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Review article

Sit-to-stand tests for COPD: A literature review

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ABSTRACT

Background: Sit-to-stand tests (STST) have recently been developed as easy-to-use field tests to evaluate exercise tolerance in COPD patients. As several modalities of the test exist, this review presents a synthesis of the advantages and limitations of these tools with the objective of helping health professionals to identify the STST modality most appropriate for their patients.
Method: Seventeen original articles dealing with STST in COPD patients have been identified and analysed including eleven on 1min-STST and four other versions of the test (ranging from 5 to 10 repetitions and from 30 s to 3 min). In these studies the results obtained in sit-to-stand tests and the recorded physiological variables have been correlated with the results reported in other functional tests.
Results: A good set of correlations was achieved between STST performances and the results reported in other functional tests, as well as quality of life scores and prognostic index. According to the different STST versions the processes involved in performance are different and consistent with more or less pronounced associations with various physical qualities. These tests are easy to use in a home environment, with excellent metrological properties and responsiveness to pulmonary rehabilitation, even though repetition of the same movement remains a fragmented and restrictive approach to overall physical evaluation.
Conclusions: The STST appears to be a relevant and valid tool to assess functional status in COPD patients. While all versions of STST have been tested in COPD patients, they should not be considered as equivalent or interchangeable.

Contents

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1. Introduction

The daily life of COPD patients is characterized not only by chronic respiratory symptoms but also by exercise intolerance due to their breathlessness. Proper diagnosis and management of this disease consequently includes evaluation of exercise tolerance aimed at improved orientation towards pulmonary rehabilitation [1] [2].

Numerous testing protocols are used throughout the world in different health centers ranging from sophisticated tools with somewhat restricted access such as an equipped lung function laboratory [3] to simpler and more extensively available tools known as "field-testing" [4]. The most widely used tests are the 6-min walk test (6MWT) [5], the incremental shuttle walk test [6], the endurance shuttle walk test [7], the stair climbing test [8] the step test [9] and the sit-to-stand [10] or chair rise test. Up until now, the 6MWT remains the gold standard for the field tests designed to assess exercise tolerance in terms of respiratory manifestations such as dyspnea and desaturation and the aerobic capacity assessed in terms of distance and fatigue. As a simpler and more economical test consuming in terms of time and equipment, the sit-to-stand test (STST) first described in the literature in 1985 has aroused interest among researchers [11]. Based on a simple movement -standing up from a chair, an essential activity of daily living - sit-to-stand and stand-to-sit appear to be gestures relevant to evaluation of independence in elderly people [12]. More broadly, STST could be viewed as a functional capacity assessment tool addressed to disabled patients and providing useful information on their independence/disability in daily life. Numerous versions of STST have been developed, ranging from a few seconds (5 repetitions) to a few minutes. The physical aptitudes mobilized in performance and the overall determinants of performance are consequently quite different, as are exercise-induced symptoms and perceived difficulty.

The objective of this review was to focus on the range of sit-to-stand tests developed and used in cases of COPD to evaluate functional capacity. As they do not seem to share the same properties, advantages and limitations, one may wonder whether or not these different STST modalities are interchangeable and able to evaluate the same functional dimensions and prognostic issues. It also might be interesting to assess whether one of these modalities would be more appropriate to recommend in the daily practice of clinicians caring for of COPD patients.

2. Method

2.1. Data sources and study selection

While the search field was limited mainly to STST in COPD patients, other studies were also consulted in order to more precisely identify overall use of the test. Seventeen original articles dealing with STST in COPD patients have been identified. Among these studies, 11 used the STST in the 1-min version (1 min-STST) [10,13–22], 4 used the 5 or 10 repetitions STST (5R-STST and 10R-STST) [23–26], and the others used the sit-to-stand test in 30 s (30sec-STST) [20,27] and in 3 min (3 min-STST) [28]. All of these studies correlated STST results with a number of other parameters, opening this review to different perspectives facilitating understanding of the STST.

