

The Remote Assessment of Physical Capacities of Patients with COPD, Feasibility and Learning Effect of the 5-Repetition Sit-to-Stand Test (5STS)

Espérance Moine^{1,*}, Nicolas Oliver^{1,2,*}, François Alexandre¹, Virginie Molinier¹, Florine Barbaste², Maurice Hayot³, Nelly Heraud¹

¹Scientific and Health Research Department of Clariane, Lodève, France; ²Clinique du Souffle La Vallonie, Inicea, Lodève, France; ³Phymedexp, University of Montpellier, INSERM, CNRS, CHU Montpellier, Montpellier, France

*These authors contributed equally to this work

Correspondence: Espérance Moine, Clinique du Souffle la Vallonie, 800 Avenue Joseph Vallot, Lodève, 34700, France, Email esperance.moine@clariane.fr

Purpose: With the rise of telehealth and telemonitoring respiratory chronic diseases, having a simple and reliable remote physical capacity assessment test is an important issue. The 5-repetition sit-to-stand test (5STS) is a good candidate, but two aspects must be studied before considering its remote implementation, the assessment of a learning effect (LE) which conditions administration and interpretation of the test, and its feasibility via videoconference.

Patients and Methods: 40 stable patients with COPD were enrolled. From home, they performed 5STS tests during three visits (V1–V3) of five trials (T1–T5), each with a 5-min rest period. V2 took place 24–48h after V1 and V3 took place one month later. To assess remote feasibility, reasons for non-inclusion related to digital technology use, connection failures, adverse events, and patient satisfaction were recorded. LE was assessed by timing the 5STS tests performed at each visit and corresponds to an improvement in performance over repeated trials.

Results: No adverse events were reported. 19% of patients were not enrolled due to a hardware issue or insufficient computer skills. 3% of visits were cancelled due to connection/camera failure. Test acceptability showed an overall satisfaction rate of 96%. Repeatability was excellent with ICC [CI95] of 0.91 [0.85–0.95] at V1; 0.98 [0.96–0.99] at V2; and 0.95 [0.91–0.97] at V3. The smallest detectable change at 95% was 0.99 seconds. Friedman ANOVA of V1 confirmed a LE, with significant differences between the first trial (V1T1) and V1T3, V1T4 and V1T5, and between V1T2 and V1T5 (all $p < 0.01$). The median difference between V1T1 and V1T5 was $-1.50 [-2.09/-0.81]$ seconds. Inter-visit comparison between V1 and V2 showed no difference between V1T5 and any of the trials in V2, confirming a stabilisation of LE after five trials.

Conclusion: The remote 5STS is a feasible, safe, and reliable test. Performing five trials is essential to monitor the LE and to avoid underestimating initial physical condition of COPD patients at the start of an exercise training programme.

Trial Registration: NCT05852821.

Keywords: 5-repetition Sit-to-stand test, learning effect, COPD, remote evaluation, videoconference

Introduction

The development of telehealth, defined as the provision of healthcare using information and communication technologies,¹ has accelerated dramatically in recent years, driven by the COVID-19 pandemic.² In the context of chronic respiratory disease, remote monitoring has the advantage of limiting travel and facilitating access to care for all patients, with the aim of providing clinical support equivalent to face-to-face monitoring. In addition, it can contribute to earlier detection of complications, better monitoring of disease progression,³ and easier adherence to treatment,⁴ leading to a reduction in hospital admissions.^{5,6} It is therefore essential that as many in-person interventions as possible have a remote alternative. One of the areas of concern is the remote assessment of exercise capacity, both for safety reasons

(falls, cardiac risk, etc.) and for feasibility reasons (equipment, instructions, etc). Indeed, exercise capacity is a key indicator in the management of chronic respiratory diseases, as it is the main predictor of exacerbation risk and life expectancy,^{7–9} and the central outcome of pulmonary rehabilitation and exercise training programmes.^{10,11} Without a reliable, feasible and validated remote functional test, full remote support for chronic respiratory patients will simply be impossible, making face-to-face visits a minimum requirement for this type of assessment and thus excluding some patients from remote support (eg, those living far from the medical centre).

Among the available tests for functional assessment in COPD patients, five have already been conducted remotely and/or at home, the timed-up and go test (TUG),¹² the 5-repetitions sit-to-stand test (5STS),¹² the 6-minute walk test (6MWT),¹³ the 3-minute step test (3MST),¹⁴ and the hand-grip test (HG).¹⁵ While these five tests share good metrological qualities, the 5STS has complementary qualities that make it stand out.^{16,17} Indeed, its instructions are simple, it requires little time, minimal space and no specific equipment.^{18,19} These specific features give it the best potential in terms of feasibility at home and remotely.

However, its remote and routine use in patient monitoring is hampered by two concerns that need to be addressed. The first concern is linked to the controversy over a possible learning effect (LE) in the literature. A LE is defined as any improvement resulting from simply repeating the test under the same conditions. LE is a well-known problem in functional testing and has been reported for example for 6MWT^{20,21} or 1-minute STS.^{22,23} The need to resolve this controversy is all the more crucial given the potential clinical impact of a LE. In practice, an uncontrolled LE (ie, an inadequate number of trials needed to eliminate the effect) could lead to an underestimation of the initial performance and, possibly, to an overestimation of the benefit of an exercise programme. In the case of 5STS in COPD patients, some authors have suggested the existence of a LE,¹² while others have reported contrary findings.¹⁹ Unfortunately, none of these studies were designed to conclude on the presence or absence of a LE, specifically due to the bias of an inadequate number of trials. Indeed, in the field of cognitive testing, where LE is also a major issue, it has been shown that up to 5 tests may be required before performance stabilises.²⁴ Therefore, with the current state of knowledge, it is not possible to conclude on a potential LE for the 5STS and on the exact number of tests required to control this effect. The second major limitation to the deployment of remote 5STS is the lack of data on the feasibility of 5STS in videoconferencing. Indeed, it is crucial to assess both the metrological properties and the level of patient satisfaction and acceptance of this remote test before considering its routine use. In addition, safety concerns, the prevalence of patients who can effectively engage in this type of assessment via videoconferencing, and the likelihood of connection disruptions are important criteria for evaluating its feasibility. Several studies have reported on elements such as reliability, safety or technical feasibility of remote 5STS in different populations.^{12,25–28} However, none of these studies has provided a detailed overview of all these parameters, as well as patient satisfaction, in the context of remote functional assessment in COPD patients.

