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ORIGINAL RESEARCH

A comparative study of the five-repetition sit-to-stand test and the 30-second sit-to-stand test to assess exercise tolerance in COPD patients

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Purpose: The sit-to-stand test (STST) has been used to evaluate the exercise tolerance of patients with COPD. However, mutual comparisons to predict poor exercise tolerance have been hindered by the variety of STST modes used in previous studies, which also did not consider patients' subjective perceptions of different STST modes. Our aim was to compare the five-repetition sit-to-stand test (5STS) with the 30-second sit-to-stand test (30STS) for predicting poor performance in the six-minute walking test and to evaluate patients' subjective perceptions to determine the optimal mode for clinical practice.

Patients and methods: Patients with stable COPD performed 5STS, 30STS and the 6MWT and then evaluated their feelings about the two STST modes by Borg dyspnea score and a questionnaire. Moreover, we collected data through the pulmonary function test, mMRC dyspnea score, COPD assessment test and quadriceps muscle strength (QMS). A receiver operating characteristic curve analysis of the 5STS and 30STS results was used to predict 6-minute walk distance (6MWD) <350 m.

Results: The final analysis included 128 patients. Similar moderate correlations were observed between 6MWT and 5STS (r=–0.508, P<0.001) and between 6MWT and 30STS (r=0.528, P<0.001), and there were similar correlations between QMS and 5STS (r=–0.401, P<0.001) and between QMS and 30STS (r=0.398, P<0.001). The 5STS and 30STS score cutoffs produced sensitivity, specificity and positive and negative predictive values of 76.0%, 62.8%, 56.7% and 80.3% (5STS) and 62.0%, 75.0%, 62.0% and 75.0% (30STS), respectively, for predicting poor 6MWT performance. The 5STS exhibited obvious superiority in terms of the completion rate and the subjective feelings of the participants.

Conclusion: As a primary screening test for predicting poor 6MWD, the 5STS is similar to the 30STS in terms of sensitivity and specificity, but the 5STS has a better patient experience.

Keywords: sit-to-stand test, six-minute walk test, COPD, exercise endurance

Introduction

Reduced exercise tolerance is one of the significant clinical features of COPD. The six-minute walk test (6MWT) is a common method of assessing the exercise tolerance of COPD patients, whose 6-minute walk distance (6MWD) <350 m demonstrated a significant increase in mortality,[1,2] but it has been difficult to popularize in primary medical institutions due to the need for an appropriate site (a 30 m flat course is required, and the layout of the track may influence the performance).[3,4] In recent years, the sit-to-stand test (STST) has also been used to indirectly evaluate exercise tolerance[5–7] and lower extremity skeletal muscle function. However, the STST currently lacks unified standards, ranging from 5 to 10 repetitions[5,8] (measuring the time taken to complete

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the given number of repetitions of the sit-to-stand action) or 30 seconds to 3 minutes[9–11] (measuring the maximum number of sit-to-stand actions completed in a given time). Most studies have assessed the correlation of one of the STST modes with the 6MWD or quadriceps muscle strength (QMS).[12,13] At present, no studies have evaluated differences between the different STST modes in predicting poor exercise tolerance (6MWD $<$350 m) or have taken patients' subjective perceptions of different modes into account. Therefore, in this prospective study, we compared the correlation between the five-repetition sit-to-stand test (5STS) and the 30-second sit-to-stand test (30STS) with the 6MWT and QMS in COPD patients, and we evaluated patients' subjective perceptions of the two modes of STST to determine which mode is more suitable for assessing COPD patients in clinical practice.

Patients and methods

Study subjects

A total of 151 consecutive patients with COPD referred to the Department of Respiratory and Critical Care Medicine of the First Hospital of China Medical University and the First Hospital of Dalian Medical University between August 2017 and December 2017 were considered for enrollment in the study. In total, 128 patients with COPD who met the inclusion criterion and did not meet the exclusion criteria were enrolled in the study. The inclusion criterion was a diagnosis of stable-stage COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD), as updated in 2017. The exclusion criteria were as follows: recent exacerbation of COPD within the 4 weeks preceding the test; limitations on walking and performing the sit-to-stand action, including predominant neurological or musculoskeletal limitation (such as hemiplegia and injury or pathology at lower limb); lower limb joint disease or surgery within the 3 months prior to the test; unstable cardiac condition within the 4 months prior to the test[5,14] and long-term oral corticosteroid therapy. The study was approved by the research ethics committees of the First Hospital of China Medical University and the First Hospital of Dalian Medical University, and written informed consent was obtained from all patients.

