Original Article

Correlation between handgrip strength and air trapping in patients with stable chronic obstructive pulmonary disease

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Background: Chronic obstructive pulmonary disease (COPD) often presents with dyspnea resulting from the condition of air trapping, assessed by lung volume measurement studies. This study aimed to investigate the relationship between handgrip strength (HGS) and air trapping in COPD patients.

Methods: Cross-sectional research was conducted in COPD patients at Thammasat University Hospital, Thailand between May 2022 and December 2023. HGS was assessed using the Jamar® Smart Hand Dynamometer, and air trapping was measured using a body plethysmograph. Air trapping was defined as a ratio of residual volume (RV) to total lung capacity (TLC) greater than 40%. Receiver operator characteristic (ROC) curves, sensitivity, and specificity values were calculated to determine the optimal cutoff value of HGS for predicting air trapping.

Results: A total of 72 patients (90.3% male) were included, with an average age of 72.4±9.7 years. The body mass index was 23.5±4.3 kg/m^2. The smoking history was 23.2±14.8 pack-years. Common comorbidities included hypertension (36.1%) and diabetes (22.2%). Post-bronchodilator forced expiratory volume in 1 second (FEV1) was 72.1%±21.2%. Air trapping was found in 55.6%. A negative correlation was found between HGS and RV/TLC (R=−0.399, P=0.001). The best cutoff value for HGS to predict air trapping was 28.3 kg, with 71.9% sensitivity and 65.0% specificity. The area under the ROC curve for identifying air trapping was 0.681 (95% CI: 0.554 to 0.808, P=0.009).

Conclusions: Air trapping is common in COPD patients, and HGS is significantly correlated with air trapping. Thus, HGS may serve as an alternative tool for assessing air trapping.

Keywords: Chronic obstructive pulmonary disease (COPD); handgrip strength (HGS); air trapping; sensitivity; specificity

Submitted Apr 16, 2024. Accepted for publication Jul 19, 2024. Published online Aug 30, 2024.
doi: 10.21037/jtd-24-631
View this article at: https://dx.doi.org/10.21037/jtd-24-631

Introduction

Chronic obstructive pulmonary disease (COPD) is a common disease with the third-highest mortality rate globally (1). In Thailand, the prevalence of COPD is 7.1% (2), making it a significant health concern. It is progressive and irreversible, with a key feature being the inability to fully exhale, leading to trapped air in the lungs (3). This results from decreased elasticity of the lung tissues and obstruction

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of the airways during exhalation. Additionally, COPD patients often experience difficulty breathing, contributing to the development of air trapping in the lungs (4).

Studies of the effects of air trapping in the lungs on clinical outcomes in patients with COPD have found various impacts, including fatigue (5), respiratory muscle function (6), limb muscle function (7), and risk of exacerbations (8).

It is well-established that individuals with COPD commonly experience issues related to the depletion of muscular mass (9). Notably, there is a significant relationship between handgrip strength (HGS) and reduction in mortality rates among COPD patients (10). Consequently, it is reasonable to infer that the assessment of HGS is a valuable tool in monitoring COPD patients.

Air trapping can be assessed through techniques such as closed-circuit helium dilution and body plethysmography (3). Specifically, an abnormal value of the ratio of residual volume (RV) to total lung capacity (TLC) greater than 40% is indicative of air trapping (11). The implementation of these diagnostic methods necessitates specialized equipment and proficient individuals for accurate interpretation. Some alternative tools might be beneficial for assessing air trapping. The correlation between HGS and air trapping has not been investigated. Therefore, this study aimed to investigate the relationship between HGS and air trapping in stable COPD patients. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-631/rc).

Highlight box

Key findings

- Handgrip strength (HGS) shows a significant negative correlation with air trapping in stable chronic obstructive pulmonary disease (COPD). Additionally, HGS correlates with other lung functions, including forced vital capacity, forced expiratory volume in 1 second, and diffusing capacity of the lung for carbon monoxide.

What is known and what is new?

