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# Reference Respiratory Muscle Strength Values and a Prediction Equation Using Physical Functions for Pulmonary Rehabilitation in Korea

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## ABSTRACT

**Background:** In Korea, tests for evaluating respiratory muscle strength are based on other countries' clinical experience or standards, which can lead to subjective evaluations. When evaluating respiratory function based on the standards of other countries, several variables, such as the race and cultures of different countries, make it difficult to apply these standards. The purpose of this study was to propose objective respiratory muscle strength standards and predicted values for healthy Korean adults based on age, height, weight, and muscle strength, by measuring maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), and peak cough flow (PCF).
**Methods:** This cross-sectional study analyzed MIP, MEP, and PCF in 360 people, each group comprising 30 adult men and women aged 20–70, diagnosed as healthy after undergoing medical check-ups at a general hospital. Hand grip strength (HGS) and the five times sit-to-stand test (FTSST) results were also recorded. Correlations among respiratory muscle strength, participant demographics, and overall muscle strength were evaluated using Pearson's correlation analysis. The predicted values of respiratory muscle strength were calculated using multiple regression analysis.
**Results:** Respiratory muscle strength differed from the values reported in studies from other countries. In the entire samples, both MIP and MEP had the highest correlations with peak HGS ($r = 0.643$, $r = 0.693$; $P < 0.05$), while PCF had the highest correlation with forced expiratory volume in 1 s ($r = 0.753$; $P < 0.05$). Age, body mass index, peak HGS, and FTSST results were independent variables affecting respiratory muscle strength. A predictive equation for respiratory muscle strength was developed using the multiple regression equation developed in this study.
**Conclusion:** Respiratory muscle strength index may differ by country. For more accurate diagnoses, standard values for each country are required. This study presents reference values for Korea, and a formula for estimation is proposed when no respiratory muscle strength measurement equipment is available.

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**Author Contributions**
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**Keywords:** Hand Strength; Maximal Respiratory Pressures; Muscle Strength; Pulmonary Ventilation; Respiratory Function Tests; Respiratory Muscles

## INTRODUCTION

The human body weakens, and its muscle mass decreases because of aging and disease in a process termed sarcopenia.[1] Among the types of sarcopenia, the weakening of respiratory muscle strength is referred to as respiratory sarcopenia.[2,3] Respiratory sarcopenia can cause breathing difficulties, reducing physical activity and leading to respiratory failure.[3] Thus, respiratory muscle strength management is an important contributor to physical health. In addition to respiratory sarcopenia, evaluating respiratory function and muscle strength is an important factor in various other diseases such as neuromuscular diseases (NMDs) and chronic obstructive pulmonary disease (COPD).[4-6]

A representative method for evaluating respiratory function is the pulmonary function test. Pulmonary function tests measure forced vital capacity (FVC), forced expiratory volume in 1 second ($FEV_1$), and the $FEV_1$/FVC ratio.[7,8] In addition to lung capacity, a respiratory muscle strength test is used to evaluate respiratory function.[5,9,10] Respiratory muscle strength can be measured using maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), and peak cough flow (PCF). MIP and MEP are indicators related to individual health, ventilation ability, and postoperative mortality.[11,12]

In cases of respiratory muscle strength problems, difficulty in breathing, reduced exercise resistance, and in severe cases, respiratory failure occurs.[13] Therefore, the evaluation of respiratory muscle strength is clinically important and must be accurately measured and interpreted.[14,15] When providing respiratory training to patients whose respiratory muscles have weakened due to acute or chronic diseases, treatment should be initiated according to the patient's ability. This means that each country must have a normal level of respiratory muscle strength to set its final training goal.

Currently, data on predicted lung capacity are available for healthy Korean adults[16]; however, data on MIP, MEP, and PCF, indicating respiratory muscle strength, for healthy Korean adults are not available.

