to the mid-axillary line between the 8$^{th}$ and 9$^{th}$ ribs, to obtain a 2D image. Diaphragm thickness is the distance between two parallel lines each in the middle of the pleura and peritoneum. The participants were asked to breathe out comfortably, and diaphragm thickness at a functional residual capacity (FRC) was measured three times (Fig.

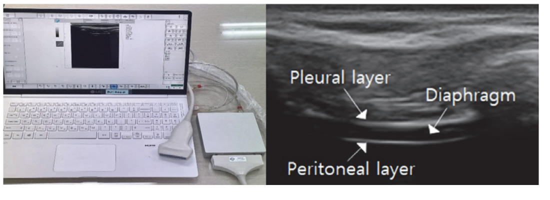


Fig. 1. Evaluation of diaphragmatic thickness.
(A) Ultrasonography device (MicrUs EXT-1H, Telemed UAB, Lithuania), (B) B-mode ultrasonography image of diaphragm thickness.

1B). Next, diaphragm thickness at total lung capacity ($D_{con}$) was measured three times. The mean of three measurements was recorded and the thickening ratio (TR) was then calculated: $D_{con}$ / diaphragm thickness at the FRC [17].

### 3. Data Analysis

This study performed statistical analysis using IBM SPSS 25.0 (SPSS, IBM, USA). A Shapiro-Wilk test was performed to verify the general characteristics of the study subjects and the normality of the measured data. The statistical significance level (α) was set to .05, and all data were described with a mean and standard deviation. An independent samples t-test was performed to compare the measurements between the underweight and normal groups.

## Ⅲ. Results

The subjects of this study were 30 healthy male and female adults in their 20s, and the general characteristics of the subjects were as follows (Table 1).

For pulmonary function, FVC and $FEV_1$ showed no significant differences between the two groups ($p > .05$). The percentage of predicted forced vital capacity (%FVC) and percentage of predicted forced expiratory volume in one second (%$FEV_1$) showed significant differences between the two groups ($p < .05$), with the normal group exhibiting higher values than the underweight group (Table 2).

There was no significant difference between the two groups ($p > .05$) in MIP, an indicator of respiratory muscle strength; but a significant difference between the groups

Table 1. General characteristics of the study participants (n=30)

| Variable | Underweight group (n = 15) | Normal group (n = 15) | t | p |
|---|---|---|---|---|
| Age (years) | 22.07 ± 1.16 | 22.87 ± 1.60 | -1.568 | .130 |
| Gender (male/female) | 4/11 | 6/9 | .756 | .460 |
| Height (m) | 1.66 ± .07 | 1.65 ± .09 | .247 | .800 |
| Weight (kg) | 48.00 ± 5.30 | 59.04 ± 7.90 | -4.477 | < .001* |
| Body mass index | 17.39 ± 1.01 | 21.53 ± 1.22 | -10.140 | < .001* |
| Smoking (never/current/past) | 13/2/0 | 10/5/0 | -1.288 | .210 |
| Waist circumference (inch) | 24.13 ± 1.23 | 27.70 ± 1.96 | -5.978 | < .001* |
| Hand grip (kg) | 20.83 ± 5.23 | 28.99 ± 9.53 | -2.905 | .010* |

*p < .05
Mean±SD.

Table 2. Respiratory function of the study subjects

| Variable | Underweight group (n = 15) | Normal group (n = 15) | t | p |
|---|---|---|---|---|
| Pulmonary function | | | | |
| FVC (L) | 3.58 ± .75 | 3.99 ± 1.06 | -1.222 | .233 |
| %FVC | 85.20 ± 7.97 | 92.33 ± 9.78 | -2.190 | .037* |
| $FEV_1$ (L) | 3.13 ± .64 | 3.44 ± .90 | -1.180 | .078 |
| %$FEV_1$ | 88.47 ± 10.34 | 98.47 ± 15.69 | -2.061 | .049* |

Table 2. (Continued)

| Variable | Underweight group (n = 15) | Normal group (n = 15) | t | p |
|---|---|---|---|---|
| $FEV_1/FVC$ | 86.80 ± 8.48 | 87.53 ± 5.24 | - .285 | .778 |
| $\%FEV_1/FVC$ | 101.67 ± 9.80 | 103.87 ± 5.90 | - .745 | .463 |
| Respiratory muscle strength | | | | |
| MIP ($cmH_2O$) | 56.40 ± 13.23 | 65.53 ± 15.75 | -1.719 | .097 |
| MEP ($cmH_2O$) | 68.00 ± 15.04 | 91.13 ± 30.86 | -2.610 | .017* |
| Diaphragm thickness | | | | |
| Diaphragm thickness at the FRC (cm) | .10 ± .12 | .14 ± .04 | -3.012 | .008* |
| $D_{con}$ (cm) | .21 ± .07 | .23 ± .05 | -1.033 | .310 |
| TR | 1.86 ± .58 | 2.04 ± .67 | .819 | .420 |

