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Research Article

Cut-off values of one-minute sit-to-stand test for determining physical performance in mild-post-COVID-19 individuals

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Abstract

Background

This study aims to establish cutoff values for the one-minute sit-to-stand test (1STST) to predict physical performance in mild-post- coronavirus disease 2019 (COVID-19) individuals and to compare the 1STST with the 6-minute walk test (6MWT) in assessing hemodynamic response and to explore the correlation between 1STST, 6MWT, and muscle strength, including leg and respiratory muscle strength.

Methods

A cross-sectional study of 93 participants with mild post-COVID-19 symptoms was conducted. Sociodemographic and anthropometric data were collected, and pulmonary function, as well as respiratory and quadriceps muscle strength, were evaluated. Functional capacity was assessed using the 6MWT and 1STST. Additionally, hemodynamic responses, fatigue, and dyspnea were measured before and after each test.

Results

The cutoff for the 1STST in mild post-COVID-19 individuals was ⩾29 repetitions, with an AUC of 0.84, sensitivity of 80.52%, and specificity of 75.00%. The 1STST resulted in higher heart rate, systolic blood pressure, and dyspnea compared to the 6MWT, and showed a significant moderate correlation with the 6MWT ($r = 0.532$, $p < 0.0001$) and weak correlations with leg strength and respiratory muscle strength.

Conclusion

A cutoff of less than 29 repetitions on the 1STST indicates functional impairment in mild post-COVID-19 cases, as it induces greater physiological stress than the 6MWT and correlates with muscle strength, making it crucial for rehabilitation assessment.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has profoundly impacted global health, leaving many individuals with post-viral symptoms and complications even after recovering from the acute phase of the illness.[1] While severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) primarily targets the respiratory system, it often manifests with extrapulmonary symptoms, indicating its systemic impact.[2] These persistent symptoms, which generally last more than 4 weeks, include fatigue, decreased muscle strength, weakness characterized by a pervasive lack of energy that hinders routine activities, and physical stress, significantly affecting the quality of life of survivors.[1,3,4]

Respiratory muscle weakness is prevalent among individuals recovering from COVID-19, contributing to ongoing breathing difficulties despite normal lung function.[5] This weakness, coupled with diminished muscle strength, exercise intolerance, and limb weakness, poses significant challenges for rehabilitation and functional recovery activities, even with normal lung and cardiac function.[6,7] Assessing physical performance and functional status is crucial in managing post-COVID-19 patients to tailor rehabilitation programs effectively and promote their long-term recovery.

The 6-minute walk test (6MWT) is commonly used to evaluate exercise tolerance and desaturation in chronic lung diseases.[8] However, its need for a 30-meter corridor and time-consuming nature may limit its practicality in primary care or clinical settings where time and space are constrained.[9] In such cases, alternative tests like the one-

minute sit-to-stand test (1STST) offer a more feasible option.[10] Sit-to-stand tests (STSTs), involving only a chair and quick administration, are highly applicable in assessing physical performance, particularly in cardiopulmonary conditions like chronic obstructive pulmonary disease (COPD), lung transplantation, and pulmonary hypertension.[11] Furthermore, the 1STST has shown consistent performance and a strong correlation with the 6MWT for assessing exercise-induced desaturation in patients with interstitial lung diseases.[12] In COVID-19 patients, desaturation during the 1STST has been found to correlate with desaturation during the 6MWT, making it a valuable tool for identifying reduced physical capacity and exertional desaturation.[13]

In the context of challenges faced during comprehensive physical assessments, especially in resource-limited settings or during outbreaks, it is essential to find practical and reliable measures for evaluating post-COVID-19 functional impairment. Therefore, the primary objective of this study was to establish cutoff values for the 1STST to predict physical performance in mild-post-COVID-19 individuals. Additionally, we aimed to compare the 1STST with the 6MWT in assessing hemodynamic response and to explore the correlation between 1STST, 6MWT, and muscle strength, including leg and respiratory muscle strength. These cutoff values may help identify patients who require adjustments in their routine treatment or who may benefit from new rehabilitative approaches.