In Korea, tests for evaluating respiratory muscle strength are based on the clinical experience of medical staff or standards of other countries,[17] which can lead to subjective evaluations. When evaluating respiratory function based on the standards of other countries, several variables, such as the race and cultures of different countries, make it difficult to apply these standards.[18] Although many studies have been conducted on respiratory muscle strength in different countries, each country has a different standard for respiratory muscle strength.[19-25]

Therefore, this study aimed to establish the reference values for respiratory muscle strength in healthy Korean adults by measuring MIP, MEP, and PCF in healthy Korean adults. We also aimed to confirm the correlation between respiratory muscle strength and the participants' general characteristics, hand grip strength (HGS), and five times sit-to-stand test (FTSST) result, and propose predictions for respiratory muscle strength in healthy adults in Korea using multiple regression analysis.

## METHODS

### Participants

This study was conducted on individuals who visited the Health Examination Center and the National Cancer Examination Center. Among the individuals who visited a family doctor and were diagnosed as healthy, those whose pulmonary function test results were normal were selected. In total, 360 subjects aged 20–70 years were selected; the participants were organized into groups of 30 according to age group and sex (180 men and 180 women; **Fig. 1**). The sample size of this study was evaluated according to a study by Simões et al.[14] Using the G*Power 3.1 program, H0 was set to −0.81 and H1 −0.86. The significance level (α) was set to 0.05, the power was 0.85, and 327 people were required. We recruited people considering the dropout rate, and among them, 360 people who could participate in the study were selected, and their data were analyzed. The inclusion criteria were as follows: healthy adults in their 20s and 70s and non-smokers (people with a smoking cessation period of ≥ 2 years). The exclusion criteria were as follows: individuals with diseases of the nervous, musculoskeletal, cardiovascular, and respiratory systems; individuals with a history of the chest and abdominal incision surgeries; and individuals with an abnormal lung capacity ($FEV_1$/FVC < 70% and FVC < 80%). The study cohort comprised those who showed interest in the study and voluntarily wished to participate.

### Protocol

Lung capacity was measured in terms of FVC, $FEV_1$, and $FEV_1$/FVC using a spirometer (Pony Fx; Cosmed Srl, Rome, Italy). The measurements were performed while the participants were sitting on a chair with a 90° flexion posture of the hip joint. The mouthpiece of the measuring device was brought close to the mouth to prevent air from leaking, and the nose was blocked using a nose clip. The highest value among the reproducible values was used after

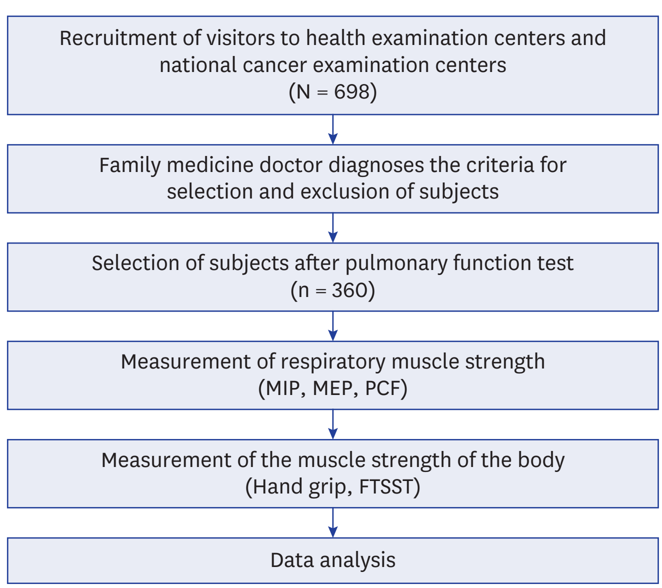


**Fig. 1.** Research progress flow.
MIP = maximal inspiratory pressure, MEP = maximal expiratory pressure, PCF = peak cough flow, FTSST = five times sit-to-stand test.


