Reproducibility and Validity of the 6-Minute Stationary Walk Test Associated With Virtual Reality in Subjects With COPD

Maria CM Frade, Ivanize MM dos Reis, Renata P Basso-Vanelli, Alexandre F Brandão, and Mauricio Jamami

BACKGROUND: The importance of evaluating the functional capacity of patients with COPD is well known, and there is a wide range of tests described in the literature. The 6-min stationary walk test associated with virtual reality (STVR-6) was created in light of the current limitations of evaluation tests. It does not require a large physical space or sophisticated equipment, and it is not costly; furthermore, it can be performed by a single rater. The objective of this study was to evaluate intra- and inter-rater reproducibility and to verify the criterion validity of the STVR-6. METHODS: 50 subjects with COPD were evaluated over the course of 3 d. The execution order of the tests was randomized; the STVR-6 was performed over 2 d, and the 6-min walk test was performed in 1 d. The 6-min walk distance variables and number of steps in the STVR-6 were obtained with a gas analysis performed for both tests. RESULTS: Relative reproducibility was found for intraclass correlation coefficient values (0.57–0.94, $P < .001$) between the number of steps and the highest value of oxygen consumption during the test ($\dot{V}_{O_2}$ peak), intra- and inter-rater. In terms of absolute reproducibility, the standard error of measurement and minimum detectable difference values were verified. In the Bland-Altman analysis, the intra- and inter-rater mean difference values were 21 and 17 steps and 0.002 and 0.242 mL/min/kg, respectively. Pearson correlation values were 0.57–0.75 ($P < .001$) between the number of steps and $\dot{V}_{O_2}$ peak. CONCLUSIONS: STVR-6 had excellent intra-rater reproducibility and excellent to good inter-rater reproducibility, but the high values of error measures demonstrated that there is a learning effect and a need to perform at least 2 tests. In addition, there was high to moderate correlation between the STVR-6 and the 6-min walk test. Therefore, the STVR-6 proved to be reproducible and valid for evaluating the functional capacity of subjects with COPD. *Key words: COPD; exercise test; reproducibility; reliability; criterion validity; virtual reality.* [Respir Care 2019;64(4):425–433. © 2019 Daedalus Enterprises]

Introduction

COPD may lead to a reduction in tolerance to physical exercise and quality of life.[1,2] In view of these changes and their possible consequences, evaluating the functional capacity of patients with COPD is extremely important to determine individualized behaviors and treatment programs. Different tests are described in the literature for this purpose, each with specific characteristics, objectives, and limitations.[3-6]

The 6-min walk test (6MWT) is one of these tests, and it is widely used because it is sensitive to change after pulmonary rehabilitation programs and the distance trav-

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eled, and because it is a valid and reproducible test.[3] It is also a predictor of mortality, particularly for COPD, and it is highly associated with the risk of hospitalization in people with chronic respiratory diseases.[3,4] It is recommended that the 6MWT is performed twice due to the learning effect.[3]

However, the 6MWT is very sensitive to variations in the methodology because the consistency of the test depends on several factors, such as offering encouragement and using supplemental oxygen and medications.[3,4] The place where the test is performed, using gait devices, the team's training, instruction and preparation of the patients, and factors for interrupting the test may also alter the results obtained.[3,4] It is important to be aware of these factors to choose the best option among the available evaluation tests and when interpreting the results.

Another example of a functional capacity assessment test is the stationary gait test, described for the first time in the literature as a 2-min stationary gait test of controlled cadence.[5] The performance in this test has a moderate correlation with the performance in the 1-mile walk test and the treadmill walk test. It also shows a perception of effort comparable to the 6MWT in the elderly.[6,7] It was observed that the test was valid and had good sensitivity and specificity to evaluate the functional capacity of hypertension in the elderly, with and without associated chronic conditions.[8]

Therefore, our research group proposed a 6-min stationary walk test associated with virtual reality (STVR-6).[9] Virtual reality integrates the user with a synthetic 3-dimensional environment,[10] creating an immersive and interactive virtual experience that occurs in real time. It also stimulates the active participation of patients even with physical and cognitive disability.[11] This potential new test option does not require a large physical space or sophisticated expensive equipment, and it requires only one rater. Furthermore, it provides patients with an integrative and fun assessment in a practical and simple way. To allow for the use of the STVR-6 in clinical practice, it is important to test its reproducibility and validity in subjects with COPD. Thus, this study aimed to evaluate the intra- and inter-rater reproducibility of the STVR-6, as well as to assess the criterion validity by correlation of the STVR-6 with the 6MWT in subjects with COPD.

