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**Research Article**

# MAXIMAL VOLUNTARY VENTILATION VERSUS VITAL CAPACITY AS PREDICTORS OF EXERCISE CAPACITY IN HEALTHY YOUNG ADULT MALES: A CROSS-SECTIONAL STUDY

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## Abstract

**Background:** Exercise capacity reflects integrated cardiopulmonary function and is influenced by multiple physiological determinants, including pulmonary ventilatory reserve. While forced vital capacity (FVC) is routinely assessed in spirometry, maximal voluntary ventilation (MVV) provides a functional measure of respiratory muscle endurance and ventilatory capacity. However, the comparative predictive roles of MVV and FVC for exercise performance in healthy young adults remain inadequately explored. This study aimed to evaluate and compare MVV and FVC as predictors of exercise capacity among healthy young adult males.

**Methods:** A cross-sectional observational study was conducted in the Department of Physiology, North Bengal Medical College and Hospital, Darjeeling. Fifty healthy male medical students aged 18–22 years participated after providing written informed consent. Pulmonary function parameters including FVC and MVV were measured using computerized spirometry. Exercise capacity was assessed using a motorized treadmill following the Bruce protocol, with treadmill exercise duration until achievement of target heart rate taken as the primary outcome. Data were analyzed using SPSS version 16. Descriptive statistics were applied, and associations between pulmonary parameters and exercise capacity were evaluated using Pearson's correlation coefficient and one-way analysis of variance. A p-value $< 0.05$ was considered statistically significant.

**Results:** The mean FVC and MVV values were 3.15 ± 0.12 L and 110.34 ± 5.90 L/min, respectively, while the mean treadmill exercise duration was 9.03 ± 0.62 minutes. Both FVC ($r = 0.565$, $p < 0.001$) and MVV ($r = 0.664$, $p < 0.001$) showed significant positive correlations with exercise duration, with MVV demonstrating a stronger association. Analysis of variance revealed significant differences in both FVC ($p = 0.035$) and MVV ($p = 0.002$) across exercise duration groups, with MVV showing greater discriminatory ability. Neither parameter exhibited significant association with target heart rate.

**Conclusion:** Both MVV and FVC are associated with exercise capacity in healthy young adult males; however, MVV emerges as a superior physiological predictor compared to FVC. Incorporating MVV into routine pulmonary assessment may provide a more comprehensive evaluation of ventilatory fitness and functional exercise performance.

**Keywords:** Maximal voluntary ventilation, Forced vital capacity, Exercise capacity, Spirometry, Treadmill test, Young adults

## INTRODUCTION

Pulmonary function plays a central role in determining an individual's capacity for physical exertion, as the respiratory system must meet the increasing ventilatory demands that accompany exercise. Spirometry, including measurements of forced vital capacity (FVC) and maximal voluntary ventilation (MVV), provides objective assessment of lung volumes and ventilatory capacity, which are integral to evaluating respiratory efficiency and functional reserve in both clinical and healthy populations. FVC represents the maximal amount of air that can be forcefully exhaled after full inhalation and is widely utilized as a basic indicator of lung capacity in pulmonary function testing.[1]

Maximal voluntary ventilation is defined as the greatest volume of air that can be inhaled and exhaled over a short period and extrapolated to one minute, offering insights into maximal ventilatory capacity. MVV reflects not only lung mechanics but also respiratory muscle strength, endurance, and neural drive, thereby serving as a composite measure of ventilatory reserve.[2,3] During exercise, the respiratory system must respond dynamically to increased metabolic demand, and limitations in ventilatory capacity may influence exercise tolerance even in apparently healthy individuals.[4]

Traditionally, static spirometric parameters such as FVC have been correlated with cardiorespiratory fitness and endurance performance in both athletic and general populations. Recent studies have demonstrated that FVC exhibits moderate predictive value for maximal oxygen uptake ($\dot{V}O_2max$); however, static lung volumes alone may not fully capture the complex physiological determinants of aerobic performance, including cardiac output, respiratory muscle endurance, and peripheral oxygen utilization.[5] Pulmonary function indices nevertheless remain valuable in resource-limited or field settings where direct cardiopulmonary exercise testing is not routinely feasible.