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measurements were repeated at least three times and up to eight times.[26,27] For respiratory muscle strength, MIP and MEP were measured using a respiratory pressure meter (Pony Fx; Cosmed Srl). This was measured with participants in the same posture as that used for lung capacity measurements, and to accurately measure respiratory muscle strength, the measurement method was demonstrated to the participants. The mouthpiece of the measuring equipment was brought in close contact with the mouth to prevent air from leaking during the measurement, and the nose was blocked using a nose clip. PCF was measured using a peak flow meter (Peak Flow Meter; Clement Clarke International, Harlow, UK). The posture used during the measurement was the same as that used during the measurement of lung capacity. After inhaling deeply in a sitting posture, the mouthpiece of the equipment was brought into close contact with the mouth and blown as quickly as possible. Respiratory muscle strength and PCF were measured three times in total, and the highest value was used.[24,27]

The HGS was measured using a digital grip force meter (TKK 5401 GRIP D; Takei, Tokyo, Japan). In the measurement posture, both feet were spread shoulder-width apart in a straight line, both arms were extended completely, the index finger was flexed to 90°, and the handle was held. The HGS of the dominant hand was first measured, and when measuring, the grip was applied as hard as possible by maximizing the force on the hand for at least 3 seconds.[27] The grip strength of the dominant hand was measured, and after a 1-minute break, the grip strength of the opposite hand was measured in the same posture as above. This process was repeated thrice, and the average and maximum values were noted.[29,30]

Leg muscle strength was measured using the FTSST, sitting and standing up five times as fast as possible from a chair.[31,32] The measurement posture used was that of sitting on a chair without an armrest, with an arm crossed over the chest so that the hip and knee joints were at a 90° angle. In this test, the participant sits up five times as fast as possible and then sits down. The participants began the test at the instruction “start,” and the test ended after sitting five times. The researcher measured the time taken, and the minimum value obtained by measuring twice was noted.[31,32]

### Statistical analysis

The data in this study were analyzed using the R statistical package (www.R-project.org). The general characteristics of the participants, including age, height, weight, body mass index (BMI), respiratory muscle strength, HGS, and FTSST result, are described as mean and standard deviation. Pearson’s correlation analysis was used to determine the correlation between general characteristics, lung capacity, HGS, FTSST, MIP, MEP, and PCF for men and women, respectively. The significance level (α) was set at 0.05. Finally, multiple regression analysis was used to determine the effect of sex, age, BMI, maximum HGS, and FTSST results on MIP, MEP, and PCF and predictions of respiratory muscle strength. For the multiple regression analysis, the all-subsets regression method was employed, using the ols step for all possible functions in the olsrr package of the R Statistical Package. The method used in this study calculates all possible combinations using independent variables. In the multiple regression analysis, only values indicating a significant correlation with respiratory muscle strength were used. The *P* value was set at 0.05.

### Ethics statement

The study was approved by the Institutional Review Board (IRB) of the Pusan National University Hospital (IRB No. 2105-003-102) and registered with the World’s 11th Registration System, the Clinical Research Information Service, on the World Health Organization

International Clinical Trials Registry Platform (Clinical Research Information Service No. KCT0006778). Written informed consent was obtained from all subjects before participation.

## RESULTS

The general characteristics, lung capacity, and respiratory muscle strength of the participants are presented in **Tables 1** and **2** (**Supplementary Tables 1-3**). The results that confirm the correlation between general characteristics, HGS, FTSST results, and respiratory muscle