QUICK LOOK

Current knowledge

Among tests that have been described to evaluate the functional capacity of subjects with COPD, the 6-min walk test (6MWT) presents some limitations in execution. Therefore, the 6-min stationary walk test associated with virtual reality (STVR-6) was developed. It is not costly, and it can be performed by a single rater while providing the patient with an integrative evaluation in a practical way.

What this paper contributes to our knowledge

The STVR-6 had excellent relative intra-rater reproducibility and excellent to good inter-rater reproducibility. However, high values of error measures were found, emphasizing that at least 2 tests need to be carried out per subject due to the learning effect. In addition, the STVR-6 was also valid for evaluating the functional exercise capacity of subjects with COPD.

Methods

This observational and cross-sectional study was developed in the Spirometry and Respiratory Physiotherapy Laboratory at the Federal University of São Carlos (UFSCar). Subjects were recruited using a laboratory database and were screened at the following health centers: UFSCar Health Center School, Municipal Specialty Center, Family Health Centers, and Basic Health Centers in São Carlos. The study was approved by the Research Ethics Committee at UFSCar (no. 1,884,641). All subjects signed a free and informed consent form in accordance with Resolution 466/2012 of the National Health Council.

The subjects included in the study were of both genders ages of 50–80 y who were diagnosed with COPD confirmed by physician-performed spirometry ($FEV_1/FVC < 70\%$ post-bronchodilator) with mild (stage I) to very severe (stage IV) obstruction ($FEV_1\%$ predicted > 80 and < 30).[12,13] The subjects were clinically stable, had no history of infections or exacerbation of respiratory symptoms or change of medications in the 3 months prior to the study, and scored > 25 in the Mini-Mental State Examination questionnaire to assess cognitive ability.

Individuals who had a body mass index of ≥ 35 kg/m^2 were excluded, as well as those who did not complete all the evaluations of the proposed protocol, used supplemental oxygen at home, or showed signs of associated comorbidities, such as rheumatic, orthopedic, neurological, and other associated heart diseases (uncontrolled) that would prevent them from following the proposed protocol. This also included any other respiratory disease besides COPD.

Experimental Procedures

The subjects were submitted to 3 d of evaluations with a minimum interval of 24 h between the tests; a maximum period of 1 week was established to complete all tests, which were always performed at the same time of the day.[14] On the first day, a complete anamnesis and physical

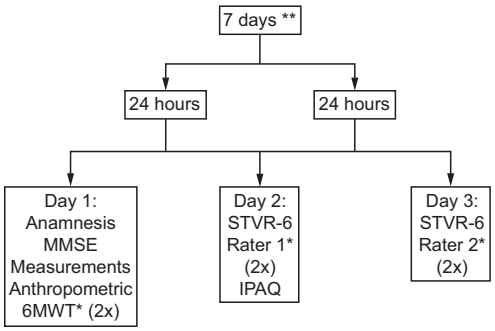

Fig. 1. Timeline of the experimental procedure of the study. MMSE = Mini-Mental State Examination; IPAQ = International Physical Activity Questionnaire. **Maximum period to complete the evaluations. *Example of a random selection, not necessarily everyone followed in that order.

exam were performed on the subjects. This included an evaluation of cognition by Mini-Mental State Examination and anthropometric measurements, such as body mass and height on an anthropometric scale (WELMY, Santa Bárbara d'Oeste, Brazil). The test to be performed (ie, STVR-6 or 6MWT) was chosen randomly with the use of a randomization web site.[15] On this site, the second generator was selected, which provides a random balanced permutation of the evaluations, and the total number of subjects, to determine the 3 evaluations for each subject (6MWT, STVR-6-Rater 1, and STVR-6-Rater 2).[15]

Consequently, the subjects randomly performed the STVR-6 on 2 different days applied by 2 different raters (Rater 1 or 2) and the 6MWT on another day. All tests were performed twice in the same day with an interval of 30 min between them.[16] In addition, on the second day during the interval of the tests, subjects completed the International Physical Activity Questionnaire to assess the level of physical activity of each subject. The International Physical Activity Questionnaire enables the rater to obtain physical activity measurements, which are internationally comparable. The short version contains 7 questions that can estimate the time spent in different dimensions of physical activity. This test's validity was verified in Brazil by Matsudo et al.[17] After their application, subjects were classified as very active, active, irregularly active (A and B) and sedentary.[18] Figure 1 shows an example of randomization and how the evaluation sequence was given.