METHODS

STUDY DESIGN AND PARTICIPANTS

A cross-sectional study was conducted with 93 mild post-COVID-19 participants at the Phukamyao Subdistrict Health Promoting Hospital in Phayao Province, Thailand, which serves as a primary care setting. Recruitment occurred from July to August 2022, using posters and a network of village health officers in the surrounding community. The inclusion criteria were as follows: a) over 18 years of age; b) outpatients with mild post-COVID-19 who were diagnosed with COVID-19 and discharged from the hospital within four weeks before evaluation. Participants were excluded if they: a) were unable to perform the test due to limited mobility or any joint/mobility pain; b) had hemodynamic instability, defined as systolic blood pressure (SBP) >180 mmHg or diastolic blood pressure (DBP) >100 mmHg, heart rate (HR) >120 bpm and oxygen saturation (SpO_2<95%). This study was approved by the Human Research Ethics Committee of the University of Phayao (UP-HEC 1.2/044/65), and all participants provided written informed consent. The minimum estimated sample size required was 93 participants for a diagnostic study, determined with 95% confidence, 10% margin of error, and 60% sensitivity based on a previous study.[14]

PROCEDURE

During the visit, each participant underwent an assessment procedure, including measurements of functional exercise capacity (e.g., 6MWT, 1STST), knee extensor strength, and respiratory muscle strength. Sociodemographic data (age, sex) and clinical information (comorbidities, smoking status, exercise habits) were collected during the visit. Anthropometric data (height, weight, and body mass index) were also recorded, along with vital signs, peripheral oxygen saturation (SpO_2), fatigue, and dyspnea at rest using the modified Borg scale (mBorg). Pulmonary function was assessed by spirometry following the standardization method according to the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines, while respiratory muscle strength was measured using a respiratory pressure meter following the same guidelines. Quadriceps muscle strength was determined using a hand-held dynamometer.

Functional capacity tests were performed on the same day. Each participant performed the 1STST and 6MWT, with a 2-hour interval between each test to avoid muscle fatigue; the sequence of the tests was randomized. Immediately after completing the 6MWT and 1STST, the participant was asked to sit, and blood pressure (BP) and HR were determined. Additionally, each participant assessed their subjective fatigue and dyspnea levels using a mBorg.

6MWT

Participants were instructed to walk at a self-selected pace for 6 minutes, aiming to cover as much distance as possible 6MWT was conducted in an uninterrupted 30-m-long corridor. During the test, they could stop and rest if needed and then resume when ready. Verbal encouragement was provided to each subject.[8,15]

1STST

The 1STST were performed using a standard chair with a seating height of 46 cm. Participants were seated upright with knees and hips flexed at 90°, feet flat on the floor and hip-width apart, and arms crossed across the chest. They were instructed to perform repetitions of standing upright and then sitting down in the same position at a self-paced speed for 1 minute. The number of completed sit-to-stand repetitions was recorded.[16,17]

RESPIRATORY MUSCLE STRENGTH

The maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were assessed using a respiratory pressure meter (MicroRPM) (CareFusion, UK 232 Ltd, United Kingdom) following the standardized guidelines of the ATS/ERS Statement on Respiratory Muscle Testing.[18] The participants were seated with their trunks at a 90-degree angle to the hip and feet on the ground. They were instructed to wear a nasal clip and hold a flanged mouthpiece tightly in their mouth to prevent air leakage during all maneuvers. For MIP, the participants were asked to give maximal inspiratory effort starting from residual volume (RV) or maximal exhalation, whereas MEP was measured starting from total lung capacity (TLC) or after maximal inhalation. The highest value of maximal pressure (cmH_2O) from at least 3 efforts lasting at least 2 seconds and sustained for

1 second without leakage was recorded. A one-minute rest was allowed between each maneuver, and calibration was achieved by attaching the device to a pressure manometer as previously described.[19,20]