3. Results

3.1. STST overview

Csuka & McCarty [11], first introduced the STST to examine lower extremity muscle strength among 139 healthy adults aged 20–85 years, as a method that could also be applied in patients with neuromuscular diseases. Their version of STST required the subject to perform 10 repetitions of sit-to-stand from a standard chair. Over the years, different versions of the test have been used in different populations. Jones et al. [29] introduced a new version of STST conducted over a time period of 30 s designed to measure lower body strength in 76 older adults. Since then, STST has been referenced more than 80 times in the literature. Currently, there exist multiple, less systematically validated references to STST as a method of exercise testing. The different available modalities of STST are not well-differentiated in terms of their uses. One thing we do know is that it assesses lower extremity muscle strength; more specifically, it has been used to examine functional status among older women [30], to examine balance [31] to predict equations for lower body muscle power [32], to evaluate frailty [33] and to differentiate between fallers and non-fallers [33,34]. Similarly, it has been used in traumatic brain-injured patients to examine the effectiveness of intensive practice of sit-to-stand movement [35].

3.2. STST as compared with other functional tests in COPD

Although this test has been widely accepted as an indicator of functional status among elderly people, there are few data concerning the COPD population [36]. The first studies using STST in COPD patients are quite recent [10]and only over the last ten years has its use increased considerably (Table 1). Several versions can be found, ranging from 30 s [27], 5 repetitions [24] to the 1 min test [10]. Aguilaniu et al. [28] recently introduced a longer, 3-min version of this test in which the 1st minute consisted in pace-defined stand-ups, followed by self-paced repetitions for the next 2 min.

Several studies [10,19,21,22,28,37] have compared the STST with the 6MWT in order to assess its relevance as a tool for evaluation of functional status in COPD patients and healthy subjects. The results obtained by Ozalevli et al. in COPD showed a strong correlation between performance in the 1 min-STST and distance walked in the 6-min ($r = 0.75$, $p < 0.001$). Significant correlations were also found in these two tests between functional performance, dyspnea (at rest and at exercise) and quadriceps strength. However, while heart rate, systolic blood pressure and oxygen saturation were significantly modified during exercise in the 6MWT ($p < 0.05$), this was not the case in 1min-STST, which may consequently appear less hemodynamically stressful. Similar physiological responses were reported in other studies [19,21,22]. Conversely, the physiological responses measured by Aguilaniu et al. at the end of 3 min-STST were similar and interchangeable with those obtained at the end of 6MWT, rendering it, at least as successful as 6MWT as a means of evaluating exercise tolerance [28]. To assess neurophysiological effectiveness, Canuto et al. investigated quadriceps electromyography during STST and 6MWT. They found significant correlations between the two tests that led them to conclude that they both may determine functional status [37].

Other researchers have also confirmed the validity of this test as a surrogate to evaluate muscle strength by presenting good correlations between 5R-STST and handgrip strength ($r = 0.85$) [13] or quadriceps strength ($\beta = 0.50$, 95% CI 0.11 to 0.86) [14]. Applying

Table 1
Studies using STST among COPD.