Functional Tests

Subjects were asked to wear comfortable clothing and footwear suitable for walking, to take their regular medication without interruptions, and to refrain from stimulating beverages, smoking, and vigorous physical activity on the day of the evaluation. They were also asked to rest for at least 15 min before initiating the test to stabilize cardiorespiratory variables.[3]

In the 6MWT and STVR-6, subject heart rate was monitored with a cardio-frequency meter (POLAR, Kempele, Oulu, Finland), S_{pO_2} was measured with a portable pulse oximeter (Nonin Medical, Minneapolis, Minnesota), and the sensation of dyspnea and fatigue of lower limbs was assessed with the Borg CR10 scale,[19] in addition to pressure variables measured with a sphygmomanometer (BIC, Itupeva, Brazil) and stethoscope (Littmann, Elmhurst, Illinois). During the tests every minute, the heart rate and S_{pO_2} were performed, and before and in the recovery period (up to 6 minutes after the test) all measurements, heart rate, S_{pO_2}, dyspnea, fadigue and blood pressure were performed. A pedometer (DIGI-WALKER, SW 701, Tokyo, Japan) fixed to the middle anterior region of the right thigh of the subject was used to measure the number of steps.

During the tests, gas analyses were performed with the VO2000 model analyzer (MedGraphics, St Paul, Minnesota) using a low-flow, 2-way pneumotachograph coupled to a mask. The system measures micro-samples of expired gases using the mean collection method every 10 s.[20] During the 6MWT, the portable form was used with an outpatient kit, which utilized a pneumotachograph, mouthpiece, neoprene mask, and band. The data produced loaded into a computer in real time via a serial port and plotted on $\dot{V}_{O_2}$ graphs to show the volume of oxygen consumed in L/min expressed at standard temperature and dry pressure.

Prior to starting the test, the subjects remained in the standing position at the test site for 1 min to collect the baseline variables of the respiratory gases. The 6MWT was performed in a corridor 30 m long and 1.5 m wide, with markings every 2 m and the first and 30th meters marked with a cone and a line, to mark the beginning and the end. Subjects received test instructions to walk as far as possible without running in 6 min,[3] which is the 6-min walk distance (6MWD). Moreover, encouraging remarks were made every minute according to American Thoracic Society standardizations.[21]

In the STVR-6, the subjects carried out stationary walking for 6 min using virtual reality. When asked to begin, the subjects started the stationary walk (without running), completing as many steps as possible within the given time, and the number of steps was determined. The minimum knee height, customized for each subject, was leveled at a midpoint between the patella and the anterior superior iliac spine.[5,22] Standardized encouragement was given to the subjects every minute of the test using an adaptation of American Thoracic Society standards.[3,21]

Associated with the stationary gait test was a virtual reality application, GestureMaps, developed in the Immersive, Interactive, and Collaborative Visualization Laboratory at UFSCar, which was deployed in an air-conditioned room with an X-box Kinect (Microsoft, Redmond, Washington). This allowed navigation in different scenarios using the virtual Google Street View map. In this study, all

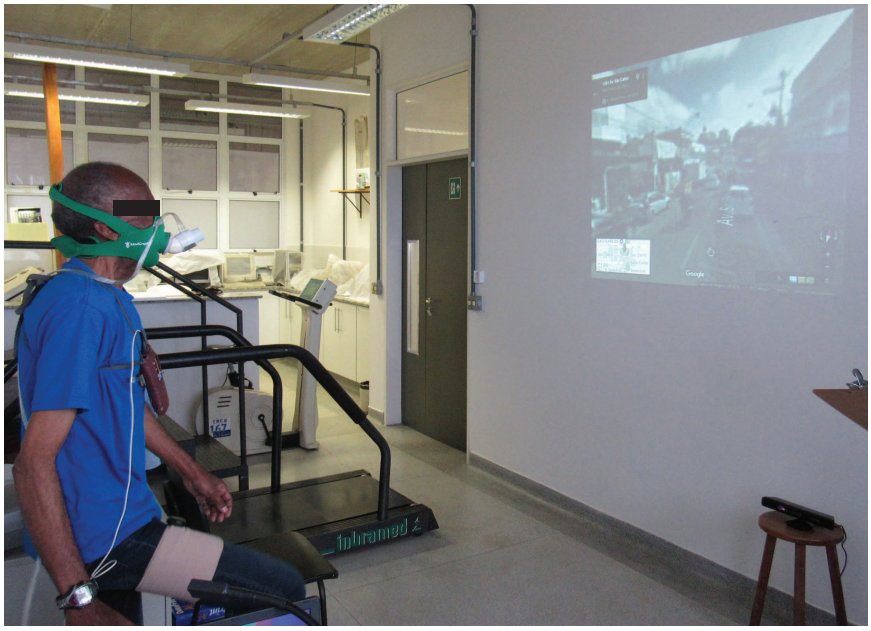

Fig. 2. Subject performing the 6-min stationary walk test associated with virtual reality.