**Table 1.** General characteristics of subjects (N = 360)

| Variables | Age, yr | Height, cm | Weight, kg | BMI, kg/m$^2$ | S/H, n |
|---|---|---|---|---|---|
| Men | | | | | |
| 20s (n = 30) | 23.63 ± 2.17 | 173.19 ± 5.50 | 72.19 ± 9.09 | 24.02 ± 2.23 | 6 |
| 30s (n = 30) | 34.07 ± 2.95 | 174.12 ± 5.48 | 72.40 ± 8.90 | 23.86 ± 2.55 | 9 |
| 40s (n = 30) | 43.57 ± 2.53 | 172.87 ± 5.19 | 74.08 ± 9.78 | 24.77 ± 2.82 | 17 |
| 50s (n = 30) | 54.77 ± 3.13 | 169.71 ± 5.47 | 71.77 ± 8.09 | 24.97 ± 2.82 | 20 |
| 60s (n = 30) | 63.97 ± 3.00 | 171.19 ± 5.52 | 70.73 ± 10.73 | 24.14 ± 3.24 | 22 |
| 70s (n = 30) | 73.07 ± 2.80 | 165.28 ± 5.40 | 65.47 ± 8.39 | 23.97 ± 2.67 | 21 |
| Women | | | | | |
| 20s (n = 30) | 26.70 ± 1.93 | 160.92 ± 5.38 | 52.40 ± 5.50 | 20.23 ± 1.75 | 0 |
| 30s (n = 30) | 33.73 ± 2.75 | 163.25 ± 5.02 | 57.37 ± 7.69 | 21.49 ± 2.34 | 0 |
| 40s (n = 30) | 44.10 ± 3.04 | 159.60 ± 4.88 | 57.11 ± 8.00 | 22.33 ± 2.98 | 0 |
| 50s (n = 30) | 55.47 ± 2.76 | 159.79 ± 4.10 | 60.56 ± 8.27 | 23.74 ± 3.14 | 0 |
| 60s (n = 30) | 63.50 ± 3.01 | 158.66 ± 4.40 | 57.80 ± 7.25 | 23.03 ± 2.61 | 0 |
| 70s (n = 30) | 73.93 ± 2.55 | 153.27 ± 4.82 | 57.49 ± 10.20 | 24.49 ± 4.30 | 0 |

Values are presented as mean ± standard deviation.
BMI = body mass index, S/H = smoking history.

**Table 2.** Data on the subject's lung capacity and respiratory muscle strength (N = 360)

| Variables | FVC, L | $FEV_1$, L | $FEV_1$/FVC, % | FVC, % | $FEV_1$, % | MIP, $cmH_2O$ (95% CI) | MEP, $cmH_2O$ (95% CI) | PCF, L/min (95% CI) |
|---|---|---|---|---|---|---|---|---|
| Men | | | | | | | | |
| 20s (n = 30) | 4.59 ± 0.44 | 3.90 ± 0.42 | 84.40 ± 5.88 | 91.66 ± 7.96 | 98.19 ± 18.96 | 99.40 ± 25.47 (91.21–107.59) | 113.70 ± 32.61 (104.53–122.87) | 539.33 ± 74.65 (513.88–564.78) |
| 30s (n = 30) | 4.53 ± 0.50 | 3.78 ± 0.42 | 82.91 ± 4.70 | 93.98 ± 7.75 | 104.82 ± 10.03 | 93.23 ± 24.21 (85.04–101.42) | 121.47 ± 27.92 (112.30–130.64) | 571.00 ± 88.06 (545.55–596.45) |