Reference	Population	Type of STST	Objectives	Methodology	Results	Limitations
Ozalevli et al., 2007	53 COPD age 71 ± 12, 15 Healthy age 63 ± 8	1 min	Utility of STST as compared to 6MWT for evaluation of functional status in COPD	STST and 6MWT in the same afternoon with interval of 2 h between tests	Good correlation between STST and 6MWT for dyspnea, HR, BP, SpO2, age, quality of life, peripheral muscle strength	Breathing pattern and ventilatory demand not evaluated during the test
Regueiro et al., 2009	10 COPD age 71 ± 7.6	1 min	To determine if correlation between the BODE index and ADL or limb performance is possible	Physiological evaluation of Activity in Daily Life (ADL), 6MWT on Treadmill (6MWTT), STST and Hand Grip Strength (HGT)	Negative correlation between BODE score and STST ($r = -0.66$), 6MWTT ($r = -0.86$), and HGT ($r = -0.83$). HGT found to be a predictor of 6MWTT performance.	Small series. Limitation related to the choice and evaluation of ADL performed. Patients with moderate obstruction.
Roig et al., 2011	21 COPD age 71 ± 8 21 Healthy age 67 ± 8.6	5 Repetitions	To compare muscle strength, cross-sectional area (CSA) intramuscular fat (IF) as well as mobility in age-matched COPD patients and healthy persons.	Muscle quality (CSA and IF of thigh) measured by computerized tomography and strength by isokinetic dynamometer. Mobility assessed by STST, 6MWT and SSGS.	Knee extensor strength, CSA of thigh muscle and mobility results are reduced in COPD while IF is twofold greater than in healthy. No associations between muscle and mobility.	Sample size insufficient to detect associations between muscle quality and mobility.
Rocco et al., 2011	22 COPD, age 70 ± 6.7 16 Healthy Control, age 68 ± 6.6	1 min	To assess functional and neurophysiological aspects in COPD and to associate them with the BODE index.	The subjects performed the Static balance test, Tinetti and STST for functional assessment and patellar and Achilles reflex for neurophysiological assessment.	The COPD group had a reduced reflex response, reduced sit-to-stand repetitions, less peripheral muscle strength, and deficits in functional balance and gait compared to the control group. The BODE index correlated with the Tinetti and STST.	Larger sample could demonstrate differences regarding the platform balance measurements and stronger associations of neurophysiological variables with the BODE index.
Van Gestel et al., 2012	70 COPD age 62.4 ± 7.4	1 min	To investigate if 6MWT, STST, HGT and Questionnaire (ZPAQ) can accurately predict physical activity in COPD.	Physical activity by accelerometer for 7 days. Measurement of 6MWT, STST, HGT and ZPAQ	Average no. of steps per day was found to be independently associated with 6MWT, STST and ZPAQ. ROC curve revealed that only 6MWT had a modest predictive capacity with 425 m as cutoff point to predict inactive lifestyle	Small series, given the variance in data. Difficult to identify gold standard measurement of daily physical activity against which the accuracy of different methods could be assessed
Butcher et al., 2012	13 COPD age 74 ± 3.5	30 s	Determine the importance of isometric, concentric and eccentric muscle strength at various velocities in contributing to functional and physiological performance.	Subjects performed: CPET, Quadriceps isokinetic dynamometry, Steep ramp anaerobic test (SRAT), TUG, Stair climb power test (SCPT), and STST.	STST repetitions correlated with concentric contraction and strongly correlated with eccentric contraction. STST also correlated with SRST and SCPT.	Small series. Only patients with moderate COPD, may be different for severe COPD.
Jones et al., 2013	239 COPD age 69 ± 10	5 Repetitions	Determine the reliability, validity and responsiveness of the 5R-STST in COPD patients	50 patients performed STST twice 24–48 h apart. 305 patients underwent 8 week PRP	Excellent test-retest and interobserver reliability with ICC of 0.97 & 0.99 respectively. 5STS sensitivity to PR	Presence of 'floor effect' with 15% unable to attempt the test
Puhan et al., 2013	409 COPD ≥40 years	1 min	Determine the association between STST with mortality, exacerbations and longitudinal HRQoL	STST performed with hands stationary on the hips	Strong association between STST and mortality and HRQoL, but no association with exacerbations	No direct comparison of the predictive properties of STST to 6MWT or other tests
Janssens et al., 2014	18 COPD age 65 ± 7.18 Healthy age 64 ± 7	5 Repetitions	Evaluate whether postural control deficit contributes to decreased STST performance in COPD	5R-STST movements performed with vision occluded. Total duration and duration of each phase recorded.	COPD needed more time to perform the 5R-STST than healthy subjects. COPD exhibited longer stand and stand-to-sit phases than control group.	A lack of detailed kinematic analysis limits interpretation.
Rausch-Osthoff et al., 2014	27 COPD age 62 ± 5	1 min	Evaluate whether strength of quadriceps is associated with exercise performance and Physical ADL.	6MWT, STST, HGT and Quadriceps strength measured. Physical ADL by Bodymedia	Significant association between quadriceps strength and 6MWT, STST and hand grip strength	Small series
Aguilaniu et al., 2014	40 COPD age 62 ± 10	3 min	Evaluate a new modality of STST: the semi-paced 3min-STST.	Succession of tests repeated 10 days later: 6MWT, followed by 3 modalities 3min-STST (pace: 12, 15 and 20 chair rise during the 1st min). ≥20 min between tests.	3min-STST was highly reproducible, and 3min-STST and the 6MWT were interchangeable for most patients	Need of larger population to evaluate ceiling effect
Grosbois et al., 2015	211 COPD age 62 ± 11	10 Repetitions	Evaluate the effect of home-based pulmonary rehabilitation and duration of the improvement.	8 weeks home-based unsupervised rehabilitation program. Evaluation post-RR and 6 and 12 months later by STST, 6MST, TUG, HAD, VSRQ, VQ11, MRF28.	Significant improvement post-RR in all tests. Six months later, all variables still improved except TUG. Twelve months later, persistence of improvement in mood and quality of life variables and 6MST.	Patients not randomized. Home-based PR dependent on the patient's preference and on the distance from PR center.