Pulmonary function and assessment of mMRC and COPD Assessment Test (CAT)

Spirometry, whole-body plethysmography and diffusion capacity measurements were performed according to the American Thoracic Society and the European Respiratory Society guidelines using a Jaeger® MasterScreen system (Jaeger®, Viasys Healthcare GmbH, Hoechberg, Germany). Dyspnea was measured using the Chinese version of the mMRC dyspnea score,[15,16] and health status was measured using the Chinese version of the CAT.[17,18]

QMS

According to the manual provided by the manufacturer and a previous description,[19] QMS was measured using the knee of the patient in 90° flexion. The plate of a push–pull handheld dynamometer (type: microFET2™; Hoggan, Salt Lake City, UT, USA) was placed with its anterior end 5 cm proximal to the lateral malleolus on the anterior surface of the leg, perpendicular to the long axis of the tibia. The participant was then asked to generate a maximal knee extension force to hold the line in the same position for a duration of 4 seconds by pushing against the dynamometer plate to which the investigator applied increasing force with no encouragement. Two more trials, for which the tested side of the limb alternated, were administered following the same procedure, with a rest interval of 30–60 seconds between attempts.[19] The average value of the final two trials on each side was documented as the maximal isometric force generated on each side, and the average forces of the two sides were added to derive the bilateral strength, the QMS.[14,19]

5STS and 30STS

A chair with a hard seat whose floor-to-seat height was 48 cm was stabilized by placing it against a wall. After a researcher explained the requirements and precautions to the participant, the participant was asked to sit with his or her feet exactly flat on the ground and his or her upper limbs folded across his or her chest and then to stand up all the way and sit down again without using his or her arms.[5,9,14,20] The participant was asked to repeat this sit-to-stand action five times as quickly as possible, and the time taken to complete the five repetitions was recorded.[5] Then, the participant was asked to repeat as many of the sit-to-stand actions as possible in 30 seconds, and the maximum number completed was recorded.[9] The minimum value of three trials of the 5STS and the maximum value of two trials of the 30STS were considered the participant's score. Once the participant was unable to perform the motion or asked to suspend the test, the test was terminated. Patients performed three 5STSs and two 30STSs with the appropriate number of intervals ($>$5 minutes).[21,22] After every interval, the participant was asked whether he or she was still tired; if the answer was "no", the tests continued, and if the answer was "yes", the participant would continue to rest until he or she no longer felt tired. Sensations of breathlessness were scored using the Borg scale before starting the STSTs, after three 5STSs and after two 30STSs. SpO_2 and heart rate (HR) were measured continuously using a finger pulse oximeter (type: MD300W1; ChoiceMMed™, Beijing, China); throughout every STST, ΔSpO_2 and ΔHR were calculated. After completing all STSTs, the participants answered the following three questions: 1) are these tests strenuous for you? (if "yes", turn to Question 2 and then turn to Question 3; otherwise, turn directly to Question 3); 2) which one is more strenuous, the 5STS or the 30STS? and 3) would you prefer the 5STS or the 30STS next time?

6MWT

STSTs were conducted prior to the 6MWT. After the participant had rested seated on a chair for a sufficient length of time (>30 minutes), the 6MWT was performed on a 30 m, flat, straight corridor by two experienced investigators using standardized encouragement strategies, and the 6MWD was measured.[23] Continuous measurements of SpO_2 and HR were performed using a finger pulse oximeter mentioned before from 1 minute before the beginning of the 6MWT to the fourth minute after the 6MWT. Additionally, sensations of breathlessness were scored using the Borg scale.

Statistical analyses

All data were analyzed using SPSS 20.0 (SPSS for Windows, version 20.0; IBM Corporation, Armonk, NY, USA). Continuous variables are expressed as the median values and IQRs, as well as the minimum and maximum values. Spearman's rank correlation coefficients were computed to compare the correlations between the STSTs and pulmonary function, including FEV_1, residual volume (RV)/total lung capacity (TLC), 6MWD and QMS. Chi-square tests were used to test for differences in the prediction of a poor 6MWD and the subjective feelings of patients. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. A receiver operating characteristic (ROC) curve analysis and the area under the curve (AUC) were used to determine the optimal cutoff value for the time of the 5STS and the maximal number of the 30STS, particularly for predicting 6MWD <350 m. A *P*-value <0.05 was considered as significant.