- COPD patients often experience difficulty breathing, which contributes to the development of air trapping in the lungs. The effects of air trapping in the lungs are associated with clinical outcomes in COPD patients, including fatigue, respiratory muscle function, limb muscle function, and risk of exacerbations. The correlation between HGS and air trapping has not been investigated.
- This study demonstrated that air trapping is common in COPD patients, and HGS is significantly correlated with air trapping.

What is the implication, and what should change now?

- HGS may serve as an alternative tool for assessing air trapping in patients with clinically stable COPD.

Methods

Study design and participants

A cross-sectional study was conducted at Thammasat University Hospital in Thailand from May 2022 to December 2023. COPD patients aged over 40 years, diagnosed by spirometry [postbronchodilator forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <0.7], and with a smoking history of 10 or more pack-years were included. Exclusion criteria included COPD exacerbation in the past 3 months, inability to perform HGS assessment, inability to measure lung volume, undergoing tracheostomy tube placement, and using mechanical ventilation.

Demographic data, respiratory symptoms, and functional capacity assessed by modified Medical Research Council (mMRC) (12), COPD Assessment Test (CAT) (13), 6-minute walking distance (6MWD), and spirometry data were collected.

The Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria for COPD severity were based on FEV_1 value: grade 1 indicates mild (≥80% of predicted value), grade 2 indicates moderate (50–79% of predicted value), and grades 3 and 4 indicate severe and very severe (<50% and <30% of predicted values), respectively (3). GOLD symptoms and risk were classified into 3 groups: A, B, and E, depending on dyspnea score and history of exacerbation (3).

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Human Research Ethics Committee of Thammasat University (Medicine) (IRB No. MTU-EC-IM-0-209/65, COA No. 083/2023). All participants provided written informed consent. This study was registered with ClinicalTrials.gov with number NCT06220851.

Procedures

The measurements of lung volume and diffusing capacity of the lung for carbon monoxide (DLCO) were conducted using a body plethysmograph (Vyntus™ BODY by CareFusion Germany 234 GmbH, Germany). These assessments adhered to the standardized protocols

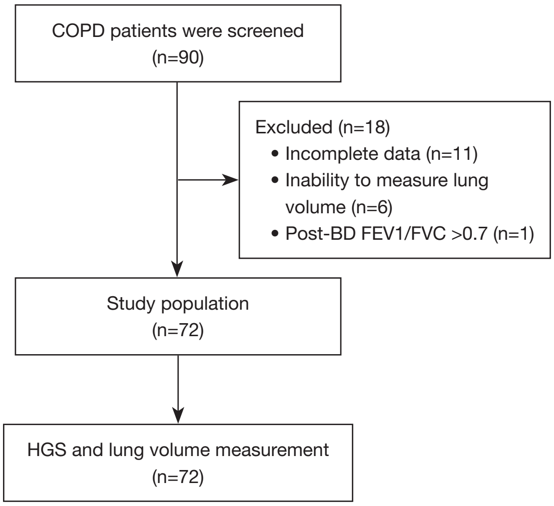

Figure 1 Flowchart of COPD patient recruitment to the study. BD, bronchodilator; COPD, chronic obstructive pulmonary disease; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; HGS, hand grip strength.

established by both the American Thoracic Society and the European Respiratory Society (14-16). Air trapping was defined as RV/TLC >40% (17).

HGS was measured by a Jamar® hand dynamometer (Asimow Engineering Co., CA, USA) and was reported in kilograms. Patients performed the test at rest in sitting position with the dominant hand unsupported, with the wrist in a neutral position, with the elbow at a 90° flexion, and the shoulder adducted. All patients were instructed to squeeze the hand dynamometer as hard as possible for 3–5 seconds. The test was performed with three attempts, with one-minute breaks between attempts. The maximal value of three efforts was recorded for the final analysis.

Outcomes

The primary outcome was the correlation between HGS and air trapping in clinically stable COPD patients. The secondary outcome was the best cutoff value of HGS to predict occurrence of air trapping.

Statistical analysis

Due to the lack of prior studies investigating the relationship between HGS and air trapping in patients with COPD, we hypothesized that there is a moderate-level correlation between HGS and air trapping, with a correlation coefficient of 0.4. The sample size was calculated for a two-sample means test using 90% power and 5% type I error. Thus, the calculated sample size would be 72.