QUADRICEPS MUSCLE STRENGTH

Quadriceps muscle strength was assessed using a handheld dynamometer (Model-01165, Lafayette Instrument Company, Lafayette IN, USA). The maximal isometric strength of the quadriceps (in kilograms) was measured with the participant in a seated position, with the hip and knee flexed at 90 degrees. The dominant lower extremity underwent testing through maximal isometric knee extension. Each measurement was repeated at least three times, and the highest recorded value was documented.[21]

STATISTICAL ANALYSIS

Statistical analysis was performed using Stata 11.5.1 (StataCorp LLC, College Station, TX, USA). The level of significance was set at 0.05. Descriptive statistics, including means, standard deviations, and percentages, were computed for participant characteristics and study outcomes. Physiological responses (BP, HR, and oxygen saturation) were compared between the 1STST and 6MWT using a paired t-test. Leg fatigue and dyspnea scores were analyzed using the signed-rank test. Additionally, the Pearson correlation coefficient was used to explore the relationship between the number of steps in the 1STST, distance covered in the 6MWT, and leg and respiratory muscle strength. Receiver operating characteristic (ROC) curve analysis was used to determine the cutoff score, sensitivity, specificity, and area under the curve (AUC) for the 1STST. A 6MWT cutoff of 400 meters,[14] which is linked to low exercise endurance in COPD patients, was employed to identify functional impairments. Based on this reference, we established an optimal threshold for the 1STST. The Youden index was applied to determine the best cutoff point on the ROC curve. The AUC interpretation is: <0.5 for no discrimination, 0.50–0.69 for poor, 0.70–0.79 for acceptable, 0.80–0.89 for excellent, and ⩾0.90 for outstanding discrimination.[22,23]

RESULTS

The study included 93 mild-post-COVID-19 individuals, with a mean age of 59.12 ± 10.07 years and 35.83% being male. The majority had no previous coexisting disease (63.44%), while hypertension (17.20%) and diabetes mellitus (8.60%) were the most common comorbidities. Spirometry results indicated a mean forced vital capacity (FVC) of 74.05 ± 14.14% predicted and a mean forced expiratory volume in the first second (FEV1) of 82.33 ± 15.48% predicted. MIP and MEP averaged 75.73 ± 28.25 cm H_2O and 92.35 ± 30.13 cm H_2O, respectively. Fractional exhaled nitric oxide (FeNO) was measured at 17.88 ± 8.00 ppb to evaluate airway inflammation to determine respiratory recovery in post-COVID-19 patients.[24] The mean 6-minute walk distance (6MWD) was 430.34 ± 70.55 meters, and participants performed an average of 32.34 ± 8.82 repetitions in the one-minute sit-to-stand test. Leg strength averaged 22.71 ± 8.80 kg (Table 1).

The cutoff value for 1STST to determine physical performance in mild-post-COVID-19 individuals was ⩾29 repetitions, with an area under the ROC curve (AUC) of 0.84 (95% CI: 0.72-0.95) (Figure 1), indicating good discriminative ability. The sensitivity and specificity of the test were 80.52% and 75.00%, respectively (Table 2).

Comparison between the 1STST and 6MWT in mild-post-COVID-19 individuals showed significant differences in hemodynamic responses and dyspnea severity. Final HR and SBP were significantly higher after the 1STST (101.83 ± 19.44 bpm vs. 89.34 ± 17.45 bpm, $p < 0.001$; 147.57 ± 18.17 mmHg vs. 143.54 ± 18.65 mmHg, $p < 0.001$). Dyspnea scores were also significantly higher post-1STST compared to the 6MWT (2.84 ± 1.24 vs. 2.12 ± 1.48, $p < 0.001$). However, no significant differences were found in baseline and final SpO_2, DBP, or baseline leg fatigue between the two tests ($p > 0.05$) (Table 3).