| 40s (n = 30) | 4.23 ± 0.57 | 3.45 ± 0.45 | 81.43 ± 5.72 | 93.75 ± 9.20 | 104.78 ± 12.64 | 107.00 ± 26.24 (98.81–115.19) | 123.20 ± 26.86 (114.03–132.37) | 551.00 ± 85.72 (525.55–576.45) |
| 50s (n = 30) | 3.78 ± 0.50 | 3.03 ± 0.36 | 80.08 ± 5.40 | 92.99 ± 6.93 | 103.08 ± 8.70 | 95.10 ± 27.41 (86.91–103.29) | 118.67 ± 30.62 (109.50–127.84) | 502.67 ± 81.03 (477.22–528.12) |
| 60s (n = 30) | 3.70 ± 0.44 | 2.90 ± 0.36 | 78.05 ± 4.88 | 92.60 ± 9.74 | 102.63 ± 11.06 | 88.37 ± 28.44 (80.18–96.56) | 120.77 ± 32.35 (111.60–129.94) | 510.67 ± 86.78 (485.22–536.12) |
| 70s (n = 30) | 3.25 ± 0.51 | 2.56 ± 0.41 | 78.69 ± 5.21 | 95.94 ± 10.99 | 111.84 ± 15.40 | 83.87 ± 28.68 (75.68–92.06) | 102.97 ± 30.94 (93.80–112.14) | 469.00 ± 87.35 (443.55–494.45) |
| Women | | | | | | | | |
| 20s (n = 30) | 3.28 ± 0.37 | 2.86 ± 0.32 | 86.81 ± 5.75 | 92.17 ± 6.65 | 92.31 ± 7.65 | 69.67 ± 18.88 (61.48–77.86) | 81.70 ± 21.23 (72.53–90.87) | 387.00 ± 63.58 (361.55–412.45) |
| 30s (n = 30) | 3.30 ± 0.40 | 2.85 ± 0.33 | 85.97 ± 4.39 | 93.11 ± 8.22 | 92.70 ± 8.03 | 71.47 ± 18.46 (63.28–79.66) | 82.97 ± 18.52 (73.80–92.14) | 385.33 ± 56.37 (359.88–410.78) |
| 40s (n = 30) | 3.00 ± 0.38 | 2.52 ± 0.31 | 83.74 ± 4.29 | 97.50 ± 9.86 | 95.74 ± 9.54 | 73.70 ± 21.10 (65.51–81.89) | 76.50 ± 20.38 (67.33–85.67) | 375.00 ± 52.24 (349.55–400.45) |
| 50s (n = 30) | 2.83 ± 0.35 | 2.34 ± 0.29 | 82.63 ± 4.13 | 96.47 ± 10.37 | 95.92 ± 10.85 | 64.40 ± 15.08 (56.21–72.59) | 74.67 ± 21.14 (65.50–83.84) | 373.67 ± 57.02 (348.22–399.12) |
| 60s (n = 30) | 2.66 ± 0.40 | 2.15 ± 0.32 | 80.50 ± 5.48 | 100.86 ± 12.99 | 99.39 ± 11.75 | 57.17 ± 18.02 (48.98–65.36) | 69.27 ± 23.36 (60.10–78.44) | 334.33 ± 52.11 (308.88–359.78) |
| 70s (n = 30) | 2.12 ± 0.32 | 1.74 ± 0.29 | 81.62 ± 4.33 | 106.07 ± 14.73 | 107.93 ± 18.23 | 57.23 ± 16.93 (49.04–65.42) | 65.57 ± 13.05 (56.40–74.74) | 301.00 ± 48.73 (275.55–326.45) |