Baseline characteristics were shown in number (%) and mean ± standard deviation (SD). Pearson correlation was used to determine the correlation between HGS and spirometry or lung volume data. The relationship between two variables was reported as correlation coefficient (r). To determine the set of variables associated with air trapping, we used the linear regression model with RV/TLC set as the dependent variable. All independent variables—age, body mass index, CAT scores, and DLCO level—were entered into the regression model. Regression coefficients (95% confidence interval) were reported.

The receiver operator characteristic (ROC) curve was used to determine the best HGS cutoff value to predict air trapping. A two-sided P value <0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 26.0 software (IBM Corp., Armonk, NY, USA).

Results

Participants

A total of 90 patients were screened, and 18 were excluded (*Figure 1*). Seventy-two patients (90.3% male) were included, with an average age of 72.4±9.7 years. The body mass index was 23.5±4.3 kg/m^2, and the smoking history was 23.2±14.8 pack-years. Common comorbidities included hypertension (36.1%) and diabetes (22.2%). Most patients were classified as COPD grade 2 and group E. The mean postbronchodilator FEV_1 was 72.1%±21.2%, and RV/TLC was 44.2%±10.3%. The prevalence of air trapping was 55.6%. Mean HGS was 30.5±8.1 kg (*Table 1*). Air trapping in COPD group A, B, and E was 1.4%, 27.8%, and 26.4%, respectively (P=0.39).

Association between HGS and air trapping

There was a negative correlation between HGS and RV/TLC (r=−0.399, P=0.001) (*Table 2* and *Figure 2*). The equation for predicting air trapping is as follows: predicted RV/TLC (%) =59.63 − 0.51 × HGS. Additionally, HGS had a negative correlation with RV (r=−0.272, P=0.02). Moreover, positive correlation was observed between HGS and DLCO (r=0.393, P=0.001), FVC (r=0.320, P=0.007), and FEV_1 (r=0.260, P=0.02) (*Table 2*). HGS was also positively correlated with 6WMD (r=0.378, P=0.03).

Table 1 Baseline characteristics of patients with chronic obstructive pulmonary disease

Characteristics	Data (n=72)
Age, years	72.4±9.7
Male	65 (90.3)
BMI, kg/m^2	23.5±4.3
Smoking, pack-years	23.2±14.8
Dominant right hand	64 (88.9)
Comorbidity	
Hypertension	26 (36.1)
Diabetes	16 (22.2)
Clinical history	
COPD grade	
1	24 (33.3)
2	34 (47.2)
3	13 (18.1)
4	1 (1.4)
COPD group	
A	4 (5.6)
B	33 (45.8)
E	35 (48.6)
AECOPD in the past year	22 (30.6)
AECOPD with hospitalization in the past year	10 (13.9)
Oxygen saturation level, %	96.6±1.6
Medication	
SABA/SAMA	36 (50.0)
ICS/LABA/LAMA	27 (37.5)
PDE4i	25 (34.7)
LABA/LAMA	21 (29.2)
ICS/LABA	18 (25.0)
LAMA	15 (20.8)
SABA	9 (12.5)
Macrolide	4 (5.6)
Spirometry data	
Post-BD FVC, L	2.78±0.82
Post-BD FVC, % predicted	94.2±20.9
FVC change after BD test, %	4.0±7.1
Post-BD FEV_1, L	1.62±0.59
Post-BD FEV_1, %predicted	72.1±21.2
FEV_1 change after BD test, %	7.6±7.6
Post-BD FEV_1/FVC, %	58.7±13.2
Lung volume and DLCO data	
TLC, L	5.19±1.05
TLC, % predicted	90.4±14.6
RV, L	2.44±0.66
RV, % predicted	100.6±25.5
RV/TLC, %	44.2±10.3
DLCO, mL/mmHg/min	13.12±4.44
DLCO, %	63.7±22.8
KCO, mL/mmHg/min/L	3.43±2.36
KCO, %	86.6±26.6
Air trapping in all groups	40 (55.6)
Air trapping in COPD group A*	1 (1.4)
Air trapping in COPD group B*	20 (27.8)
Air trapping in COPD group E*	19 (26.4)
Functional performance	
mMRC, points	2.1±0.8
CAT scores	14.9±6.9
6MWD, m	358.0±121.9
Hand grip strength, kg	30.5±8.1