The 1STST exhibited a significant positive moderate correlation with the 6MWT (r = 0.532, $p < 0.0001$; see Figure 2). Additionally, both tests demonstrated positive correlations with leg strength: a weak correlation with the 6MWT (r = 0.324, $p = 0.002$) and a moderate correlation with the 1STST (r = 0.413, $p < 0.0001$). Regarding respiratory muscle strength, the correlations indicated that MIP had a weak correlation with the 6MWT (r = 0.373, $p = 0.0002$) and a weak correlation with the 1STST (r = 0.389, $p = 0.0001$). Similarly, MEP exhibited a weak correlation with the 6MWT (r = 0.326, $p = 0.001$) and a weak correlation with the 1STST (r = 0.272, $p = 0.008$) in mild-post-COVID-19 individuals (Table 4).

DISCUSSION

This study mainly aimed to determine the optimal cut-off value of the 1STST for assessing physical performance in mild-post-COVID-19 individuals. “Mild post-COVID” refers to individuals who experience persistent mild symptoms, including fatigue and respiratory issues such as shortness of breath, wheezing, coughing, and chest discomfort, beyond the initial 4-week recovery period of COVID-19, without needing hospitalization.[25,26] Our key findings include: (1) A 1STST of less than 29 repetitions suggest functional impairment in mild-post-COVID-19 individuals. (2) The 1STST induced greater physiological stress, with a higher increase in HR, SBP and dyspnea compared to the 6MWT in mild-post-COVID-19 subjects. (3) Both the 1STST and 6MWT exhibited significant positive correlations with each other and with measures of muscle strength in mild-post-COVID-19 individuals, highlighting their importance in evaluating physical function during rehabilitation.

The 1STST appeared to be a method which is objective, safe and easy to perform and interpret. There are several studies that investigated the reference or cut-off values for 1STST, but the literature is rather limited in this context.[14,27-30] Our study showed that the cut-off value less than 29

Table 1. Clinical characteristics and laboratory results of 93 mild-post COVID-19 individuals.

Characteristics	Total *(N = 93)*
Baseline characteristics	
Age (years)	59.12 ± 10.07
Female	69 (64.17)
Height (cm)	158.03 ± 7.20
Weight (kg)	60.29 ±11.63
BMI (kg/m2)	24.09 ± 4.01
mMRC ≥ 2	2 (1.86)
Duration after COVID (day)	112.04 ± 47.51
Previous coexisting disease, number (%)	
No	59 (63.44)
Hypertension	16 (17.20)
Diabetes mellitus	8 (8.60)
Hypertension with diabetes mellitus	7 (7.53)
Coronary artery disease	3 (3.23)
Smoking history, number (%)	
Active smoker	2 (2.15)
Former smoker	7 (7.53)
No smoker	84 (90.32)
Exercise, number (%)	
≥3 days/week	33 (35.48)
1-2 days/week	30 (32.26)
No exercise	30 (32.26)
Spirometry	
FVC (% of predicted)	74.05 ± 14.14
FEV1 (% of predicted)	82.33 ± 15.48
FEV1/FVC (% of predicted))	85.02 ± 5.41
MIP (cmH_2O)	75.73 ± 28.25
MEP (cmH_2O)	92.35 ± 30.13
FeNO (ppb)	17.88 ± 8.00
6MWD (meters)	430.34 ± 70.55
1STS (repetitions)	32.34 ± 8.82
Leg strength (kg)	22.71 ± 8.80

Values are presented as mean ± standard deviation or number (%). BMI, body mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in the first second; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure; FeNO, Fractional exhaled nitric oxide measured in parts per billion (ppb). 6MWD; 6-minute walk distance, 1STST, One-minute sit to stand test.

repetitions in the 1STST indicate functional impairment in mild-post-COVID-19 individuals. A previous study indicated that the 1STST showed a cut-off of 19.5 repetitions in the 1STST to discriminate people with COPD with or without a functional impairment accurately.[14] A cut-off of 22 repetitions or 59% predicted on the 1STST has prognostic value to assess risk of postoperative complications in people undergoing surgery.[29]