Emerging evidence highlights the added utility of MVV as a functional index that may better reflect respiratory muscle endurance and ventilatory reserve, particularly in relation to exercise performance. In clinical cohorts, MVV has demonstrated stronger associations with functional capacity compared to conventional forced expiratory parameters alone.[6] Furthermore, MVV has been shown to improve following respiratory muscle training and aerobic conditioning, indicating its sensitivity to physiological adaptation and its potential relevance in exercise prescription and rehabilitation.[7]

Although the relationship between pulmonary function and exercise performance has been explored extensively in patients with cardiopulmonary disease and in trained athletes, comparatively fewer studies have examined these associations in healthy young adults. Establishing normative relationships in this population is important, as young adulthood represents a period of peak physiological capacity and provides a reference framework for identifying early functional decline. Recent population-based studies emphasize the clinical relevance of spirometry even among asymptomatic individuals, underscoring its role in preventive health assessment.[8,9]

Moreover, most available literature has focused on forced expiratory indices, while comparatively limited attention has been given to MVV as a predictor of exercise capacity in healthy individuals. Normative pulmonary function data in young adults suggest substantial interindividual variability, reinforcing the need for population-specific evaluation of ventilatory predictors of exercise performance.[10]

The present cross-sectional study therefore aims to evaluate and compare the predictive roles of MVV and FVC for exercise capacity in healthy young adult males, using treadmill exercise duration as a functional outcome measure. By clarifying whether ventilatory endurance (MVV) provides superior predictive information compared to static lung volumes (FVC), this study seeks to contribute to a more nuanced understanding of respiratory determinants of exercise performance. Such insights may have implications for clinical screening, fitness evaluation, and the development of targeted interventions to enhance cardiopulmonary capacity.

## METHODOLOGY

This observational cross-sectional study was conducted to evaluate and compare the predictive roles of maximal voluntary ventilation and forced vital capacity on exercise capacity among healthy young adult males. The study was carried out in the Department of Physiology, North Bengal Medical College and Hospital, Sushrutnagar, Darjeeling, over a period of one year following approval from the Institutional Ethics Committee. The study population consisted of first-year MBBS male students from two consecutive academic batches who voluntarily consented to participate. Participation in the study was entirely voluntary, and written informed consent was obtained from all participants after explaining the purpose and procedures involved.

All healthy male students aged between 18 and 22 years who were willing to participate were included in the study. Students who did not provide written consent, those with obesity, smoking history, alcohol or substance abuse, or any known cardiovascular, respiratory, metabolic, or neurological disorders were excluded. Additional exclusion criteria included history of bronchial asthma, exercise-induced bronchospasm, recent surgery or fracture, and current use of medications affecting cardiovascular or respiratory function such as beta-blockers or calcium channel blockers. As the study aimed to assess physiological associations within a single healthy cohort, a separate control group was not required. A total of 50 participants who met the inclusion criteria were enrolled.

Anthropometric measurements including height and weight were recorded using a standard stadiometer and electronic weighing scale, and body mass index was calculated. Pulmonary function testing was performed using a computerized spirometer (RMS Helios 401, Recorders & Medicare Systems Pvt. Ltd., Chandigarh, India) in accordance with American Thoracic Society guidelines. Forced vital capacity (FVC) was obtained by instructing participants to perform a maximal forced expiratory maneuver following full inspiration, and the best of three acceptable attempts was recorded. Maximal voluntary ventilation (MVV) was assessed by asking participants to breathe as deeply and rapidly as possible for 12–15 seconds, with values extrapolated to one minute.

Exercise capacity was evaluated using a motorized treadmill (Whispermill 594XL, Schiller Healthcare India Pvt. Ltd.) operated with SPANDAN software (version 4.0), following the standard Bruce protocol. Continuous electrocardiographic monitoring and periodic blood pressure measurements were performed throughout the test. Target heart rate (THR), calculated as 85% of age-predicted maximal heart rate, was considered the functional endpoint of exercise testing. Treadmill exercise duration until achievement of THR (TMT) was recorded and used as the primary indicator of exercise capacity. Testing was terminated upon reaching THR or earlier if participants developed symptoms or signs warranting discontinuation.