Therefore, the main objective of this study was to investigate a potential LE for the 5STS test by assessing changes in test time between the first and the last trial in a set of five trials, conducted remotely via videoconference in COPD patients. The secondary objectives regarding LE were, i) to determine the number of trials required to control LE during the first set of trials, ii) to assess the persistence of LE after 24–48h, and iii) to assess LE after one month. We also aimed to evaluate the feasibility of remote assessment of 5STS with a focus on safety and patient acceptability.

Materials and Methods

This prospective study was conducted between April 2023 and January 2024. All patients enrolled provided oral informed consent prior to participation in the study. The procedures were approved by an independent French ethics committee (named “Comité de Protection des Personnes Est-1” at Dijon, reference number, 23.00672.000176) and complied with the principles of the Declaration of Helsinki for human experimentation. The protocol was registered on clinicaltrials.gov (Clinical Trial registration number, NCT05852821).

Participants

Patients with stable COPD diagnosed according to the Global initiative for chronic Obstructive Lung Disease (GOLD) guidelines were recruited among patients who have followed a pulmonary rehabilitation (PR) programme in the Clinique du Souffle La Vallonie (Lodève, France).²⁹ All patients included were adults with home internet access and a videoconferencing

device. Exclusion criteria were as follows, acute exacerbation within the last four weeks, physical inability to stand up from a chair and sit back down without assistance, significant and unstable cardiovascular disease, any acute or chronic condition limiting the performance of a functional test (including psychiatric, neurological, orthopaedic or cognitive disorders), inability or difficulty using digital tools, participation in another protocol involving a period of relative exclusion, adults protected by law or under guardianship, individuals deprived of liberty by a judicial or administrative decision, current or planned pregnancy, breastfeeding, and individuals not covered by social security.

Protocol

The study protocol is detailed in Figure 1. Patients were recruited at the end of a four-week stay in the PR centre. The inclusion visit (V0) was conducted in person, 48 to 72 hours before discharge from the centre. After obtaining oral consent and validating the inclusion criteria, anthropometric and medical data were retrieved and an appointment using the videoconferencing platform Microsoft Teams® (Microsoft 365) was scheduled for the first remotely visit (V1), which took place at home, 3 to 14 days after discharge. During V1, five trials of 5STS were performed, the patient had to rest while seated for 5 minutes between each trial. Sensation of fatigue was assessed before each trial using a Borg Scale. At the end of V1, a new appointment was scheduled for the second remote visit (V2), 24 to 48 hours after V1. The V2 procedure was identical to that of V1. The final visit (V3) took place one month after V2. It followed the same procedure as the first two visits and concluded with a satisfaction questionnaire, after which patients were informed of the end of their participation in the study. Patients could be assisted by a third party for videoconferencing if necessary and possible. A safety procedure was established, including telephone contact with a nearby person who could intervene if needed. All assessments were conducted by the same evaluator and lasted between 30 and 45 minutes. No personal data were stored on the Microsoft Teams® videoconferencing platform.

Procedures and Data Collection

Clinical Data

Data on patient demographics such as age, gender, weight, height, and clinical respiratory markers such as post-bronchodilator forced expiratory volume in one second (FEV₁), forced vital capacity (FVC) and BODE index, were collected during the inclusion visit.

Feasibility Data

Among the selected patients, reasons for non-inclusion related to the use of digital technology were assessed, lack of suitable equipment or internet connection, insufficient perceived computer skills. At each visit, the number of connection failures was recorded, as along with the number of tests not performed and the reasons for non-performance. To assess patient safety, the number of adverse events was reported.