The 6MWT is widely used and recommended for assessing exercise capacity due to its practicality, reflection of daily activities, and ease of administration.[8] However, the most important barrier to the use of 6MWT is that it requires trained staff, space, and equipment, which is not commonly available in many practice settings.[31] The reference test to assess physical capacity in respiratory, cardiovascular, or metabolic diseases is the 6MWT. However, performing the 6MWT can be challenging in various settings due to the need for a 30-meter corridor (or at least 20 meters), which is not always readily available in clinics, hospitals, or home environments. The pandemic highlighted the need for alternative tests that can be conducted in more confined spaces without compromising accuracy.[9] Our results show that there is a moderate correlation between the 6MWT and the 1STST. These results are in line with similar studies in COVID-19 patients ($r = 0.68$, $p < 0.001$)[32] and in different populations, such as lung transplant candidates

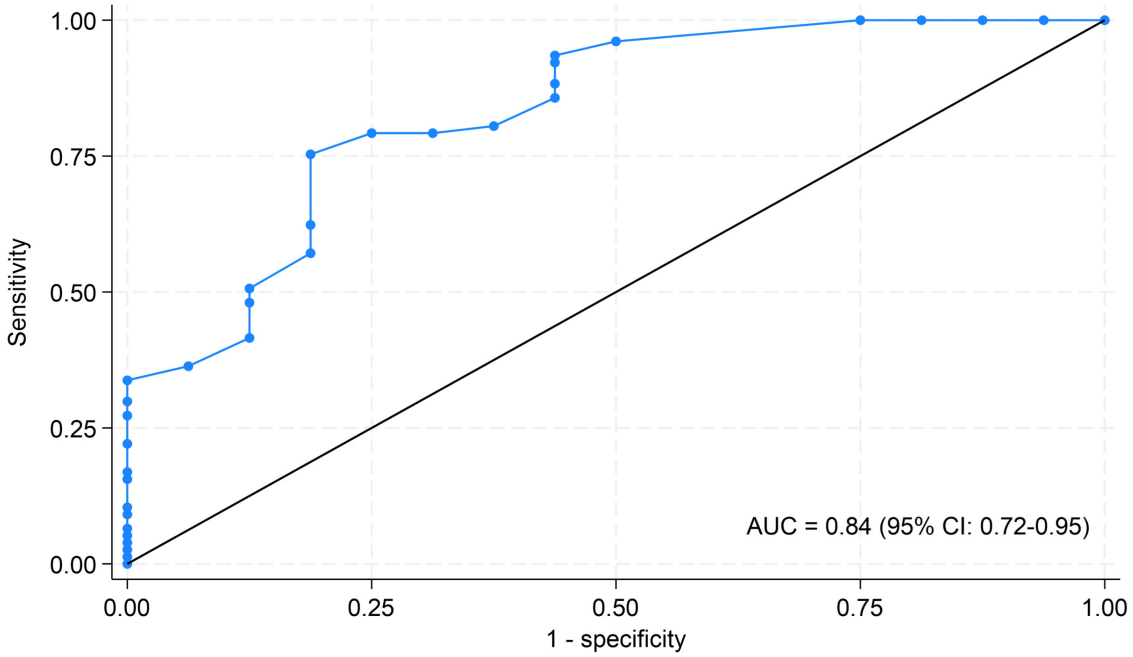

Figure 1. The ROC curves, area under the curve (AUC), and 95% confidence intervals (CI) for the one-minute sit-to-stand test.

Table 2. The cut-off score of the 1STST to determine physical performance in mild-post COVID-19 individuals.

Variables	Cutoff value	AUC (95%CI)	Sensitivity (%)	Specificity (%)
1STST	≥29	0.84 (0.72- 0.95)	80.52%	75.00%

1STST, One-minute sit to stand test; AUC, area under ROC curve; CI, confidence interval.

Table 3. Comparison of hemodynamic responses, fatigue, and dyspnea severity to 1STST and 6MWT in mild-post-COVID-19 individuals.