Results

Patient characteristics

A total of 128 patients were enrolled in the final analysis. The baseline characteristics of these patients are given in Table 1. Based on the FEV_1% predicted (FEV_1% pred) after the use of a bronchodilator, the severity of airway limitation was divided into the following categories: mild (n=14), moderate (n=60), severe (n=34) and very severe (n=20).

Table 1 Patient characteristics (median [IQR] or number [%])

	Total sample (N=128)	Range
Age, years	65 (11)	34–81
Sex, male:female	86:42	N/A
FEV_1, L	1.23 (1)	0.43–2.89
FEV_1% pred	54 (36.65)	15.0–100.0
FVC, L	2.5 (1.23)	0.97–4.78
FEV_1/FVC, %	51 (17.97)	25.0–69.0
RV, L	3.6 (2.18)	1.34–9.21
TLC, L	6.59 (2.15)	3.68–10.32
RV/TLC, %	59.62 (19)	31.00–91.39
BMI, kg/m²	23.7 (5.45)	15.5–33.7
FFMI, kg/m²	16.68 (3.21)	10.43–22.05
Height, cm	163.25 (11.63)	142.0–180.0
Weight, kg	62 (16.7)	32.5–95.0
mMRC	2 (2)	0–4
≥2, n (%)	72 (56.25)	N/A
CAT	20 (9.25)	0–40
5STS score, seconds	6.57 (1.28)	3.30–15.60
30STS score, repetitions	24 (5.5)	6–43
6MWD, m	361 (109.5)	108–554
QMS[a], kg	7.63 (2.22)	16.33–68.95

Note: [a]No significant difference was observed between the maximal isometric force generated on each side of the lower limb (*P*=0.714).
Abbreviations: N/A, not applicable; FEV_1% pred, FEV percentage predicted; RV, residual volume; TLC, total lung capacity; BMI, body mass index; FFMI, fat-free mass index; CAT, COPD Assessment Test; 5STS, five-repetition sit-to-stand test; 30STS, 30-second sit-to-stand test; 6MWD, 6-minute walk distance; QMS, quadriceps muscle strength.

Correlation of STSTs with other outcome measures (convergent validity of STSTs)

The correlations of the outcomes of the 5STS and the 30STS with the outcomes of the 6MWD (Figure 1), lower extremity muscle strength (Figure 1), pulmonary function and other characteristics of the patients are given in Table 2. In addition, lower extremity muscle strength was measured by assessing QMS. There was a significant strong negative correlation between the 5STS and 30STS scores, as expected (r=–0.783, P<0.001).

Completion rates of different STSTs and subjective feelings of patients

Nine patients (7.0% of total) failed to complete two trials of the 30STS, with two of these patients unable to complete even one trial, while all the patients completed all trials of the 5STS. Among all 128 patients, 88 patients (68.8%) felt that it was strenuous to undergo one or both of the STSTs. Of these 88 patients, most patients (93.2%) felt that the