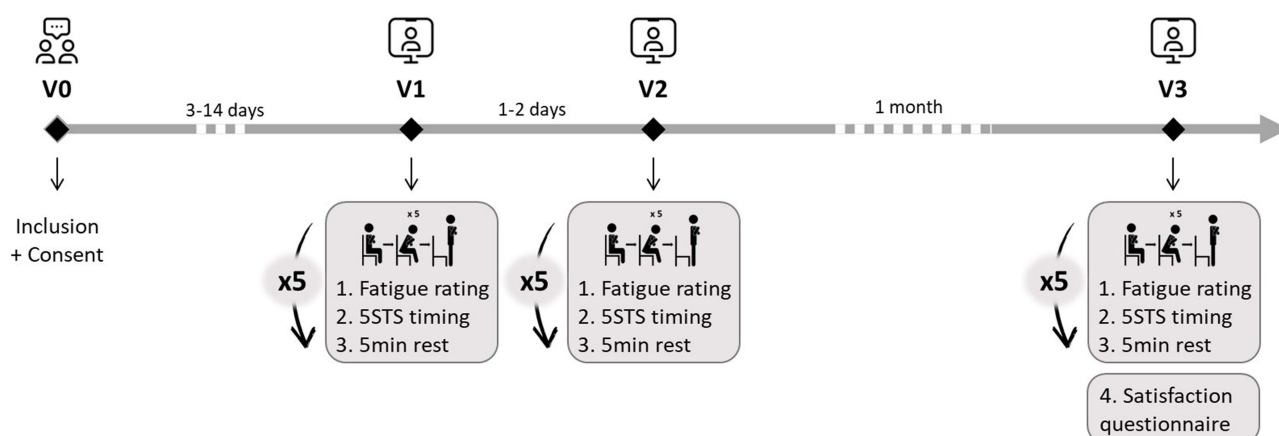


Figure 1 Study protocol. V0, visit 0; V1, visit 1; V2, visit 2; V3, visit3; 5STS, five repetitions sit-to-stand test; , physical meeting in the centre; , remote meeting via videoconference.

5STS Procedure

The 5STS tests did not require any specific equipment other than an armless chair with a straight back and a hard seat. The height of the patient's chair was measured prior to the study to ensure compliance with current recommendations (44–47 cm), and the patient was required to use the same chair throughout the study. Five trials of 5STS were performed at each visit and the patient was instructed to rest in a seated position for 5 minutes between each trial. To explain the test procedure, the assessor gave the following instructions before the first trial,

"You will need to stand up completely from the chair to a fully upright position, with your legs straight, and sit back down firmly without leaning back. You will repeat this five times, as fast as possible and without using your arms. You will start immediately after the following signal, Ready? Set, Go!"

Timing with a stopwatch was started on the command "go" and stopped at the end of the fifth completed stand; the time taken was recorded as the participant's score.¹⁹ Before the first trial, the assessor checked that the chair was stabilised against a wall and that the digital device was correctly positioned to ensure a reliable measurement of the test.

Learning Effect Assessment

The LE is defined as any improvement resulting from simply repeating the test under the same conditions. Herein, LE was assessed by timing the 5STS trials performed during each visit of the protocol, and corresponds to an improvement in the 5STS performance (ie, a reduction in the time to complete the test). First, the presence of a LE during the first visit of the protocol was evaluated by measuring the difference in time between the 1st and the 5th test (delta VIT5-VIT1). The stabilisation of the LE during visit 1 was then evaluated by comparing time differences among the five trials. The persistence of LE at 24–48h was then assessed by comparing time differences between trials at visit 1 and trials at visit 2. Finally, presence of a LE after one month was assessed through trials of visit 3. Visits 1 and 2 are not compared with visit 3 because of the time interval that could introduce bias, such as medical events or a change in physical abilities. To rule out any effect related to an increase in fatigue during the repetition of the test, perceived fatigue was recorded before each 5STS trial using a Borg scale.

Patient Satisfaction

At the end of the third visit, patients' opinions were collected through a satisfaction questionnaire. In the absence of a validated questionnaire specifically designed to assess patient satisfaction in the specific context of our study, we adopted the approach of Levy et al,³⁰ by adapting the Telehealth satisfaction scale questionnaire³¹ to our research context. This questionnaire assessed satisfaction on the following items, ease of connection, image quality, sound quality, privacy protection, understanding of instructions, the proposed test and overall experience of patient participation. For each item, participants were asked whether they agreed or disagreed with the statement using a five-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A higher total score indicated greater satisfaction. Finally, two *yes/no* questions were used to assess their apprehension about taking this test remotely and their willingness to use this evaluation method in the future.

Statistical Analyses

All statistical analyses were performed using Statistica software (TIBCO Software Inc., 2018; version 13.5.0.17) and R Studio Software (version 4.1.2), using *readxl*, *dplyr* and *tidyverse* packages.

Descriptive statistics were used to characterise the study population, feasibility, and satisfaction analyses. Data are reported as means and standard deviation (SD) in cases of normal distribution (test with Q-Qplot, Shapiro–Wilk, Skewness, Kurtosis); otherwise, data are presented as medians [lower quartile (LQ)/upper quartile (UQ)].

To examine repeatability of the remote 5STS tests, test-retest reliability was first assessed using intraclass correlation coefficients (ICCs) with two-way mixed-effects models.³² ICCs were reported with their 95% confidence interval (CI95) for each visit. A Bland-Altman plot was used to provide a graphical representation of repeatability at visit 1. To ensure that the observed difference was not due to internal variability of the 5STS, the smallest detectable change (SDC) of the study population was calculated using the following formula, $SEM \times 1.96 \times \sqrt{2}$ where SEM (standard error of the mean) represents the error in the sample of times measured during V1 for all patients. The SEM value indicates the variability of

the measurements in our data sample and was calculated using the following formula, $SEM = SD * \sqrt{(1 - ICC)}$, where SD is the standard-deviation.

For the evaluation of learning effect, the times of the repeated 5STS trials were compared. First, a Mauchly's test of Sphericity was performed on the dataset to validate the use of a one-way repeated measures analysis of variance (ANOVA). If the assumption of sphericity was met, an ANOVA was performed, otherwise a Friedman repeated measures ANOVA for non-parametric data was used, to determine whether there was a statistically significant difference between the 5STS test times across all visits. In the case of significant difference, a Sign test was conducted to compare pairwise the times between the different trials. A p-value < 0.05 was considered statistically significant. The evolution of fatigue between 5STS trials was assessed using the same statistical procedure as described above for the learning effect.

Results

Population Characteristics at Baseline

Among the 93 screened COPD patients, 52 were eligible (detailed in [Figure 2](#)). Ten declined to participate and two were not available for testing during the following week. Of the 40 patients included, six withdrew from the study before the first evaluation and one patient had aberrant data. Thirty-three COPD patients participating in a centre-based PR programme were enrolled before discharge. Descriptive characteristics of the participants are presented in [Table 1](#).