Variables	1STST	6MWT	*p*-value
HR baseline (bpm)	79.01 ± 11.73	78.37 ± 11.55	0.657
HR final (bpm)	101.83 ± 19.44	89.34 ± 17.45	<0.001*
SpO_2 baseline (%)	97.76± 1.24	97.46 ± 1.21	0.057
SpO_2 final (%)	97.46 ± 1.53	97.70 ± 1.15	0.284
SBP baseline (mmHg)	129.34 ± 13.24	127.80 ± 15.95	0.317
SBP final (mmHg)	147.57 ± 18.17	143.54 ± 18.65	<0.001*
DBP baseline (mmHg)	82.23 ± 9.82	81.33 ± 9.81	0.058
DBP final (mmHg)	84.72 ± 10.00	84.87 ± 9.56	0.509
Dyspnea baseline (0-10 grade)	0.41 ± 0.72	0.38 ± 0.57	0.871
Dyspnea final (0-10 grade)	2.84 ± 1.24	2.12 ± 1.48	<0.001*
Leg fatigue baseline (1–10 grade)	0.36 ± 0.84	0.42 ± 0.83	0.474
Leg fatigue final (1–10 grade)	1.96 ± 1.82	1.61 ± 1.55	0.057

Values are presented as mean ± standard deviation. 6MWD, 6-minute walk distance; 1STST, One-minute sit to stand test; HR, Heart rate; bpm, beats per minute; SpO_2, Oxygen saturation; SBP, systolic blood pressure; DBP, diastolic blood pressure, mmHg, millimeters of mercury. *p <0.05, statistically significant.

(r= 0.79, $p < 0.001$).[33] Therefore, when there are limitations to performing the 6MWT in COVID-19 patients, the 1STST could be used as an alternative test.

The 6MWT and 1STST assess distinct facets of exercise capacity, yet both exhibit notable correlations with muscle strength. In our investigation, both the 1STST and the 6MWT displayed comparable associations with knee exten-

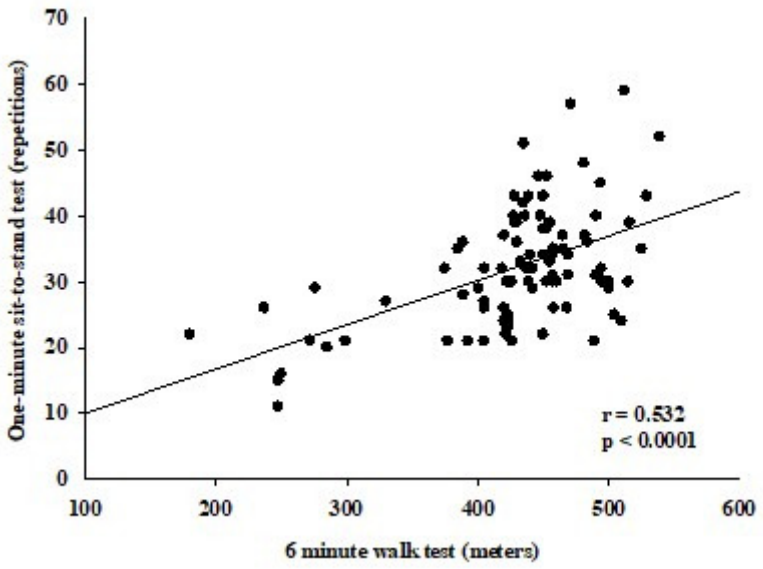

Figure 2. The correlation coefficient between the one-minute sit-to-stand test and the 6-minute walk test.

Table 4. Relationships of 1STST and 6MWT with muscle strength in mild-post-COVID-19 individuals.