Values are presented as mean ± standard deviation.
FVC = forced vital capacity, $FEV_1$ = forced expiratory volume in 1 second, MIP = maximal inspiratory pressure, MEP = maximal expiratory pressure, PCF = peak cough flow, CI = confidence interval.

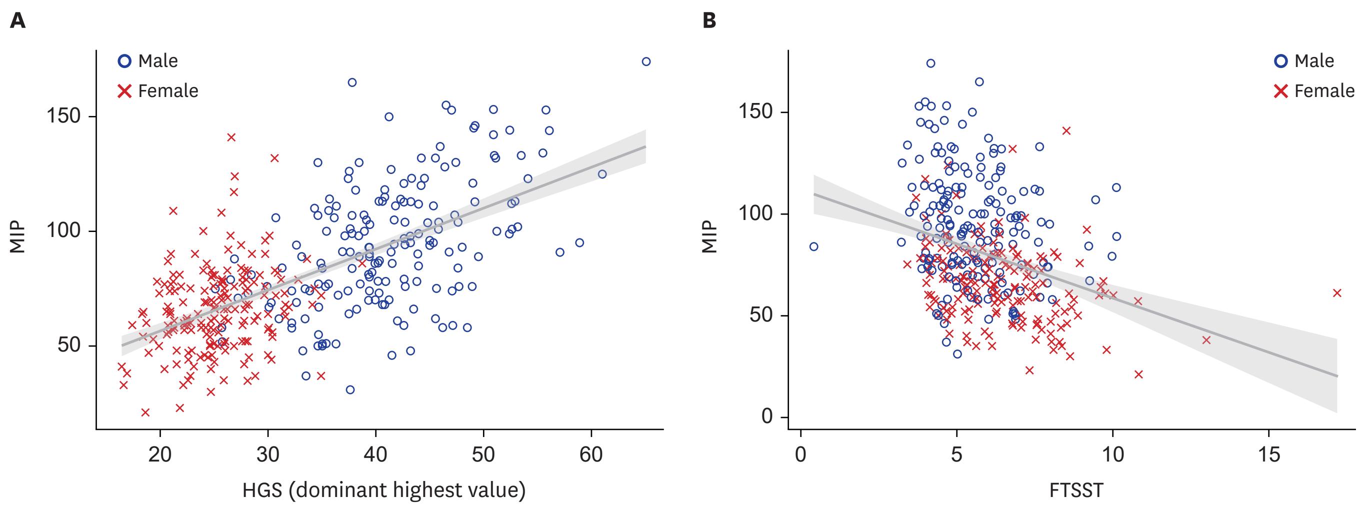


**Fig. 2.** Correlation between maximal inspiratory pressure and HGS (**A**) and FTSST result (**B**).
HGS = hand grip strength, FTSST = five times sit-to-stand test, MIP = maximal inspiratory pressure.

strength of men and women in healthy Korean adults, as measured in this study, are presented in **Fig. 2** (**Supplementary Tables 4-6**).

When the data for both men and women were combined, MIP had the highest correlation, with the highest value of dominant HGS ($r = 0.643$; $P < 0.05$). MEP had the highest correlation with the highest value of dominant HGS ($r = 0.693$; $P < 0.05$). PCF had the highest correlation with $FEV_1$ ($r = 0.753$; $P < 0.05$). When sex was classified and confirmed, MIP had the highest correlation with the highest value of dominant HGS in men ($r = 0.517$; $P < 0.05$). For MEP, the correlation was the highest with the highest value of dominant HGS ($r = 0.438$; $P < 0.05$). PCF had the highest correlation with $FEV_1$ ($r = 0.566$; $P < 0.05$). In women, MIP had the highest correlation with $FEV_1$ ($r = 0.327$; $P < 0.05$). MEP had the highest correlation with the highest value of dominant HGS ($r = 0.356$; $P < 0.05$). PCF had the highest correlation with $FEV_1$ ($r = 0.580$; $P < 0.05$).

In the regression equation, the predicted value of respiratory muscle strength was confirmed by substituting the value of the independent variable suitable for each criterion for the sex to be identified and 0 for the other sex (**Table 3**, **Supplementary Table 7**).

## DISCUSSION

In the case of physical muscle strength of the individuals participating in this study, it was confirmed that it was numerically similar to that noted in muscle strength studies on healthy

**Table 3.** Regression equation for respiratory muscle strength

| Variables | Sex | Equation |
| --- | --- | --- |
| MIP, $cmH_2O$ | Men | 7.88 + {1.28 × HGS + 1.82 × BMI − 0.21 × (Age − 0.32)} |
| | Women | 7.88 + (1.28 × HGS + 1.82 × BMI − 0.21 × Age) |
| MEP, $cmH_2O$ | Men | 69.49 + {−4.49 × (FTSST − 3.36) × (HGS + 1.08)} |
| | Women | 69.49 + {−4.49 × (FTSST + 1.75) × HGS} |
| PCF, L/min | Men | 391.71 + {−0.84 × (Age − 1.77) × (HGS + 2.24)} |
| | Women | 391.71 + {−0.84 × (Age + 4.18) × HGS} |

Example of MIP calculation for a 33-year-old man with HGS 35 and BMI 23; 7.88 + (1.28 × 35 + 1.82 × 23 − 0.21 × 33 − 0.32 × 0 = 87.65).
BMI = body mass index, FTSST = five times sit-to-stand test, HGS = handgrip strength.