Feasibility and Repeatability of Remote 5STS

No adverse events were reported in any of the 5STS trials conducted in this study.

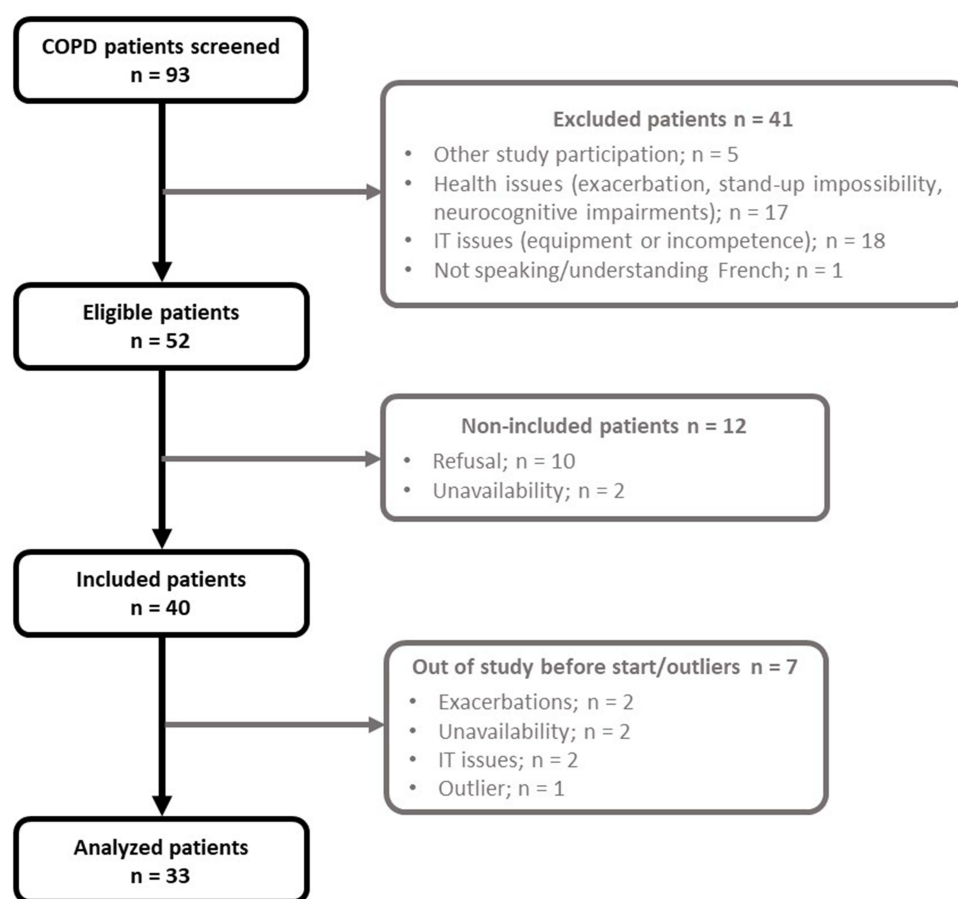


Figure 2 Flowchart of the study.

Table 1 Descriptive Characteristics of the Sample

	Mean (SD)/Median [LQ/UQ]
Baseline characteristics	
Patients	n = 33
Age (years)	63.2 (8.9)
Female sex, n (%)	17 (51.5)
BMI (kg.m ⁻²)	26.2 (6.2)
Respiratory parameters	
FEV ₁ (% predicted)	45.6 (19.7)
FVC (% predicted)	78.3 (24.5)
FEV ₁ /FVC (%)	50.0 (16.2)
Bode Index	Q1 = 14 (42.4%); Q2 = 12 (36.4%); Q3 = 4 (12.1%); Q4 = 3 (9.1%)
GOLD category	
I	1 (3.0%)
II	13 (39.4%)
III	10 (30.3%)
IV	9 (27.3%)

Abbreviations. BMI, Body mass index; FEV₁, Forced expiratory volume in one second; FVC, Forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; Q1, Bode score between 0–2; Q2, Bode score between 3–4; Q3, Bode score between 5–6; Q4, Bode score between 7–10.

Regarding the use of digital tools, 18 out of 93 pre-selected patients were excluded before inclusion due to hardware issues (absence or malfunction) or insufficient computer skills. Of the 99 scheduled visits (3 visits per patient), only 3 (3%) were cancelled due to connection or camera failure. During the completed visits, 4 out of 447 tests (1%) could not be measured due to video quality issues. The acceptability of the test, as measured by the satisfaction questionnaire at the final visit (visit 3), showed an overall satisfaction rate of 96% (n=28). 14% of patients reported apprehension prior to first testing. However, 100% were comfortable with routine use.

The remote 5STS test via videoconference showed excellent repeatability with an ICC of 0.91 [CI95 0.85 to 0.95] at visit 1, 0.98 [CI95 0.96 to 0.99] at visit 2, and 0.95 [CI95 0.91 to 0.97] at visit 3. The SDC95% of the study population was 0.99 sec. Visual inspection of the Bland-Altman plot (Figure 3) revealed a trend towards improvement in test performance between V1T1 and V1T5, with a positive difference in 91% of patients (30/33). The differences in time between two consecutive trials of V1 suggest a decrease in the average bias as the tests are repeated (Figure 4).

Learning Effect of the 5STS

The median times recorded for the 5STS trials of the three visits, the intra-visit comparisons of the 5STS times, and the median fatigue level before each trial are presented in Table 2.