Variables	Correlation coefficient	6MWD (m)	1STST (no.)
Leg strength (kg)	r	0.324	0.413
	p-value	0.002*	<0.0001*
MIP (cmH_2O)	r	0.373	0.389
	p-value	0.0002*	0.0001*
MEP (cmH_2O)	r	0.326	0.272
	p-value	0.001*	0.008*

1STST, One-minute sit to stand test; 6MWD, six-minute walk distance; kg, kilograms; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure. *p <0.05, statistically significant.

sor strength, aligning with prior studies involving subjects with cystic fibrosis,[34,35] COPD,[36] and lung transplant candidates.[33] Additionally, in our study, both tests exhibited comparable correlations with respiratory muscle strength, suggesting the importance of both lower extremity and respiratory muscle strength in performing sit-to-stand and walking tasks. This finding implies that the 1STST may serve as a predictor of lower extremity muscle strength in mild-post-COVID-19 individuals, along with the leg strength test and maximal respiratory pressure. Lower extremity muscle dysfunction is a known cause of exercise impairment in mild-post COVID-19 individuals, and when coupled with reduced respiratory and lower extremity muscle strength, it contributes to decreased exercise and functional capacity in these individuals.[37]

Regarding the hemodynamic response to the effort of each test, our results comparing the 1STST and 6MWT in mild-post-COVID-19 subjects showed that the 1STST led to significantly higher final HR, SBP, and dyspnea scores compared to the 6MWT. Most participants rated both tests below a modified rating of perceived exertion (mRPE) score of 6, indicating a low to moderate intensity level. Since an mRPE score of 5 to 6 correlates with 40-59% of an individual's maximal oxygen consumption (VO_2 max),[38] the 1STST could potentially serve as a submaximal fitness test. Consistent with recent studies on lung transplantation candidates[33] and subjects with COPD,[39] the 1STST elicited greater dyspnea compared to the 6MWT. This difference may be due to several factors, including the 1STST's greater demand due to its rapid, intense movements, eccentric muscle contractions during the stand-to-sit phase, cardiovascular demand, coordination, and balance control.[33,40]

The 1STST can be valuable for assessing both functional capacity and lower limb muscle endurance, making it useful for quantifying submaximal exercise capacity, particularly in home health settings. However, it has notable limitations. The 1STST mainly assesses lower extremity strength and balance, which may not fully capture aerobic capacity or cardiopulmonary endurance in some individuals. The rapid and repetitive nature of the test can lead to significant fatigue, especially in older adults or those with pre-existing lower limb muscle weakness. Additionally, the 1STST may be less suitable for individuals with orthopedic issues, mobility limitations, or joint pain, which could affect the accuracy of the results.

The limitations of our study include a relatively small sample size of 93 participants, which may affect the generalizability of the results. The study specifically targeted in-

dividuals with mild post-COVID-19 symptoms, so the findings may not be applicable to those with more severe post-COVID-19 conditions or substantial comorbidities. Furthermore, the cross-sectional nature of the study restricts the assessment of long-term outcomes and the progression of physical recovery. To address these gaps, future research should involve larger and more diverse cohorts, including individuals with varying severities of post-COVID-19 symptoms. Longitudinal studies would be valuable to track recovery over time and assess the effectiveness of various assessment tools and rehabilitation strategies. Additionally, exploring the impact of different interventions on functional recovery could provide deeper insights into optimizing post-COVID-19 care.

CONCLUSION

A 1STST cutoff of less than 29 repetitions indicates functional impairment in individuals with mild post-COVID-19 conditions and reflects greater physiological stress than the 6MWT, making it a sensitive measure of physical capacity. Moderate positive correlations with muscle strength further emphasize its relevance in rehabilitation assessment when the 6MWT is impractical.

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CONTRIBUTIONS

Conceptualization, A. Srithawong. P. Poncumhak. and T. Promsrisuk; Methodology, A. Srithawong. P. Poncumhak. S. and T. Promsrisuk; Formal Analysis, A. Srithawong.; Investigation, A. Srithawong. P. Poncumhak. S. and T. Promsrisuk; Data Curation, A. Srithawong. P. Poncumhak. S and T. Promsrisuk; Writing, A. Srithawong. and P. Amput; Original Draft Preparation, A. Srithawong. and P. Amput; Writing—Review and Editing, A. Srithawong. and P. Amput. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICAL APPROVAL

This study was approved by the Human Research Ethics Committee of the University of Phayao (UP-HEC 1.2/044/65).

AI STATEMENT

The authors confirm no generative AI or AI-assisted technology was used to generate content.

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