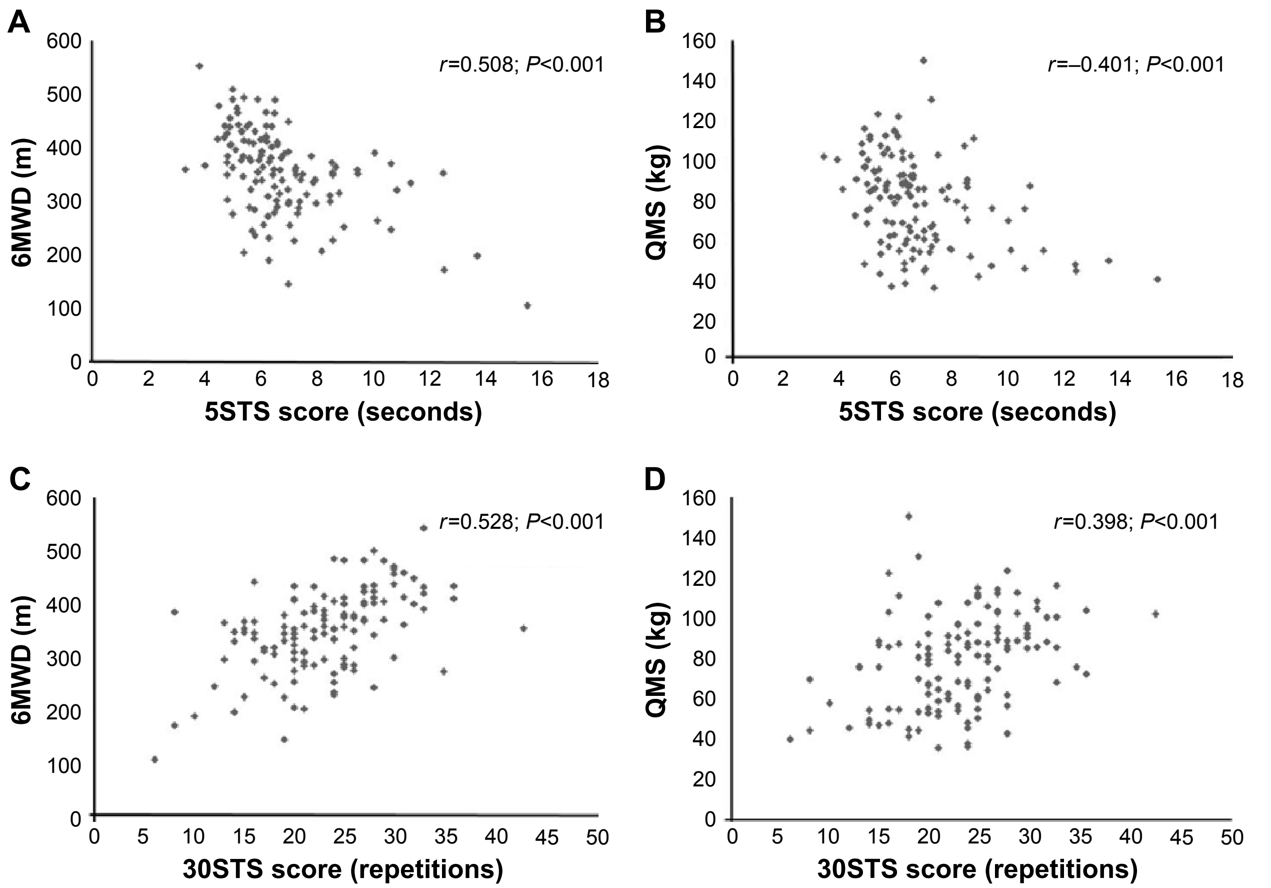

Figure 1 Relationships between the two modes of STSTs and the 6MWD and QMS.

Notes: (**A**) Relationship between the 5STS score and the 6MWD, N=128. (**B**) Relationship between the 5STS score and QMS, N=128. (**C**) Relationship between the 30STS score and the 6MWD, n=126. (**D**) Relationship between 30STS and QMS, n=126.

Abbreviations: STST, sit-to-stand test; QMS, quadriceps muscle strength; 5STS, five-repetition sit-to-stand test; 30STS, 30-second sit-to-stand test; 6MWD, 6-minute walk distance.

30STS was more strenuous than 5STS, while six patients (6.8%) thought that the 5STS was more strenuous. When asked which test was preferred if an STST needed to be performed later, 42.2% (54/128) of patients chose the 5STS, 25.0% (32/128) of patients chose the 30STS, and the rest (32.8%, 42/128) thought both were acceptable. Additionally, the 30STS (mean 4.224) resulted in significantly higher Borg dyspnea scores than the 5STS (mean 3.607; $P<0.001$). ΔHR after 5STS (6±5 beats/min) was significantly lower than ΔHR after 30STS (15±10 beats/min; $P<0.001$), but there was no significant difference between ΔSpO_2 after 5STS (–1%±1%) and ΔSpO_2 after 30STS (–1%±1%).

Table 2 Correlations of STSTs with participant characteristics

	5STS score	*P*-value	30STS score	*P*-value
6MWD	–0.508	<0.001	0.528	<0.001
QMS	–0.401	<0.001	0.398	<0.001
FEV_1% pred	–0.154	0.083	0.309	<0.001
RV/TLC	0.344	0.001	–0.498	<0.001
mMRC	0.289	0.001	–0.408	<0.001
CAT	0.160	0.073	–0.252	0.005
Age	0.301	0.001	–0.297	0.001

Abbreviations: STST, sit-to-stand test; 5STS, five-repetition sit-to-stand test; 30STS, 30-second sit-to-stand test; 6MWD, 6-minute walk distance; QMS, quadriceps muscle strength; FEV_1% pred, FEV_1 percentage predicted; RV, residual volume; TLC, total lung capacity; CAT, COPD Assessment Test.