After obtaining ethical clearance (IEC number: NBMC/IEC 2016-17/15) from the Institutional Ethics Committee of North Bengal Medical College and Hospital, all measurements were conducted under medical supervision in a controlled laboratory environment. Participant confidentiality was maintained throughout the study.

Collected data were entered into Microsoft Excel and analyzed using SPSS version 16 statistical software. Continuous variables were expressed as mean ± standard deviation. Pearson's correlation coefficient was used to assess relationships between pulmonary parameters and exercise capacity. One-way analysis of variance (ANOVA) was applied to compare pulmonary function variables across treadmill exercise duration groups. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

A total of 50 healthy young adult male participants aged between 18 and 22 years were included in the final analysis after fulfilling the inclusion criteria. Descriptive statistics were used to summarize baseline characteristics, while inferential statistics were applied to evaluate the association between pulmonary function parameters and exercise capacity

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**Table 1. Baseline characteristics and pulmonary function parameters of study participants (n = 50)**

| Parameter | N | Mean | Standard Deviation |
|---|---|---|---|
| **Age (years)** | 50 | 19.92 | 1.259 |
| **Height (cm)** | 50 | 166.92 | 2.906 |
| **Weight (kg)** | 50 | 64.36 | 2.431 |
| **FVC (L)** | 50 | 3.15 | 0.117 |
| **MVV (L/min)** | 50 | 110.34 | 5.904 |
| **TMT (min)** | 50 | 9.03 | 0.621 |

| | | | |
|---|---|---|---|
| **MHR (beats/min)** | 50 | 200.08 | 1.259 |
| **THR (beats/min)** | 50 | 170.07 | 1.070 |

Table 1 presents the baseline demographic, anthropometric, pulmonary, and exercise-related characteristics of the study population. The mean age of participants was 19.92 ± 1.26 years. The mean height and weight were 166.92 ± 2.91 cm and 64.36 ± 2.43 kg, respectively.

Regarding pulmonary function, the mean Forced Vital Capacity (FVC) was 3.15 ± 0.12 L, while the mean Maximal Voluntary Ventilation (MVV) was 110.34 ± 5.90 L/min. The mean treadmill exercise duration until achievement of target heart rate (TMT) was 9.03 ± 0.62 minutes. The mean maximal heart rate (MHR) recorded was 200.08 ± 1.26 beats per minute, and the mean target heart rate (THR) was 170.07 ± 1.07 beats per minute.

These findings indicate a relatively homogeneous cohort with comparable anthropometric profiles and pulmonary function parameters.

**Table 2. Pearson correlation of pulmonary function parameters with exercise capacity indices (n = 50)**

| Parameter | TMT (r) | p-value | MHR (r) | p-value | THR (r) | p-value |
|---|---|---|---|---|---|---|
| **FVC** | 0.565 | <0.001 | 0.184 | 0.202 | 0.184 | 0.202 |
| **MVV** | 0.664 | <0.001 | 0.254 | 0.075 | 0.254 | 0.075 |

Correlation analysis between pulmonary function variables and exercise capacity indices is summarized in Table 2. Both FVC and MVV demonstrated significant positive correlations with treadmill exercise duration (TMT). FVC showed a moderate correlation with TMT ($r = 0.565$, $p < 0.001$), whereas MVV exhibited a stronger correlation ($r = 0.664$, $p < 0.001$). However, neither FVC nor MVV showed statistically significant correlations with target heart rate (THR) or maximal heart rate (MHR). These findings suggest that pulmonary parameters were more closely related to exercise endurance (duration) rather than heart rate responses.

**Table 3. Comparison of pulmonary parameters across THR groups using ANOVA (n = 50)**

| Variable | Source | Sum of Squares | df | Mean Square | F | p-value |
|---|---|---|---|---|---|---|
| **FVC** | **Between groups** | 0.058 | 5 | 0.015 | 1.065 | 0.385 |
| | **Within groups** | 0.615 | 45 | 0.014 | | |
| | **Total** | 0.673 | 50 | | | |
| **MVV** | **Between groups** | 151.067 | 5 | 37.767 | 1.092 | 0.372 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **Within groups** | 1556.846 | 45 | 34.597 | | |
| | **Total** | 1707.913 | 50 | | | |

When participants were stratified based on achievement of target heart rate, no statistically significant differences were observed in either FVC ($p = 0.385$) or MVV ($p = 0.372$), as shown in Table 3. This indicates that pulmonary function parameters did not vary significantly across THR categories, further emphasizing that exercise duration rather than heart rate endpoints better reflected ventilatory capacity.