Data shown as mean ± SD or n (%). *, P=0.391 for the comparison between the 3 groups. AECOPD, acute exacerbation of chronic obstructive pulmonary disease; BD, bronchodilator; BMI, body mass index; CAT, COPD Assessment Test; COPD, chronic obstructive pulmonary disease; DLCO, diffusing capacity of the lung for carbon monoxide; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; ICS, inhaled corticosteroid; KCO, carbon monoxide transfer coefficient; LABA, long-acting beta2 agonist; LAMA, long-acting muscarinic receptor; mMRC, modified Medical Research Council; 6MWD, 6-minute walking distance; PDE4i, phosphodiesterase-4 inhibitor; RV, residual volume; SABA, short-acting beta2 agonist; SAMA, short-acting muscarinic receptor; TLC, total lung capacity.

HGS cutoff value for predicting air trapping

The optimal cutoff value for HGS to predict air trapping was 28.3 kg, with a sensitivity of 71.9% and specificity of 65.0%. The area under the ROC curve for identifying air trapping was 0.681 (95% CI: 0.554 to 0.808, P=0.009) (*Table 3* and *Figure 3*).

The linear regression analysis revealed that HGS was the only variable associated with air trapping in the model (regression coefficients of −0.334, P=0.04) (*Table 4*).

Table 2 Correlation between hand grip strength, pulmonary function data and 6-minute walking distance

Variable	Correlation coefficient	P value
Spirometry data		
Post-BD FVC, L	0.320	0.007
Post-BD FVC, % predicted	0.070	0.55
Post-BD FEV_1, L	0.260	0.02
Post-BD FEV_1, % predicted	0.032	0.78
Post-BD FEV_1/FVC, %	–0.026	0.82
FEV_1/FVC, % predicted	0.121	0.31
FVC change after BD, %	0.192	0.10
FEV_1 change after BD, %	–0.050	0.67
Lung volume and DLCO data		
TLC, L	0.115	0.33
TLC, % predicted	–0.055	0.64
RV, L	–0.272	0.02
RV, % predicted	–0.155	0.19
RV/TLC, %	–0.399	0.001
DLCO, mL/mmHg/min	0.393	0.001
DLCO, % predicted	0.218	0.06
KCO, mL/mmHg/min/L	0.169	0.15
KCO, %	0.126	0.29
6-minute walking distance, m	0.378	0.03

BD, bronchodilator; DLCO, diffusing capacity of the lung for carbon monoxide; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; KCO, carbon monoxide transfer coefficient; RV, residual volume; TLC, total lung capacity.

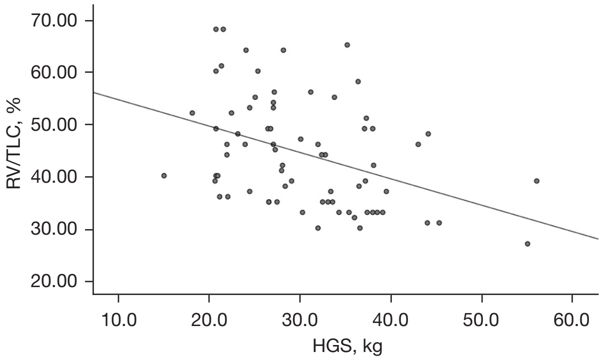

Figure 2 The correlation between RV/TLC and HGS. The equation for predicting air trapping, predicted RV/TLC (%) =59.63 − 0.51 × HGS. HGS, hand grip strength; RV, residual volume; TLC, total lung capacity.