The Friedman ANOVA of V1 highlights an effect of the trial repetition (N = 28, df = 4, $\chi^2 = 32.31$, $p < 0.0001$). Post-hoc analysis confirmed a significant difference between the first trial (V1T1) and V1T3, V1T4 and V1T5 ($p < 0.01$, $p < 0.001$ and $p < 0.0001$, respectively). The median difference between V1T1 and V1T5 was $-1.50 [-2.09/-0.81]$ seconds, which is higher than the calculated SDC95 for our population (0.99 seconds). Individually, 70% of patients (23/33) improved their 5STS time between V1T1 and V1T5 (delta V1T5-V1T1) more than the calculated SDC95. In addition, V1T5 was significantly different from V1T2 ($p < 0.01$). The Friedman analysis of the V2 trials showed an effect of the trial repetition (N = 29, df = 4, $\chi^2 = 12.74$) with a significant difference between V2T1 and V2T4, V2T5 and between V2T2 and V2T4 (all $p < 0.05$). The Friedman analysis of the V3 trials showed an effect of the trial repetition (N = 26, df = 4, $\chi^2 = 10.00$) with a significant difference between V3T1 and V3T3, V3T4 and V3T5 (all $p < 0.05$).

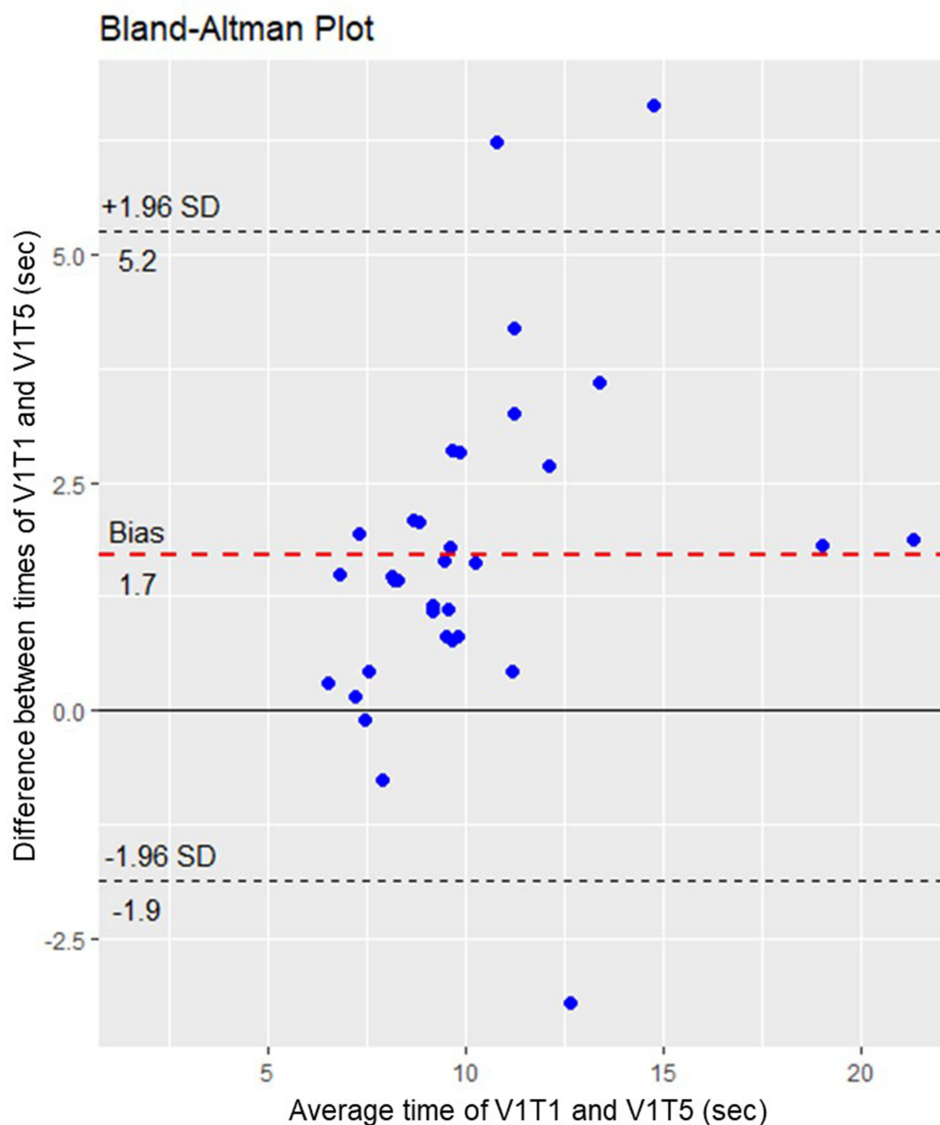


Figure 3 Bland-Altman graphical representation of the difference between the first trial (V1T1) and the fifth trial (V1T5) of 5STS during visit 1. The means on the x axis are the average of the two trials, and the differences between the two scores are in the y axis. (n = 33).

The inter-visit comparison between visit 1 and visit 2 is shown in [Figure 5](#). The Friedman analysis of V1 and V2 highlights an effect of the visit ($N = 25$, $df = 9$, $\chi^2 = 68.64$, $p < 0.0001$). V1T5 is the only trial in V1 that shows no significant difference from all the trials in V2 ([Figure 5](#)).

Regarding fatigue, no significant differences were observed between trials for V1, V2 and V3 ([Table 2](#)).