of the subjects were positioned to begin the test at an address on São Carlos Avenue, in the city of São Carlos, São Paulo. This navigation is done by controlling an avatar with gestures that simulate the stationary gait. Hip and knee flexion movements make the individual "walk" on the map, and lateral flexion of the trunk to the right or left enables the subject to change direction (Fig. 2).[23]

Because this test requires some unusual movements, a familiarization protocol of 1 min was adopted on the first day of the STVR-6, performed by both Rater 1 and Rater 2, depending on the randomization.

Statistical Analysis

For the sample size calculation, 50 subjects were needed for the sample size to be considered "good" according to the consensus-based Standards for Health Measurement Instruments.[24] The normality of the data were verified using the Komolgorov-Smirnov test. Data were presented as mean ± SD means for parametric variables or as median (interquartile range) for non-parametric variables. The paired Student *t* test and the Wilcoxon test were used for the parametric and non-parametric variables, respectively, in the intragroup comparison. When the mean of the difference between the 2 STVR-6 outcomes was obtained, the test performed by Rater 1 was selected and the best STVR-6 (ie, test with the greatest number of steps) was selected. The data were analyzed using SPSS (version 20.0, Chicago, Illinois). Significance level of $P < .05$ and 95% CI were considered.

The relative intra- and inter-rater reproducibility was verified through the ICC.[25] The intra-rater reproducibility was tested with the first and second tests performed by both Raters 1 and 2, depending on the random drawing. In the inter-rater analysis, the best test of each of the 2 raters was selected, based on the number of steps; we considered values < 0.4 to indicate low reproducibility, values between 0.4 and 0.75 to indicate good reproducibility, and values > 0.75 to indicate excellent reproducibility.[26]

The absolute reproducibility was verified by the standard error of measurement (SEM), calculated as $SD \times \sqrt{(1 - ICC)}$; the SD was the largest SD found between the 2 compared tests, and 95% CI was calculated as $SEM \times 1.96$.[27] The minimum detectable difference (MDD) was calculated as $MDD = 1.64 \times \sqrt{(2)} \times SEM$, as well as the Bland-Altman analysis.[25,28]

For the criterion validation, correlations were made between the 6MWT Test 1, Test 2, and the best among the STVR-6 Test 1, Test 2, and the best one performed by Rater 1. The test was characterized as valid when the Pearson correlation coefficient (r) was > 0.7.[27] In addition, r values ranging from 1.0 to 0.9 were considered as very high correlation, 0.89–0.7 as high, 0.69–0.5 as moderate, 0.49–0.26 as low, and 0.25–0 as small to no correlation.[29]

Results

A total of 153 individuals with COPD were screened, of whom 92 were excluded. The remaining 61 subjects were evaluated. In this stage, 11 were excluded due to associated comorbidities, 3 dropped out, 3 had pre-test desaturation, and 1 subject had an exacerbation, leaving 50 subjects in the statistical analysis (Fig. 3).

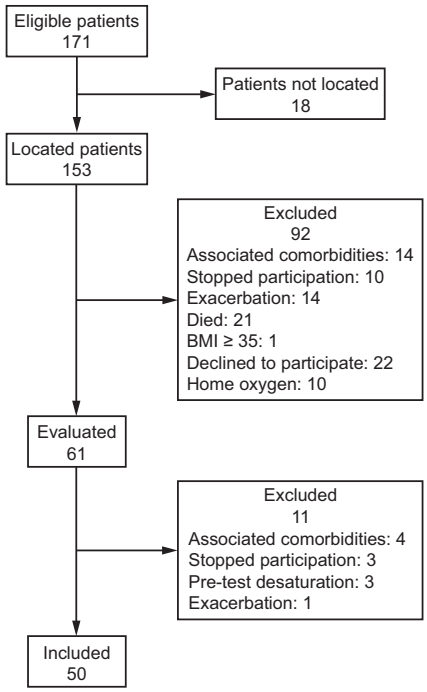

Fig. 3. Flow chart. BMI = body mass index.