**Figure 1. Scatter plot showing correlation between MVV and treadmill exercise time (TMT)**

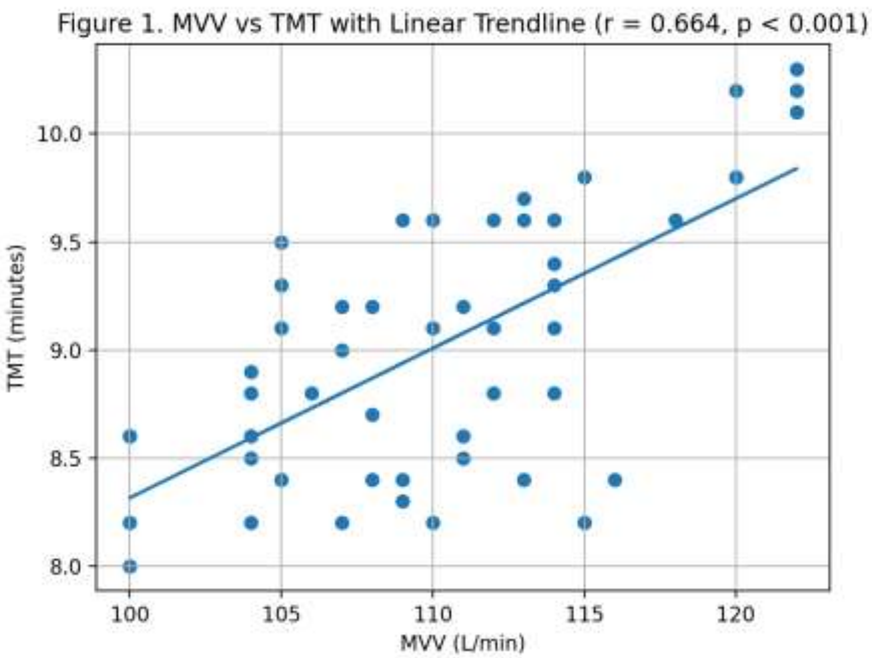


Figure 1 illustrates the relationship between MVV and treadmill exercise duration. A strong positive linear association was observed ($r = 0.664$, $p < 0.001$), demonstrating that participants with higher MVV values tended to achieve longer exercise durations. The upward trend of the regression line highlights the progressive increase in exercise capacity with increasing ventilatory reserve.

**Figure 2. Scatter plot showing correlation between FVC and treadmill exercise time (TMT)**

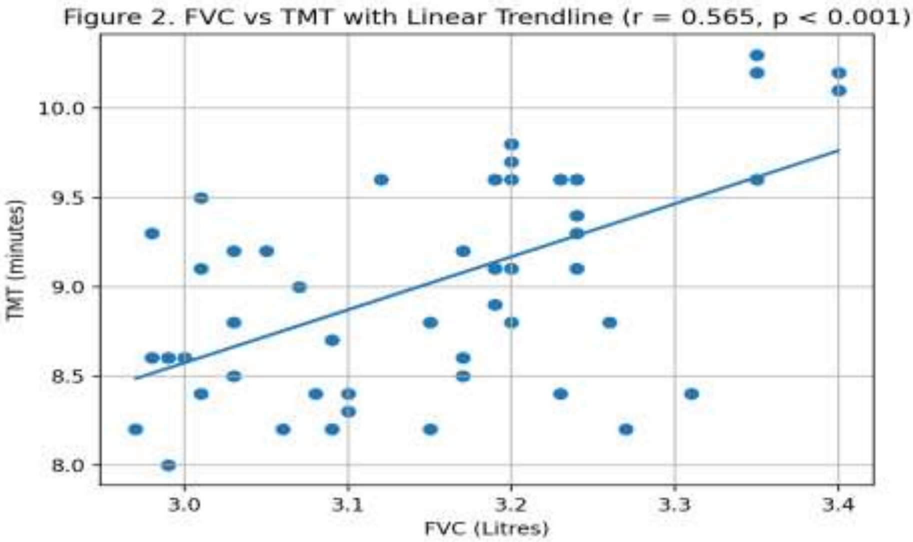


Figure 2 depicts the association between FVC and treadmill exercise duration. A moderate positive correlation was noted ($r = 0.565$, $p < 0.001$), indicating that higher vital capacity was associated with improved exercise endurance. However, the dispersion of data points was greater compared to MVV, suggesting relatively weaker predictive strength.