Discussion

The aims of this study were to assess the feasibility of administering the 5STS test remotely via videoconference, and to investigate a potential learning effect for this functional test. In terms of feasibility, no adverse events occurred, technical issues were limited, and a high level of satisfaction was achieved. Repeatability was excellent with ICC values > 0.90 for each visit in the protocol. The significant improvement in performance over the course of the V1 trials confirms the existence of a LE for the 5STS. This progression was observed up to the fifth trial, but no significant improvement was found between the fifth trial of V1 and the trials of V2. A LE was once again observed one month later during V3.

First, no adverse events occurred in our study and no falls were reported. It is important to note that precautions were taken to limit risk, including the use of the standard procedure for the 5STS assessment (ie, leaning the back of the chair

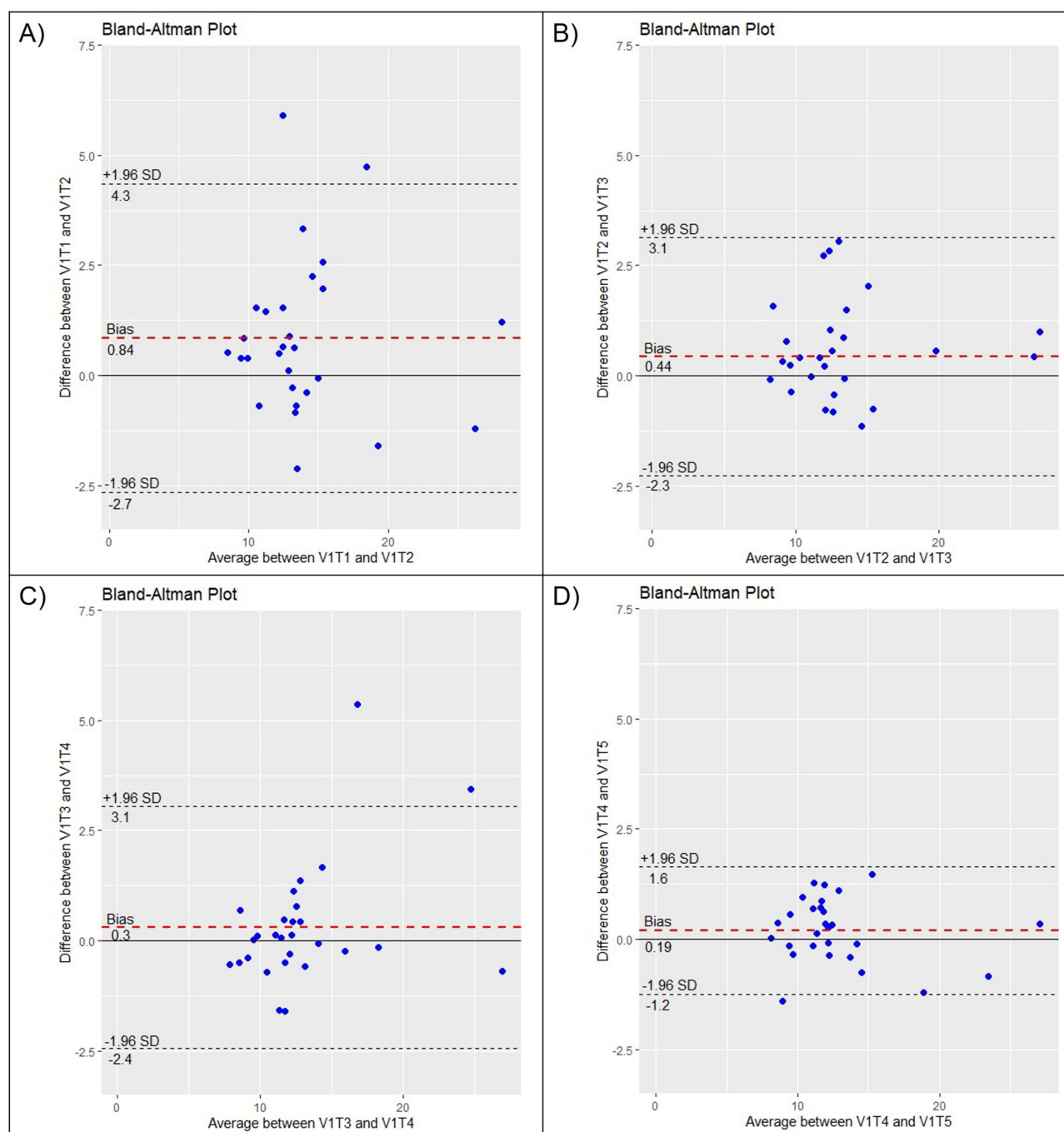


Figure 4 Bland-Altman graphical representation of the time difference in 5STS performance between trials during visit 1. (A) Between VIT1 and VIT2; (B) Between VIT2 and VIT3; (C) Between VIT3 and VIT4 and (D) Between VIT4 and VIT5.

against a hard surface) and requiring contact with a relative who could intervene if necessary. The presence of a support person was not mandatory, unlike in other studies of remote assessment.^{12,25} Altogether, the remote 5STS can be considered safe for patients with COPD.