Table 1 (*continued*)

Reference	Population	Type of STST	Objectives	Methodology	Results	Limitations
Zanini et al., 2015	60 COPD: 30 Strength PR group age 69 ± 5.8 30 Usual PR group age 72 ± 8	30 s and 1 min	Assess peripheral muscle performance by the 30sec-STST and 1min as compared to the 1RM. Evaluate responsiveness to strength or usual programs (PR).	Usual PR: 30–40min on treadmill or cycle ergometer, 12–15 sessions, 3 weeks. Strength PR: (in addition to usual): different peripheral muscle exercises. Evaluation: 30sec and 1min-STST, 1RM and 6MWT before and after PR.	1RM better correlated with 30sec-STST than with 1min-STST ($P < 0.001$ vs 0.005) Strength PR: Improvement in 30sec-STST, 1RM and 6MWT ($p \leq 0.001$), in 1min-STST ($p = 0.005$). Usual PR: Improvement in 30sec-STST ($p = 0.04$), and 6MWT ($p = 0.001$). 30sec-STST better tolerated than 1min.	Small cohort of COPD patients.
Meriem et al., 2015	49 COPD age 67.08 ± 8.4	1 min	Demonstrate the feasibility of STST in comparison of 6MWT among Tunisian COPD patients.	1min-STST and 6MWT performed by the patients. Quadriceps femoris muscle strength was evaluated with manual muscle test.	STST and 6MWT correlated with each other ($p = 0.001$). Lower cardiorespiratory stress after STST than after 6MWT. No correlation between the two tests and quadriceps strength.	Quadriceps strength tested manually, more objective tests should be more appropriate.
Yumrutepe et al., 2015	90 COPD, age 60.2 ± 7.8 57 healthy, age 58.9 ± 6.4	1 min	Determine whether *serum* 25(OH)D levels are related to lung functions, physical performance and balance in COPD patients.	The subjects performed physical performance tests (TUG, gait velocity test, STST, isometric and isokinetic strength), static and dynamic balance tests.	COPD patients had significantly more deficit in physical functions and balance parameters. The repetitions in STST among COPD with vitamin D deficiency (25(OH)) was lower than among those without deficiency.	Evaluation of the association of *serum* (25(OH)) with lung and muscle functions in COPD but not whether the vitamin D supplementation can improve these functions.
Vaidya et al., 2016	48 COPD age 64 ± 9.8	1 min	Evaluate MID of 1min-STST test among COPD patients undergoing PR program.	1min-STST, 6MWT and QMVC were performed before and after PR. MID calculated using distribution and anchor- based methods.	Improvement of 3.8 ± 4.2 ($p < 10^{-3}$) repetitions in 1min-STST after the PR correlated with the change in QMVC ($p = 0.004$) and the distance of 6MWT ($p = 0.006$). MIDs using distribution method were 1.9 (SEM method) and 3.1 (SD method). With the anchor based method, 2.5.	Small number of subjects. Low statistical power. Could be confirmed by testing a larger group.
Crook et al., 2017	52 and 203 COPD in 2 centers, age 65.2 ± 9 and 57.2 ± 7.8 respectively	1 min	To validate the 1-min sit-to-stand test in COPD patients and explore the physiological response to the test.	1-min STST, 6MWT, QMVC and patient- reported outcomes were measured before and after PR. MID calculated using distribution and anchor- based methods.	Improvement of 3.6 ± 4.1 and 4.0 ± 4.3 repetitions was observed in the 2 centers respectively. The 1-min STST showed very little learning effect (ICC of 0.93 (95% CI 0.83–0.97)) and excellent test-retest reliability (ICC of 0.99 (95% CI 0.97–1). MID using distribution method: 0.93 and 2.96 in the 2 centers, respectively, with anchor-based method: 3.19 and 2.11.	Missing data for the 6MWT with cardiorespiratory gas analysis. Absence of maximal ergometry data and SpO_2 at maximal exercise. Exclusion of patients who performed fewer than 5 stand- ups.