Both FVC and MVV demonstrated significant associations with exercise capacity as measured by treadmill exercise duration. MVV showed stronger correlation coefficients and higher ANOVA F-values compared to FVC, suggesting superior predictive utility. Neither pulmonary parameter exhibited significant association with heart rate indices. Overall, MVV emerged as a more robust physiological predictor of exercise capacity in healthy young adult males.

## DISCUSSION

The present study evaluated the comparative predictive roles of maximal voluntary ventilation (MVV) and forced vital capacity (FVC) on exercise capacity among healthy young adult males using treadmill exercise duration as the functional outcome. The principal findings demonstrated that both MVV and FVC were significantly correlated with treadmill exercise time (TMT); however, MVV exhibited a stronger association ($r = 0.664$, $p < 0.001$) compared to FVC ($r = 0.565$, $p < 0.001$). Furthermore, analysis of variance across TMT groups revealed higher discriminatory power for MVV ($F = 3.209$, $p = 0.002$) than for FVC ($F = 2.085$, $p = 0.035$). In contrast, neither pulmonary parameter showed significant association with target heart rate (THR), indicating that ventilatory indices were more closely related to exercise endurance than to heart rate responses. These results suggest that MVV serves as a superior physiological predictor of exercise capacity compared to static lung volumes in healthy young adults.

Our findings align with the growing body of literature emphasizing the functional relevance of ventilatory reserve in determining exercise performance. Guazzi et al. reported that ventilatory capacity indices, particularly MVV-derived measures, correlated more strongly with exercise tolerance than traditional spirometric volumes in healthy individuals and patients undergoing cardiopulmonary testing[11]. Similarly, Molgat-Seon et al. demonstrated that respiratory muscle endurance plays a significant role in sustaining prolonged exercise, even in individuals without overt pulmonary disease[12]. These observations support our results, wherein MVV—reflecting respiratory muscle strength and endurance—emerged as a stronger determinant of exercise duration than FVC.

FVC, while commonly used as a marker of lung capacity, represents a static measurement and does not fully account for the dynamic demands placed on the respiratory system during exercise. In our study, FVC showed only moderate correlation with TMT, suggesting limited predictive value when considered in isolation. This finding is consistent with work by Albarrati et al., who observed that static lung volumes were less predictive of functional exercise capacity compared to indices reflecting ventilatory mechanics and muscle performance[13]. Collectively, these data reinforce the concept that exercise capacity depends not merely on lung size but on the integrated performance of respiratory muscles, airway mechanics, and ventilatory control.

The stronger association observed between MVV and exercise duration may be explained by the physiological basis of MVV itself. MVV incorporates elements of respiratory muscle strength, endurance, lung compliance, and airway resistance, thereby providing a composite assessment of ventilatory reserve. During progressive treadmill exercise, increasing metabolic demands require rapid and sustained ventilation, placing significant load on the respiratory muscles. Individuals with higher MVV values are therefore better equipped to tolerate prolonged exertion before ventilatory limitation occurs. This mechanism has been supported by Hopkinson et al., who demonstrated that respiratory muscle capacity directly influences exercise tolerance even in non-athletic populations[14].

Another notable observation in our study was the lack of significant association between pulmonary parameters and heart rate indices. Both MVV and FVC failed to correlate meaningfully with THR or MHR. This suggests that in healthy young adults, cardiovascular responsiveness to exercise is relatively uniform, while variability in exercise endurance is more closely related to ventilatory performance. Similar findings were reported by Faisal et al., who noted that heart rate responses during submaximal exercise showed limited association with pulmonary function in healthy subjects, whereas ventilatory variables were more predictive of exercise sustainability[15]. This further supports the use of exercise duration rather than heart rate endpoints as a functional marker of respiratory capacity.