From technical aspects, the remote use of 5STS demonstrates a good feasibility. Connection issues and video quality problems were rare and do not represent a limitation for the routine use. Of the patients approached, 19% (n = 18) were not included in the study due to inadequate equipment or lack of computer skills, although some others were included thanks to the assistance of a third party more familiar with technology and videoconferencing applications. These data

Table 2 Time Recorded for the 5STS Trials

	T1	T2	T3	T4	T5
Visit 1	n=33	n=29	n=31	n=33	n=33
Time (sec)	12.91 [11.15/15.38]	12.81 [11.10/14.32]	11.94 ** [10.09/13.47]	12.04 *** [9.81/12.60]	11.26 *** ## [9.84/12.31]
Fatigue (Borg scale)	1 [0/2]	2 [0/2]	2 [0/2]	2 [0/3]	2 [0/3]
Visit 2	n=31	n=30	n=30	n=30	n=31
Time (sec)	11.50 [10.16/13.63]	11.25 [10.10/13.04]	11.21 [10.22/13.16]	11.08 *.# [10.10/13.13]	11.06 * [9.41/13.03]
Fatigue (Borg scale)	1 [0/3]	1 [0/3]	1 [0/3]	1 [0/3]	1 [0/3]
Visit 3	n=26	n=26	n=26	n=26	n=26
Time (sec)	11.24 [10.56/13.00]	10.22 [9.60/13.34]	10.19 * [9.53/12.84]	10.50 * [9.75/11.75]	10.35 * [9.69/12.75]
Fatigue (Borg scale)	1 [0/3]	1 [0/3]	1 [0/3]	1 [0/3]	1 [0/3]

Notes, results are expressed as median [LQ/UQ]. Intra-visit assessment, * $p<0.05$, ** $p<0.01$, *** $p<0.001$ versus T1; # $p<0.05$, ## $p<0.01$ versus T2. Bold font indicates statistically significant differences.

should be compared with previous studies reporting the 15% of COPD patients do not use the internet daily³³ and that up to 25% of precarious smokers have low usage of digital technologies.³⁴ These figures confirm that videoconferencing is not straightforward for the entire COPD population. However, this barrier should not be considered as inevitable as support and training can be provided. For example, the development of teleconsultation booths, particularly in pharmacies or medical centres, would be beneficial for individuals who lack the appropriate equipment or need help using digital tools. Improving computer skills could also be included in the educational objectives of programmes for patients with chronic diseases.³⁵ In this context, a recent study showed that an 8-week weekly training programme can improve digital literacy in older adults by more than 60%.³⁶ The addition of a digital literacy training programme is therefore a promising approach to promoting access to telemonitoring, pulmonary telerehabilitation or remote exercise training. From a practical perspective, the remote 5STS also demonstrated strong feasibility, with excellent test-retest reliability.

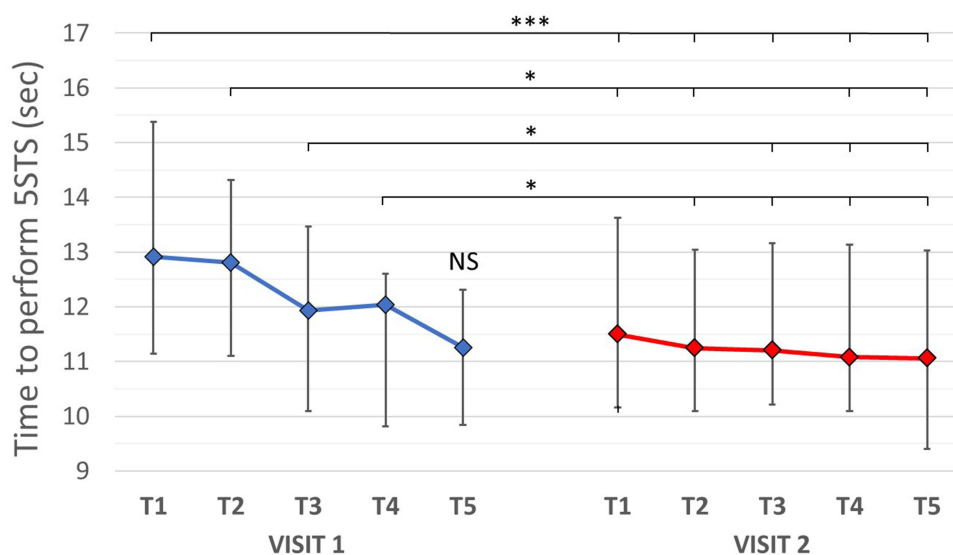


Figure 5 Time to perform 5STS trials, inter-visit comparison between visit 1 (in blue) and visit 2 (in red). Represented as median [LQ/UQ]. * $p<0.05$, *** $p<0.001$ between visit 1 and visit 2. NS, not significant.

Among the participants, only one (3%) was lost to follow-up. Other missed visits were due to acute illness (5%) or connection issues (3%). Acceptability of this remote physical evaluation was high, with a 96% satisfaction rate. Some patients reported apprehension before starting the test, particularly regarding their ability to complete the five trials. However, no increase in fatigue was reported during test repetition. In addition, by the end of the study, all participants expressed support for using this remote assessment modality in the future.

The repetition of remote 5STS trials herein aimed to investigate a potential learning effect due to its clinical implications. Our findings indicate that there is indeed a LE, characterised by a significant improvement in 5STS performance when the test is repeated five times during a single visit in COPD patients unfamiliar with this evaluation. This LE is evident from the third trial (V1T3) and continues to develop until the fifth trial (V1T5) of visit 1. While the LE is observable from the third trial onwards, it is reasonable to extend the assessment to five trials, as performance improvements continue throughout this period. Notably, V1T5 demonstrates a statistically significant improvement compared to trial 2 of visit 1 (V1T2), while showing no significant differences with any of the trials conducted during visit 2. The LE results in a median performance improvement of −1.5 seconds (16%) between V1T1 and V1T5, a change that cannot be attributed solely to the inherent variability of the test, as it exceeds the smallest detectable change (SDC95) established for our population. In fact, 70% of participants exhibited improvements in their 5STS times that exceeded the SDC95 between V1T1 and V1T5. Consequently, our findings suggest that conducting only two trials is insufficient to rule out the presence of a LE, as is also the case in the field of cognitive evaluations.²⁴ Furthermore, the stabilisation of the LE is supported by the results of a second visit conducted 1–2 days later, with all trials showing no significant differences from V1T5. Lastly, our data also reveal a significant progression in patients' scores at one month (visit 3) between trial 1 and trials T3, T4, and T5, further implying the existence of a LE and confirming the need to repeat five trials for an accurate assessment. It should be noted that we did not directly compare performance between visits V1–V2 and visit 3 due to the time interval which could introduce bias, such as medical events or a change in physical abilities, potentially leading to irrelevant conclusions about the persistence of the LE. Thus, considering the results reported herein, our practical recommendations for the remote application of 5STS in COPD patients involve the systematic administration of five trials to patients at each assessment. For the analysis of the recorded times, and in the context of monitoring or pre/post training programme assessment, it is advisable to retain the best performance as it allows to preclude the LE.