people (**Supplementary Tables 1** and **2**).[28] When checking the results of respiratory muscle strength, the HGS and FTSST results, including respiratory muscle strength, had numerical differences by age group. These results indicate that muscle mass decreases with age; therefore, muscle strength naturally decreases,[33] and numerical differences in muscle strength test results were also observed for each age group. This is because respiratory muscle strength also differs, along with muscle mass, according to sex.[23,34,35] However, the pattern of increase and decrease in MIP, MEP, and PCF levels in men and women until their 40s is unclear, which is consistent with the findings reported in previous studies in other countries.[23,36] There may be various causes, but the most significant is the difference in individual physical activity.[14]

In this study, a significant correlation was found between respiratory muscle strength and general characteristics, and it was observed that there were higher correlations for height and weight than age (**Supplementary Table 4**). It is suggested that the low correlation between respiratory muscle strength and age is due to individual differences in physical activity levels. Even if someone is young, if they have low levels of physical activity, their cardiovascular function and muscle strength may be lower compared to older individuals who are more physically active.[14,37,38] Moreover, the higher correlations observed for height and weight can be attributed to the fact that respiratory function is determined by overall muscle strength and physique. Predicted pulmonary function is also calculated using height, weight, and age,[16] and in the correlation results of this study, it was confirmed that respiratory muscle strength has a higher correlation with physical muscle strength. When classified according to sex, the value of the correlation coefficient ($r$) between general characteristics and respiratory muscle strength was low (**Supplementary Tables 5** and **6**). The results of this study and previous studies from other countries have confirmed that it would be difficult to establish a high level of correlation between general characteristics and respiratory muscle strength.[39,40] In the case of respiratory muscle strength, in addition to the general characteristics measured in this and previous studies, confirming the correlation with other general characteristics, such as physical activity and lean muscle mass, is necessary.

Additionally, the HGS and FTSST results were recorded to confirm the correlation between overall body muscle strength and respiratory muscle strength. The mean and highest values of grip strength were determined, and their correlation with respiratory muscle strength was confirmed. Peterson et al.[41] used the mean value of grip strength, while Shin et al.[29] used the highest value to confirm the correlation with respiratory muscle strength. Therefore, in this study, both the mean and the highest values were used to confirm the values that had a stronger correlation with respiratory muscle strength. The results confirmed that the highest value had a stronger correlation with respiratory muscle strength. These results indicated that the highest value of HGS was recorded, and the highest values of MIP, MEP, and PCF had a stronger correlation because the highest value, and not the mean value, was used when measuring respiratory muscle strength. The FTSST outcomes were also confirmed to have a low level of correlation with respiratory muscle strength. Previous studies confirming the correlation between leg muscle strength and respiratory muscle strength used the 6-minute walking test distance, isokinetic muscle strength test, and 1-minute sit-to-stand test, regardless of sex.[12,42,43] In previous studies, a high level of correlation was confirmed by checking the 6-minute walking test distance, MIP, isokinetic muscle strength test, MIP, and MEP. The 1-minute sit-to-stand test was confirmed to have a moderate level of correlation with MIP and MEP. The difference in the results of this study and those of previous studies may be because the FTSST is one of the methods of testing leg strength and function, although it could not determine the highest leg strength at all ages, compared with other leg strength tests.

In the case of the correlation between lung capacity and respiratory muscle strength, only PCF was above the moderate level. In a study by Sriboonreung et al.,[39] the correlation between lung capacity and respiratory muscle strength was confirmed in 217 people: 91 men and 126 women in their 20s to 40s. The correlation coefficient (*r*) values between FVC and MIP were 0.493 and 0.390, and the $FEV_1$ and MIP values were 0.433 and 0.332, respectively. The results of previous studies and those of this study are similar. Only PCF has a strong correlation with lung capacity results, which may be because the two tests measure respiratory flow. In contrast, because respiratory muscle strength is tested as pressure rather than a flow, the correlation with the lung capacity test measuring flow rate was low.