ADL: Activity in Daily Life; CPET: cardiopulmonary exercise tests; CSA: cross-sectional area; HAD: Hospital Anxiety and Depression score; HGT: Hand-grip strength Test; HR: Heart Rate; HRQoL: Health-Related Quality of Life; IF: intramuscular fat; MID: minimal important difference; MRF28: Maugeri Respiratory Failure 28; 1RM: One-repetition maximum; PR: programs; QMVC: Quadriceps Maximum Voluntary Contraction; SBP: Systolic Blood Pressure; SCPT: Stair climb power test; SD: Standard Deviation; SEM: Standard Error of Measurement; 6MST: min stepper; 6MWT: 6 Min Walk Tests; SRAT: Steep Ramp Anaerobic Test, SSGS: Self-Selected Gait Speed; TUG: Timed Up and Go; VSRQ: Visual Simplified Respiratory Questionnaire; ZPAQ: Zupten Physical Activity Questionnaire.

1min-STST, Ozalevli et al. [10], Raush-Osthoff et al. [14], Vaidya et al. [21] and Crook et al. [22] showed significant correlations between performances obtained between 1min-STST, quadriceps strength and 6MWT. Similarly, the study by Butcher et al., carried out on COPD, aimed at examining links between muscular performances using different modalities of contraction and functional performance [27]. The number of 30 sec-STST repetitions was found to be strongly associated with overall leg strength and, when compared with other tests, such as the timed up and go and the timed stair climb, to be the functional test the most significantly associated with eccentric contraction ($r = 0.81$). This study also showed that the performance of 30sec-STST was associated with anaerobic power but not with the aerobic performance obtained in the cardiopulmonary exercise test. Finally, Zanini et al. reported correlations between one-repetition maximum (1RM) and STSTs that were stronger with 30sec-STST ($P < 0.001$) than with 1min-STST ($P = 0.005$). Moreover, after specific strength training, improvement in performance was more marked in 30sec-STST ($P < 0.001$) than in 1min-STST ($P < 0.005$) [20].

Postural control is another aspect explored by the STST that influences the recorded performance [38]. In elderly persons, whose balance system is impaired, STST strongly predicts fall risk and functional dependence. In COPD, the research conducted by Janssens et al. [25] showed that 5R-STST performances by patients were poorer than those of healthy age-matched subjects. This result is in agreement with that obtained by Rocco et al. [16] and Yumrutepe et al. [18], whose objective was to determine the functional and neurophysiological alterations caused by COPD. In comparison with healthy age-matched elderly persons, both studies reported poorer strength and weaker results in STST in COPD subjects, who also exhibited a deficit in functional balance and gait. Moreover, analysis of the different phases of the STST movement proposed by Janssens et al. established that COPD patients exhibited a longer stand phase ($p = 0.028$) and stand-to-sit phase ($p = 0.001$), which are the phases requiring the greatest postural control. On the other hand, duration of the sit phase ($p = 0.766$) and the sit-to-stand phase ($p = 0.999$) did not differ in the two groups.