Our study, by demonstrating the existence of a LE in the 5STS assessment, highlights several clinical implications that warrant discussion. Firstly, the presence of a LE suggests that the studies previously carried out on this test, with less than 5 trials, expose to an underestimation of the functional capacities of the patients evaluated and, consequently, an overestimation of their severity. As a result, in the case of an exercise training programme, the physical activities proposed to the patients may not be fully adapted. Secondly, an uncontrolled LE may lead to an overestimation of the improvement observed around a therapeutic intervention such as PR. Our study also calls for careful and cautious consideration of the studies that preceded our work. For example, the study that defined the minimal clinically important difference (MCID) of the 5STS in COPD patients used only one trial and could not take LE into account.¹⁹ Further work is therefore needed to determine whether the MCID currently used remains valid or whether the control of LE leads to a significant change.

Study Limitations

The results of this study, particularly in terms of feasibility, may be influenced by the specific characteristics of the study population. Notably, all participants had just completed a PR programme, either as inpatients or outpatients. Consequently, these findings are relevant to a patient demographic that meets the criteria for PR, which includes a significant representation of GOLD stages 2 to 4, consistent with previous studies on pulmonary telerehabilitation.³⁷ This demographic represents the intended audience for remote assessment and monitoring after returning home, or for future consideration of an exercise training programme.^{38,39} However, it is important to note that in current clinical practice, there is a possibility - one of the critical issues at hand - that these remote programmes may be used with different patient profiles that do not typically participate in PR, raising questions about the applicability of the feasibility results to this broader population.

In addition to the characteristics of the study population, the context in which the 5STS was administered also warrants consideration. The metrological properties of the 5STS identified in this study, including the learning effect,

were assessed exclusively in a remote setting. These findings should not be extrapolated to in-person administration, as no direct comparison was conducted. Although previous work suggests that remote and in-person 5STS performance are comparable,¹² our results remain specific to remote conditions. This distinction is particularly relevant in the context of fully remote rehabilitation programs or long-term follow-up strategies, where consistent remote assessment can support clinical decision-making and help monitor patient progress over time.

Another consideration relates to the clinical applicability of the testing protocol. The 5-minute rest period between each 5STS measurement used here is indeed sufficient to minimise the fatigue associated with repeated testing and to allow the LE to be observed. However, it cannot be excluded that a shorter rest period could be appropriate. As this may improve clinical applicability, further research is needed to determine the optimal rest period between trials.

Finally, while the 5STS offers a practical and feasible solution for remote functional assessment, it cannot substitute for in-person evaluations such as the 6MWT, particularly when precise exercise prescription or monitoring of oxygen desaturation is required. Future studies are needed to better define the potential role of the 5STS in guiding remote exercise training and to explore its integration into comprehensive telerehabilitation programmes.

Conclusion

This study is the first to assess the learning effect of the 5STS through a specific design integrating five trials, across three visits, enabling practical recommendations for its remote implementation. Our results highlight a clear learning effect in 70% of COPD patients between the first and the fifth trials during the initial evaluation visit, confirming the necessity of performing five trials to provide a reliable assessment of functional capacity. Moreover, the 5STS test has been shown to be feasible when administered remotely in this population, with excellent repeatability, few connection issues, and with a high level of satisfaction. In conclusion, the 5STS appears to meet all the prerequisites for remote deployment as a functional test for monitoring COPD patients and in the context of exercise training programmes, by integrating the appropriate number of trials necessary to control for the LE in the administration procedure.

Abbreviations

3MST, 3-minute step test; 5STS, 5-repetitions sit-to-stand test; 6MWT, 6-minute walk test; ANOVA, Analysis of variance; BMI, body mass index; COPD, chronic obstructive pulmonary disease; FEV₁, Forced Expiratory Volume in one second; FVC, Forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; HG, handgrip; ICC, Intraclass correlation coefficient; LE, learning effect; LQ, lower quartile; MCID, minimal clinically important difference; PR, pulmonary rehabilitation; SD, standard deviation; SDC, smallest detectable change; SEM, standard error of the mean; TUG, timed-up and go; UQ, upper quartile.

Data Sharing Statement

All individual deidentified participant data collected during the study will be made available upon reasonable request. The shared data will include demographic information, clinical data and 5STS/fatigue scores. No additional study documents will be provided. Data can be requested by contacting the corresponding author via Email and will be accessible without time restriction.

Ethics Statements

The procedures were approved by an independent French ethics committee (named “Comité de Protection des Personnes Est-1” at Dijon, reference number, 23.00672.000176) and complied with the principles of the Declaration of Helsinki for human experimentation.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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The authors declare that they have no competing interests in this work.

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