Our results are also comparable to those of Laveneziana et al., who demonstrated that ventilatory constraints contribute significantly to exercise limitation even in individuals without cardiopulmonary pathology[16]. Their study emphasized that subtle variations in respiratory muscle function can influence perceived exertion and exercise tolerance, reinforcing the relevance of MVV as a practical surrogate of ventilatory reserve. In the present study, the stronger MVV–TMT relationship highlights the importance of respiratory muscle performance in determining functional capacity among healthy young males.

The present findings have important implications for clinical and fitness assessments. While FVC remains useful for identifying restrictive or obstructive lung pathology, MVV may provide additional functional insight when evaluating exercise capability, particularly in young adults. In settings where cardiopulmonary exercise testing is unavailable, MVV may serve as a practical screening tool for ventilatory fitness. This perspective is supported by Neder et al., who advocated incorporating MVV into routine physiological assessment due to its ability to reflect integrated respiratory performance[17].

Population-specific evaluation is particularly relevant in young adults, as this age group represents peak physiological capacity and serves as a reference for future decline. Studies by Satta et al. have shown wide interindividual variability in ventilatory performance among healthy youth, underscoring the need for functional indices beyond conventional spirometry[18]. Our cohort demonstrated relatively homogeneous anthropometric characteristics, yet substantial variability in MVV and exercise duration, further emphasizing that ventilatory endurance differs even among apparently similar individuals.

Although our study focused exclusively on male participants, previous research suggests potential sex-based differences in ventilatory mechanics and respiratory muscle strength. Dominelli et al. reported that females generally exhibit lower absolute ventilatory capacity, which may influence exercise tolerance differently across sexes[19]. Future studies incorporating female participants would therefore be valuable in establishing sex-specific predictive models.

The clinical relevance of our findings extends beyond healthy populations. MVV has been shown to predict functional outcomes in patients with cardiopulmonary disease and has been proposed as a marker of rehabilitation potential. Ramos et al. demonstrated that MVV independently predicted walking distance and quality-of-life scores in individuals with chronic respiratory conditions[20]. While our cohort consisted of healthy young adults, the observed MVV–exercise relationship suggests that early identification of reduced ventilatory reserve may help guide preventive strategies and fitness interventions.

## Conclusion

This cross-sectional study among healthy young adult male medical students demonstrated a significant association between pulmonary function parameters and exercise capacity. Both maximal voluntary ventilation and forced vital capacity showed positive correlations with treadmill exercise duration; however, maximal voluntary ventilation exhibited a stronger relationship with exercise capacity ($r = 0.664$, $p < 0.001$) compared to forced vital capacity ($r = 0.565$, $p < 0.001$). Mean MVV and FVC values were 110.34 ± 5.90 L/min and 3.15 ± 0.12 L, respectively, with a mean treadmill exercise duration of 9.03 ± 0.62 minutes. MVV also demonstrated greater discriminatory ability across exercise duration groups, highlighting its superior predictive utility over static lung volumes.

These findings emphasize the importance of ventilatory endurance, as reflected by MVV, in determining functional exercise performance in healthy young adults. Incorporating MVV into routine physiological assessment may provide a more comprehensive evaluation of respiratory fitness than reliance on forced vital capacity alone. Early identification of reduced ventilatory reserve can facilitate targeted interventions such as aerobic conditioning and respiratory muscle training. Integrating structured physical activity programs into medical curricula may help enhance cardiopulmonary fitness, promote long-term health, and foster resilient future healthcare professionals.

## LIMITATIONS

The present study was conducted in a single medical college with a relatively small sample size of 50 participants, which may limit the generalizability of the findings to broader populations. The cross-sectional design provides only a snapshot of pulmonary function and exercise capacity, thereby precluding causal inference. Exercise capacity was assessed using treadmill exercise duration to target heart rate rather than direct cardiopulmonary exercise testing with measurement of maximal oxygen uptake, which may have provided a more precise assessment of aerobic capacity. Additionally, respiratory muscle strength was not evaluated separately, which could have offered further insight into the mechanisms underlying the observed associations. Factors such as habitual physical activity, nutritional status, and psychological motivation were not assessed and may influence both ventilatory parameters and exercise performance. Future longitudinal, multicentric studies with larger sample sizes and inclusion of objective cardiopulmonary and respiratory muscle assessments are recommended for broader validation.

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