Table 3 Cutoff values of hand grip strength for predicting air trapping

Parameters	Values
Cutoff value of HGS (kg)	28.3
AUC	0.681
95% CI	0.554–0.808
Sensitivity (%)	71.9
Specificity (%)	65.0
PPV (%)	72.0
NPV (%)	64.9
P value	0.009

AUC, area under the curve; CI, confidence interval; HGS, hand grip strength; NPV, negative predictive value; PPV, positive predictive value.

Discussion

To our knowledge, this is the first study to explore the correlation between HGS and air trapping, as well as to identify an HGS cutoff value for predicting air trapping in patients with clinically stable COPD. Based on the results of our study, a significant negative correlation between HGS and air trapping suggests that HGS may be a valuable test in the assessment of air trapping in COPD patients.

The prevalence of air trapping in our study (55.6%) aligns with previous findings reported by Kim *et al.* (51.1%) (8) and Lim *et al.* (60.9%) (18). HGS is correlated with various factors in COPD patients, including age, health-related quality of life, CAT score, pulmonary functions, hospitalization rate, and mortality rate (19-22). A decline in HGS consequently reflects aspects such as CAT scores and hospitalization rates, which is consistent with findings from a systematic literature review by Martinez *et al.* (10). This review revealed that COPD patients with increased HGS were associated with decreased hospitalization rates and lower CAT scores. Furthermore, a meta-analysis conducted by Mgbemena *et al.* demonstrated a significant correlation between HGS and FEV_1 as well as between HGS and FVC (21). Similarly, a study by Jeong *et al.* found significant associations between HGS and FEV_1 (r=0.69) and FVC (r=0.76) (19), consistent with our results. Additionally, Suriyakul *et al.* demonstrated in their study that HGS correlated with peak inspiratory flow rate, which measures the inspiratory effort needed for drug inhalation (23).

HGS serves as a primary diagnostic tool for sarcopenia and is useful in assessing various chronic conditions (24). For instance, a study by Strandkvist *et al.* demonstrated that COPD patients with GOLD grade 3–4 exhibited lower HGS compared to those without COPD, and HGS was associated with FEV_1 % (25). Similarly, lower HGS was also correlated with reduced FVC and FEV_1 in research conducted by Shah *et al.* (26). Moreover, Martinez *et al.* illustrated that HGS was associated with body composition, airway thickness, body mass index, emphysema, and exacerbation rate (10). Beyond chronic conditions, HGS can also be used to assess critically ill patients (27,28). For instance, a study conducted in Thailand by Saiphoklang *et al.* revealed that HGS correlated with the rapid shallow breathing index (RSBI), a weaning parameter, in mechanically ventilated patients (29).

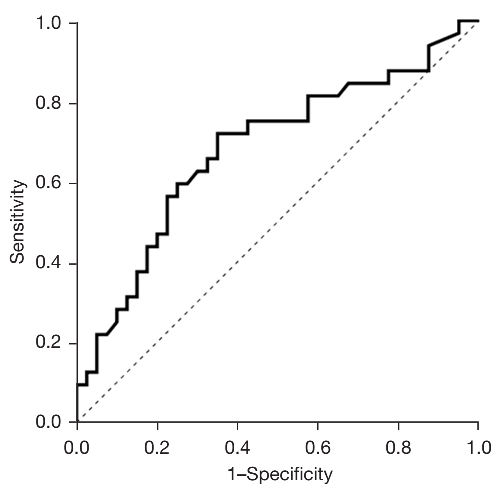

Figure 3 The ROC plot of HGS and predicting air trapping. The best cutoff value of HGS for predicting air trapping is 28.3 kg, with 71.9% sensitivity and 65.0% specificity. The area under the ROC curve for identifying air trapping was 0.681 (95% CI: 0.554 to 0.808, P=0.009). HGS, hand grip strength; ROC, receiver operating characteristic; CI, confidence interval.