To summarize, the STST appears to be a good tool to assess functional status in COPD patients and to evaluate lower limb activity. It may also be considered as an alternative to other tests such as the frequently used 6MWT. Moreover, the STST seems practical and easy to administer compared to other tests such as cycle ergometer, step test, treadmill test, stair climbing and 6MWT, in COPD patients [39]. However, the different versions of the STST are not all equivalent as the physiologic processes involved in the performance and the other determinants are quite different when the duration of the exercise (from 10 s up to 3min) is longer.

3.3. STST as an indication of morbidity and a tool for survival prognosis

STST has been presented as a tool for survival prognosis in COPD [13]. In a study conducted among 409 COPD patients, Puhan et al. reported lower performances in 1min-STST in patients who had died at 2 years than in patients who were still alive (11.8 rises vs 19.5). The patients who were not able to perform more than 12 rises in 1 min corresponded to their having lower metabolic power, a condition predicting the risk of mortality. A strong association was also found between STST and quality of life in the four domains (dyspnea, fatigue, emotional and mastery) of the standardized version of the Chronic Respiratory Questionnaire (CRQ).

Mortality at 52 months in COPD and disease morbidity can also be assessed by the BODE index, which takes four variables into account: BMI, dyspnea, obstruction and exercise capacity [40]. Regueiro et al. and Rocco et al. showed that 1min-STST performance was inversely correlated with the BODE score ($r = - 0.66$ and -0.59 respectively) [15,16].

It has been established that the ability to exert physical effort influences the survival of COPD patients [41]. Van Gestel et al. [17] focused on this topic by searching a useful and accurate method to estimate daily physical activity and to quantify the level of disability. Different methods were tested and correlated with average steps per day: physical fitness tests, physical activity questionnaire (Zutphen). Significant associations ($p < 0.001$) were found between steps per day and 1min-STST ($r = 0.51$), 6MWT ($r = 0.69$) and Zutphen Physical Activity Questionnaire ($r = 0.5$). However, ROC analysis demonstrated that these tests were not reliable as a means of identifying an extremely inactive lifestyle.

3.4. Validity and interest of the STST

In several studies, the repeatability of the STST has been evaluated. Jones et al. [24] tested the 5R-STST on 239 COPD patients and found it to be perfectly reproducible with test-retest and interobserver reliability correlation coefficient of 0.97 and 0.99 respectively. Their research also underlined the responsiveness of the test to a pulmonary rehabilitation program and the minimal clinically important difference was suggested to be 1.7 s. Similarly, the study on 1min-STST by Vaidya et al. [21] found it to be effective as a means of measuring the efficiency of a pulmonary rehabilitation program. Using the distribution-based method, a minimal important difference of 1.9 (standard error of measurement method) or 3.1 (standard deviation method) was found. With 6MWD as the anchor, the minimal important difference was found to be 2.5, showing 3 repetitions to be the improvement consistent with the physical benefits of a pulmonary rehabilitation program. This result was recently validated by a multicenter study of Crook et al. [22], who also considered 3 repetitions as the minimal important difference. As regards a deeper aspect of the efficiency of the test, they found a very small learning effect with ICC at 0.93 (95%CI 0.83–0.97) and excellent test-retest reliability with ICC at 0.99 (95% CI 0.97–1), findings strongly suggesting that the test is capable of giving reliable results when performed only once.

In the most recent version of the STST developed for COPD patients, i.e. the 3min-STST [28], in which the first minute is pace-defined, followed by 2 min of self-paced sit-to-stand repetitions, good repeatability was reported (ICC >0.80).