This study proposed predictions of respiratory muscle strength in Korean men and women through a multiple regression analysis of the participants' general characteristics, overall body muscle strength, and respiratory muscle strength. The results of the multiple regression analysis confirmed that the modified $R^2$ values for MIP, MEP, and PCF were 0.447, 0.517, and 0.609, respectively, indicating a moderate level of correlation (**Supplementary Table 7**). In the case of MEP, unlike the other values, a prediction value containing the FTSST was confirmed. MEP had the highest correlation value with the FTSST, which was confirmed in this study. When the FTSST is excluded from the MEP prediction, the prediction can be confirmed by the age and grip strength of each sex; however, the revised $R^2$ value was 0.493, which is lower than the prediction including the FTSST. Therefore, it is considered appropriate to use predictions, including the FTSST. In a study by Gil Obando et al.,[19] the general characteristics and respiratory muscle strength of the participants were analyzed regardless of sex, and the modified $R^2$ value was confirmed to be 0.256 for MIP and 0.325 for MEP. When confirming the modified $R^2$ value results of this study and that from previous studies, individual physical activity, and lean muscle mass should be measured to confirm correlations above the moderate level. In the case of these predicted values, it is highly likely to be utilized because respiratory muscle strength can be predicted based on the subject's general information and physical muscle strength without the need for respiratory muscle strength measurement equipment.

The respiratory muscle strength of the participants in Korea, as measured in this study, may differ from the values reported in studies in other countries (**Supplementary Tables 8** and **9**). These differences may occur because of various factors, such as the physical and air condition in each country.[14,18,35] When comparing the respiratory muscle strength of individuals in Korea and Japan, which are both located in East Asia, it was confirmed that the average age, height, and weight of healthy adults in their 20s in Korea and Japan were numerically similar, although Japan's MIP was higher than that of Korea.[22] Even if the race is similar, differences in respiratory muscle strength exist according to each country's lifestyle habits. This study confirmed that the reference values of respiratory muscle strength in other countries and Korea were different. In addition, if respiratory muscle strength cannot be measured, it can be predicted using the prediction formula. Pulmonary rehabilitation including the training for respiratory muscle strength for Koreans should be conducted based on an appropriate target value using the Korean reference value and prediction formula.

Lastly, in future studies, it will be necessary to measure the respiratory muscle strength of subjects with sarcopenia to provide a cut-off value for respiratory muscle weakness that is appropriate for the Korean context.

This study has some limitations. First, the amount of physical activity of the participants could not be measured. Since physical activity is related to an individual's athletic ability, future studies should evaluate the amount of physical activity to confirm its correlation with respiratory muscle strength. Second, lean muscle mass was not measured. When confirming the results of this and previous studies, it is believed that respiratory muscle strength will be correlated with lean muscle mass, as well as height, weight, and BMI. Lastly, to confirm the high correlation between leg muscle strength and respiratory muscle strength, a leg muscle test that can produce maximum strength, rather than FTSST, should be conducted. FTSST is a test that can confirm leg muscle strength and function, but it is considered insufficient to measure the maximum strength that can be applied by young subjects.

## ACKNOWLEDGMENTS

This study summarizes the contents of Tae Sung Park doctoral dissertation in 2022.

## SUPPLEMENTARY MATERIALS

### Supplementary Table 1

Hand grip strength measurement results of men subjects (N = 180)

Click here to view

### Supplementary Table 2

Hand grip strength measurement results of women subjects (N = 180)

Click here to view

### Supplementary Table 3

Five times sit-to-stand test results of normal Koreans (N = 360)

Click here to view

### Supplementary Table 4

Pearson's correlation of respiratory muscle strength (N = 360)

Click here to view

### Supplementary Table 5

Pearson's correlation of men respiratory muscle strength (N = 180)

Click here to view

### Supplementary Table 6

Pearson's correlation of women respiratory muscle strength (N = 180)

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**Supplementary Table 7**

Multiple regression analysis of respiratory muscle strength (N = 360)

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**Supplementary Table 8**

Data of healthy adult men's respiratory muscle strength from previous studies in other countries (unit: $cmH_2O$)

Click here to view

**Supplementary Table 9**

Data of healthy adult women's respiratory muscle strength from previous studies in other countries (unit: $cmH_2O$)

Click here to view

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