Different STSTs predict a poor 6MWD

A total of 50 (39.1%) patients had a 6MWD <350 m (median 291 [70] m), with the remaining 78 (60.9%) patients demonstrating 6MWD >350 m (400.5 [73] m). The ROC curve showed that the AUC of the 5STS score predicting poor 6MWD (6MWD <350 m) was 0.731, whereas the AUC of the 30STS score was 0.724 (Figure 2). The cutoff values of the 5STS and 30STS scores were 6.25 and 21.5, respectively. The sensitivity, specificity, PPV and NPV for predicting poor 6MWD analyzed from the cutoff value of the 5STS score were 76.0%, 62.8%, 56.7% and 80.3%, respectively. Our data showed 62.0% sensitivity, 75.0% specificity, 62.0% PPV and 75.0% NPV according to the cutoff value of the 30STS score.

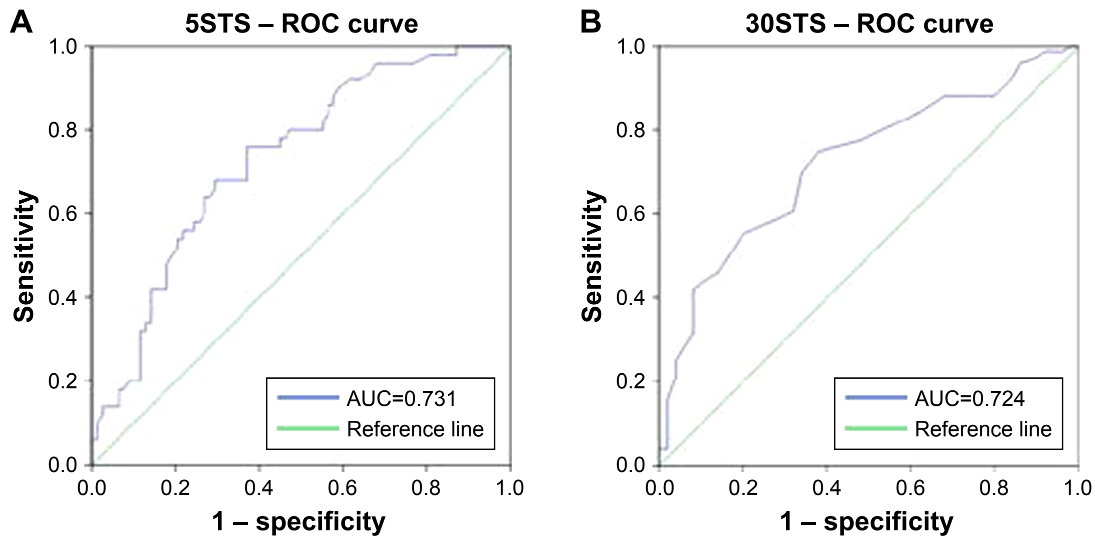

Figure 2 ROC curve analysis of the 5STS score (**A**) and the 30STS score (**B**) for predicting 6MWD <350 m.
Abbreviations: ROC, receiver operating characteristic; 5STS, five-repetition sit-to-stand test; 30STS, 30-second sit-to-stand test; AUC, area under the curve.

Discussion

In recent years, the STST has been introduced to indirectly assess the exercise tolerance and lower extremity skeletal muscle function of patients with COPD due to its ease of operation and convenience in terms of the space required. However, many different modes of STST exist, and there are no uniform standards; therefore, a comparison of these tests is needed to determine which is the best.