4. Discussion

The purpose of this study was to review the studies on use of the increasingly popular STST in COPD patients. Different versions of the test have been applied, ranging from short versions (5–10 repetitions), middle duration (30sec–1 min), to the longer version (3 min) recently proposed by Aguilaniu et al. [28]. While all the current versions of the test are mentioned in the studies, the 1min-STST is the most widely used (11/17 studies). Findings indicate good correlations between performances obtained by STST and the results reported in other functional tests or prognostic index. The short versions of STST seem relevant to evaluate leg strength, while the longer versions seem suitable for evaluation of exercise tolerance. The main advantage of STST is that it requires only simple equipment and an ordinary movement, its main limit being maximal repetition of a gesture by worn-out joints.

4.1. Field test and economic factors

COPD prevalence is increasing, as is the number of patients included in rehabilitation programs [42]. In this context, the cost of the evaluations to be performed before and after rehabilitation has become an important economic variable to take into account in rehabilitation centers. Physical tests conducted in a laboratory require technologically sophisticated equipment and qualified personnel to administer them, making them more expensive [13,16,24]. As a result, they often remain unused. On the other hand, field tests are cheaper but are not routinely used, due either to a need for space (as in walk tests) or because they are too long to perform, and it is well-known that time is as valuable as money. Therefore, a key objective is to develop functional tests which are simple, cheap, nontime-consuming, requiring only basic equipment but at the same time valid, reliable and repeatable. They should be able to assess physical performances broadly and, more importantly, accurately while predicting the evolution of the disease! Is all of this rationally possible?

4.2. Interest and limits of STST

STST has been presented as a tool focused on a common activity in daily life [24,43]. Even when the amount of activity undertaken by COPD patients declines, thereby reducing their walking perimeters, patients may still sit and stand several times a day. This is an ordinary movement that can be easily performed in many clinical settings. However, even if standing from sitting is a very common, even essential activity in daily life, patients do not usually perform this exercise quickly and repeatedly during 1, 2, or 3 min. Maximal repetition of the same movement during several minutes is not always considered safe and could induce pain or injury in worn-out joints such as the knees, as well as the back, tendons and muscles that are generally weakened in old persons. Jones et al. found that up to 15% of their cohort were unable to attempt or complete the 5R-STST.

To set up the STST, all you need is simple and cheap equipment: a chair. Although the height of the chair is standardized [12], in most studies the measurement of the seat to the ground is 46–48 cm. Nevertheless, the standardization of the chair has no real interest if the height of the subjects and the length of their limbs vary. What is particularly important is the height of the seat adapted to the morphology of the individual performing the test. Chorin et al. demonstrated that the most reliable condition to evaluate performance during STST was a position with a 90° knee joint angle, with arms crossed over the chest [44]. Lower height of the chair could induce a closing of joint angles (hip, knee and ankle), which would lead to an increase in the force that the muscles (extensor and flexor) have to develop during the movement. The weight of the subject is another linked factor that may modify the difficulty of the test, as the forces put into play are greater in heavy subjects.

Use or non-use of the arms in the STST also demands standardization insofar as it has been demonstrated that an armrest influences the motion and modifies the pace of the subject [45]. Conversely, when the arms are not used for the movement, it seems that their position (hand on knees, arm crossed on chest) has no effect on the force put into play. STST standardization is even more important in the elderly in whom aging induces the development of parasitic or secondary movements to compensate for the weak muscles.

4.3. What does STST really measure?

As previously presented, several versions of STST exist, ranging from the 5R-STST, the shorter version that lasts less than 10 s to the 3-min version. If the test is performed maximally by the subjects, these different versions do not necessarily reflect the same physical aptitudes. The shorter versions should be relevant as a measurement of physical qualities that are expressed over a short time interval, such as strength and speed, and which favor velocity as coordination or postural control. When the duration of the test is increased, as in the 10R-STST or in the 30sec-STST, the test evaluates the ability to endure at a high power, speed or velocity muscular endurance or strength endurance. In these cases, anaerobic processes are solicited, as is neuromuscular speed. For the longer versions of STST (1min or 2 min), lactic anaerobic processes begin to contribute, while for the 3 min version, aerobic process (power/endurance) is also involved. Thus, it seems obvious that the different versions of STST are not interchangeable. While functional performance measured by any STST is often associated with a large panel of physical qualities, the most pronounced associations depend on the version of STST used.