Our study revealed a significant negative correlation between HGS and the RV/TLC ratio, supporting the hypothesis that COPD patients may undergo muscle mass loss. This phenomenon could stem from various factors, including chronic oxygen deficiency, acidosis, insulin resistance, and the administration of corticosteroids in treatment (9). Moreover, increased muscle utilization within the respiratory system may trigger changes in the autonomic nervous system, responsible for regulating blood volume. This alteration can lead to heightened blood flow to respiratory muscles and diminished blood flow to extremity muscles, potentially explaining the observed skeletal muscle weakness in COPD patients (7). Furthermore, we observed a negative correlation between HGS and RV, although its association was weaker compared to the RV/TLC ratio. This finding aligns with research by de Weger *et al.*, who reported that the RV/TLC ratio exhibited a stronger correlation with patient-related outcomes than other parameters in COPD patients (30). However, the mean RV and RV/TLC% in our group are borderline high but not severe. This could be one of the reasons for the lower sensitivity and specificity of the HGS in our study.

In addition, our results indicated a significantly positive correlation between HGS and DLCO levels. In COPD patients, abnormalities in the airways, lung parenchyma, and pulmonary vasculature often lead to decreased DLCO (31). A meta-analysis conducted by Ni *et al.* revealed that reductions in DLCO were more common in emphysema-dominant COPD compared to those with

Table 4 Multiple regression analysis for air trapping and handgrip strength adjusted by age, body mass index, CAT scores, and DLCO level

Variables	Regression coefficients	95% CI of coefficients	P value
Intercept	46.579	16.634 to 76.523	0.003
Handgrip strength, kg	−0.334	−0.657 to −0.010	0.04
Age, years	0.124	−0.138 to 0.387	0.34
Body mass index, kg/m^2	0.136	−0.451 to 0.723	0.64
CAT scores, points	0.100	−0.317 to 0.517	0.31
DLCO, mL/mmHg/min	−0.447	−1.153 to 0.259	0.21

CAT, COPD Assessment Test; COPD, chronic obstructive pulmonary disease; DLCO, diffusing capacity of the lung for carbon monoxide; CI, confidence interval.

non-emphysema COPD (32). The identification of the relationship between HGS and DLCO suggests that HGS may reflect the overall lung gas exchange capabilities.

Our study unveiled that the optimal HGS cutoff values for predicting air trapping demonstrated an acceptably high area under the ROC curve (0.681) with sensitivity and specificity. Additionally, HGS was the only parameter associated with air trapping, as demonstrated by linear regression analysis in our study.

This study has certain limitations. The main limitation is its generalizability. The mean age was 72 years, and the subjects were predominantly male (90%). The results of this study may not be generalized to female COPD. The higher age in the study group could have an exaggerated effect on the findings since sarcopenia itself is more common in this group. There are other limitations in the study. Firstly, it was conducted in a single research center in Thailand, which may limit the generalizability of the results to other ethnicities or countries. Secondly, the study employed a small sample size, potentially limiting the representativeness of the findings for the broader population. Thirdly, the participants consisted of clinically stable COPD patients without acute exacerbation, raising questions about the applicability of the HGS cutoff value to more unstable COPD patients. Fourthly, this was a cross-sectional study; the observed HGS and lung function may vary over time depending on the patient's condition. Finally, the study did not collect data on participants' medication compliance. Since medication compliance is known to play a crucial role in symptom control, it could act as a confounding factor in the study.

Conclusions

Air trapping in stable COPD is a common condition. HGS shows a significant negative correlation with air trapping in stable COPD. Additionally, HGS correlates with other lung functions such as FVC, FEV_1, and DLCO. Hence, HGS may function as an assessment tool for air trapping in stable COPD patients.

Acknowledgments

The authors thank Michael Jan Everts, Faculty of Medicine, Thammasat University, for proofreading this manuscript.
Funding: This work was supported by Thammasat University Research Unit in Allergy and Respiratory Medicine, Thailand (No. 67.04.2/0904), and Faculty of Medicine, Thammasat University, Thailand.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-631/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-631/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-631/prf

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-631/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Human Research Ethics Committee of Thammasat University (Medicine) (IRB No. MTU-EC-IM-0-209/65, COA No. 083/2023). All participants provided written informed consent.

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Cite this article as: Saiphoklang N, Tirakitpanich K. Correlation between handgrip strength and air trapping in patients with stable chronic obstructive pulmonary disease. J Thorac Dis 2024;16(9):5634-5642. doi: 10.21037/jtd-24-631