In general, the correlations of the 5STS and the 30STS with exercise tolerance, lower extremity muscle strength and pulmonary function in this study were similar to those in previous studies.[5,20,22,24–29] Moderate correlations were observed between the 6MWD and both the 5STS score and the 30STS score (r=–0.508 and r=0.528, respectively), consistent with the results of previous studies.[20,24] Additionally, a similar relationship was observed between the 5STS and incremental shuttle walk (r=–0.59).[5] Although the STST was used to indirectly evaluate lower extremity muscle strength, a past study[5] found only a weak correlation (r=–0.38) between the 5STS and QMS (corresponding data on the correlation between the 30STS and QMS were lacking), similar to our results (r=–0.401 and r=0.398, respectively). In addition, the correlations between the 5STS score and pulmonary function measured by FEV_1% pred and RV/TLC (r=–0.190 and r=0.371, respectively) in our data were not as strong as those between the 30STS score and pulmonary function (r=0.344 and r=–0.498, respectively). The weaker correlations between 5STS and FEV_1% pred may be explained by the shorter time and the smaller amount of physical effort involved in the 5STS. However, in our study, the results of the two STSTs were higher than those in many European and American studies, which ranged from 11.8 to 19 seconds for the 5STS[25–29] and from 10.2 to 13 times for the 30STS.[20,22] A similar difference was also observed in body mass index and fat-free mass index. These differences may result from different studies' inclusion of different ethnicities.

The AUC for the 5STS score was 0.731, which is close to that reported in a previous study (AUC =0.711),[29] and the AUC for the 30STS score was 0.724. The performances using their cutoff values demonstrated that the two STSTs are good tools for predicting a poor 6MWD (<350 m). Nevertheless, in addition to having a strong relationship with elements of a patient's health status, including poor exercise tolerance[30,31] and poor pulmonary function,[12,32] and reflecting the response to pulmonary rehabilitation,[33,34] the role of 6MWT has been demonstrated in predicting long-term mortality[35] and quality of life[12] and in indicating the need for long-term oxygen therapy[36] in COPD patients. The 5STS and 30STS may have potential capacity to predict poor prognosis because 6MWD <350 m is a predictor for high mortality.[1,2] It has been reported that the 1-minute STST is strongly associated with long-term morality;[37] therefore, the role of 5STS and 30STS in predicting prognosis should be evaluated in further study.

A meta-analysis suggested that the short versions of the STST seem relevant to evaluate leg strength, while the longer versions seem suitable for the evaluation of exercise tolerance. However, previous studies have revealed that both 5STS and 30STS could be used to assess exercise capacity.[7,13,38] Further studies with adequate samples need to be performed. Compared with 6MWTs, the STSTs, especially the short versions, are cheap and non-time-consuming and require only basic equipment while being valid, reliable and repeatable.

There were similar correlations of the 5STS and 30STS scores with the 6MWD and QMS, meaning that there was no significant difference in the capacity of the two STST tests to indirectly assess exercise tolerance and lower extremity skeletal muscle strength. Additionally, to the best of our knowledge, few studies of STSTs have taken the subjects' subjective perceptions into consideration. Our study indicates that the 5STS is clearly superior in terms of the subjective perceptions of the participants, which is consistent with reports that fatigue in healthy volunteers' quadriceps after the 30STS was more significant than that after the 5STS[8] and that the 5STS had a higher completion rate, lower ΔHR and a lower Borg dyspnea score than the 30STS because the 5STS requires less energy and time than the 30STS. Considering the abovementioned points, the 5STS has some advantages as a tool to assess the functional status of COPD patients.

However, there were several limitations in the present study. First, the sample size of this study was relatively small, and the participants were limited to the northern Chinese population. Further investigations should be undertaken in different countries to identify differences in various ethnicities; for example, the 5STS score in Chinese COPD patients is lower than that in European patients.[5,14,25,28] Second, this study was cross-sectional, and STST data before and after rehabilitation were not compared; thus, the responses of STSTs to changes in exercise tolerance due to rehabilitation are unknown. Third, data for the 1-minute STST, which have been reported to be a good predictor of increased long-term mortality, were lacking in this study. Our study also could not answer the values of 5STS and 30STS in predicting poor prognosis, which should be evaluated in future studies.

Conclusion

The 5STS and 30STS have similar correlations with poor exercise tolerance and lower extremity skeletal muscle strength. 5STS and 30STS are both reasonable choices for use in clinical and research practices, but 5STS has a better patient experience.

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Author contributions

GH made substantial contributions to the conception or design of the work. All authors contributed toward acquisition of data for the work. GH, X-lL, QZ, YY and Y-xL performed analysis of data for the work. GH, G-qZ, X-lL and QZ carried out interpretation of data for the work. QZ and GH drafted the work. All authors revised the paper critically for important intellectual content. All authors carried out final approval of the version to be published. All authors agree to be 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.

Disclosure

The authors report no conflicts of interest in this work.

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