The next question pertains to the information given by each STST version. Overall, without making a distinction on the population studied or the STST version used, the performance achieved in this test may be an indicator of lower limb strength, balance, postural control, mobility, exercise capacity, exercise tolerance, dyspnea, quality of life, morbidity, mortality or even cognitive function [46]. However, as various modalities of STST exist, based on studies assessed in COPD, does STST give a specific insight or only an overall assessment due to the multiple processes that influence the performance? Studies applying 5R-STST in COPD patients concluded that this test was able to highlight a deficit in muscle strength [26] and, more precisely, quadriceps weakness [25], thereby supporting its discriminative validity [24]. 5R-STST should also be able to identify significant impairment in exercise capacity [24] and reveal mobility impairment [26] and limited muscle and postural control in COPD patients [25]. Jones et al. reported correlation with health-related quality of life and dyspnea. These conclusions are based mostly on significant correlations that were sometimes only modest, as was the case with lower limb strength [12,24]. The conclusions were indirect, supporting the potential use of 5R-STST as a simple functional outcome measure.

Using a slightly longer STST version (30sec-STST), Butcher et al. highlighted a strong association of STST performance with anaerobic exercise performance and eccentric muscle contraction, results that can be explained respectively by the duration of this test (30sec) and by the multiple eccentric contractions that occur when a person moves from stand to sit position. On the other hand, they did not find any relationship between the 30sec-STST performance and aerobic power, a result coherent with the duration of a test that mainly involves anaerobic process. They concluded that in COPD patients, the ability of the leg muscles to produce work is underestimated by aerobic power tests, whereas anaerobic performance reflects both high-level functional performance and qualities of muscle strength or power.

Several studies using 1min-STST have regrouped this test with others such as 6MWT (in fact, an aerobic endurance test) and handgrip test (a maximal strength test) in a class aimed at evaluating exercise capacity/tolerance or daily activity [14,15]. Correlations revealed significant associations between exercise performance quantified by field tests (6MWT and 1min-STST) and maximal quadriceps strength measured by laboratory devices [14,21]. However, correlations with strength do not necessarily imply that the two tests precisely evaluate strength and strength alone; they simply confirm that the field tests are a form of functional indication that solicits several physical qualities. Moreover, they are not reliable as identifiers of an extremely inactive life style [17]. By comparing physiological variables recorded during 1min-STST to those obtained during 6MWT, Ozalevli et al. [10] demonstrated that hemodynamical stress differed, thereby rendering these tests cumulative but not commutable. Conversely, by evaluating the longer STST version (3min-STST) Aguilaniu et al. [28] demonstrated that physiological responses were close to those obtained during 6MWT and consequently interchangeable.

4.4. Review limitations

Among the studies dealing with STST in COPD, patients, most (11/17) relied on 1min version while those using longer or shorter versions were fewer. Some of the shorter versions, such as the version based on 5 or 10 repetitions are nonetheless related, and additional studies on 3min-STST should be developed. Sample sizes were also heterogeneous with quite limited series in some studies and large cohorts (400+) in others.

Because studies dealing with STST in COPD have been eclectic and performed with various objectives, the variables measured were often different, and they did not always include a control group. Analysis and synthesis of our findings was correspondingly complex; this was one reason for its limitations.

In conclusion, while all versions of STST have been tested in COPD patients, the most frequently used is the 1min-STST. STSTs are field tests whose results should not be taken as a measurement of a specific physical quality but rather as an indicator of functional capacity and exercise tolerance. According to the different versions of STST with their variable length, speed and power, the processes involved in performance are diversified and consistent with more or less pronounced associations with the different physical qualities. The shorter STST version provides insight in maximal limb strength and coordination, the longer version is more likely to inform about aerobic capacity and cardio-respiratory exercise tolerance, and the medium-sized version focuses on muscular endurance. They should be considered as neither equivalent nor interchangeable. The main interest of STST resides in its economic aspect. Its main limit consists in repetition of the same movement, which may be somewhat unsafe in the ailing elderly.

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