*$p < .05$

Mean±SD. FVC: forced vital capacity, %FVC: % of predicted forced vital capacity, $FEV_1$: forced expiratory volume in 1 second, $\%FEV_1$: % of predicted forced expiratory volume in 1 second, MIP: maximal inspiratory pressure, MEP: maximal expiratory pressure, FRC: functional residual capacity, $D_{con}$: diaphragm thickness at the total lung capacity, TR: thickening ratio.

was evident with regard to MSP. The normal group exhibited a higher MEP than the underweight group.

Diaphragm thickness at the FEC was associated with a significant difference between the two groups ($p < .05$), with the normal group having a thicker diaphragm than the underweight group. There were no significant differences in diaphragm thickness and TR at the maximal inspiratory level between the two groups.

## Ⅳ. Discussion

According to the WHO Asian criteria, this study classified normal adults in their 20s with no respiratory diseases into underweight and normal groups to investigate differences in respiratory function. The results showed that there were no significant differences in diaphragm thickness and TR at the maximal inspiratory level between the two groups. However, there was a significant difference in the %FVC, $\%FEV_1$, MEP, and diaphragm thickness at the FRC between the two groups. In addition, an analysis of physical characteristics found that there were significant differences in grip strength and waist circumference. This result suggests that underweight bodies are associated with lower lung capacity and expiratory muscle strength, which are some of the indicators of respiratory function. However, it is difficult to generalize the effects of an underweight body to overall respiratory function.

A previous study also reported that underweight bodies may be associated with decreases in the indicators of the PFT [8]. The %FVC and $\%FEV_1$ were significantly lower in the underweight group than in the normal group. The previous study concluded that reduced diaphragm contractility might have affected decreases in the indicators of pulmonary function. There are, however, no studies measuring diaphragm contractility in underweight subjects. Against this backdrop, this study investigated the diaphragm TR using an ultrasound diagnostic system, as there is no method of measuring diaphragm contractility directly.

The results of measuring the diaphragm during breathing using an ultrasound diagnostic system showed that there were no significant differences in diaphragm thickness and contractility at total lung capacity between the underweight and normal groups. However, diaphragm thickness at the

FRC was significantly lower in the underweight group than in the normal group, it is speculated that the respiratory function of the underweight group was affected by the passive relaxation of the diaphragm and the movement of the intercostal and abdominal muscles.

In a study on rats by Lewis et al. [18], it was found that the cross-sectional area of diaphragm muscle fiber and the contractility were decreased in underweight due to nutritional deprivation. In contrast, the reason why no significant difference in diaphragm contractility was observed in this study is thought to be due to the characteristics of the subjects as normal adults in their 20s without respiratory disease. This is consistent with the results of a study by Sota et al. [19], who reported that diaphragm contractility does not reflect respiratory muscle strength in normal adults. However, in previous studies, it was difficult to distinguish the diaphragm contraction rate between underweight and normal weight because the age and BMI of the subjects were not considered. Combining these points with the results of this study, it is thought that it is difficult to evaluate respiratory function in normal adults by diaphragm contractility.

MIP and MEP measured by the respiratory muscle strength test are useful indicators of weakened respiratory muscle strength [20,21]. In this study, MIP with no significant difference, but MEP showed a significant difference, which is presumed to be due to the contraction of intercostal and abdominal muscles. A larger number of participants is needed to make a clear comparison of respiratory muscle strength between underweight and normal adults.

In this study, as the mean age of the participants was 22.07±1.16 in the normal group and 22.87±1.60 in the underweight group, there is a limitation in generalizing the effect of being underweight on respiratory function to all age groups. Moreover, the BMI was used to distinguish the underweight and normal groups, but the index alone does not provide data regarding the composition and distribution of fat and muscle. As this study did not consider the amount of fat and muscle, further studies should include expanded age groups and body composition, besides the BMI, to investigate the association between being underweight and respiratory function.

## Ⅴ. Conclusion

This study aimed to compare the respiratory function of underweight and normal adults in 30 healthy adults in their 20s. Compared to the normal group, the underweight group showed decreases in respiratory function indicators such as the %FVC, $\%FEV_1$, MEP, and diaphragm thickness at the FRC. However, it is difficult to conclude that overall respiratory function was affected by these factors. Further studies are required to clearly discern the association between being underweight and respiratory function.

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