Table 1. Key Characteristics and Level of Physical Activity of Subjects

Subject Characteristics	Data
Age, y	66.7 ± 7.2
Gender, *n* (male/female)	31/19
Height, m	1.6 ± 0.09
Weight, kg	70.9 ± 15.8
Body mass index, kg/m^2	26.9 ± 5.1
Smokers/Ex-smokers/Never, *n*	11/37/2
FEV_1, L	1.4 ± 0.6
FVC, L	2.4 ± 0.9
FEV_1/FVC, %	58.2 ± 12.1
FEV_1, % of predicted	51.5 ± 19.9
FVC, % of predicted	66.0 ± 19.4
International Physical Activity Questionnaire, *n*	
Very active	2
Active	18
Irregularly active A	11
Irregularly active B	14
Sedentary	5

n = 50 subjects. Data are presented as mean ± SD unless otherwise noted.

Subject characteristics can be seen in Table 1. Most of the subjects were men with a body mass index from normal weight to obese I, and 74% were former smokers. They were classified according to GOLD[12] as mild to very severe obstruction; with regard to the level of physical activity, 36% were considered active and only 10% were sedentary.

A significant increase in the number of steps of an average of 24.7 steps was observed in STVR-6 Test 2 compared to STVR-6 Test 1, performed by the same rater (Rater 1). In addition, when comparing the best STVR-6 and the best 6MWT also performed by Rater 1, a significant difference was observed for the $\dot{V}_{O_2}$ peak, nadir S_{pO_2} (lower oxygen saturation value during the test), and the sensation of fatigue. All values were higher in STVR-6 (Table 2).

The results obtained for relative intra-rater reproducibility of the STVR-6 were excellent for the number of steps and $\dot{V}_{O_2}$ peak variables between the 2 tests (Table 3). The relative inter-rater reproducibility was good for $\dot{V}_{O_2}$ peak and excellent for the number of steps when comparing the best tests of each rater (Table 3).

Absolute reproducibility was verified with SEM and MDD. For the number of steps, the SEM was 49.6 (95% CI 97.2), and the MDD was 115.1 for intra-rater. In the inter-rater analysis for this same variable, the SEM was 54.6 (95% CI 106.9), and the MDD was 126.5. For $\dot{V}_{O_2}$ peak, the SEM was 1.5 (95% CI 2.9), and the MDD was 3.4 for intra-rater; in the inter-rater analysis, the SEM was 2.2 (95% CI 4.3), and the MDD was 5.1.

Bland-Altman analysis (Fig. 4) showed that the mean difference was 21 steps (CI −117.5 to 159.5 steps) and 0.002 mL/min/kg for $\dot{V}_{O_2}$ peak (CI −3.8 to 4.2 mL/min/kg) intra-rater, and the inter-rater mean difference was 17 steps (CI −135.0 to 169.1 steps) and 0.242 mL/min/kg for $\dot{V}_{O_2}$ peak (CI −5.8 to 6.3 mL/min/kg).

The criterion validation was verified by the correlations between STVR-6 and 6MWT variables. It high correlation was observed between the $\dot{V}_{O_2}$ peak values of the tests, and a moderate correlation was recognized between the 6MWD and the number of steps in STVR-6 (Table 4).

Discussion

This study verified that the proposed STVR-6 has excellent intra-rater reproducibility and excellent to good inter-rater reproducibility, although error measurements presented high values. This proposed test also proved to be valid. Studies have shown the efficacy of the stationary gait test for other populations such as the healthy elderly and subjects with arterial hypertension, heart failure, and cervical compressive myeloma.[30,22,31,32]

The STVR-6 is a functional capacity assessment test that only requires a small space. Moreover, it is practical and simple to use. Alternatively, it can be performed in the hospital environment for acute conditions with better monitoring.[31] It is considered safe because it avoids falls, and it can be performed using walking aids. It can also be used by individuals with altered balance.[30,31] This test favors patients with COPD who use supplemental oxygen be-

Table 2. Data Obtained in the STVR-6 and 6MWT

Variables	STVR-6–1	STVR-6-2	*P*	STVR-6-B	6MWT-B	*P*
Number of steps in STVR, *n*	397.7 ± 194.6	422.4 ± 197.1*	< .001	429.9 ± 195.4	NA	NA
6-min walk distance, m	NA	NA	NA	NA	386.4 ± 94.9	NA
$\dot{V}_{O_2}$ peak, mL/min/kg	13.3 ± 3.4	13.4 ± 3.1	.48	13.5 ± 3.3	12.6 ± 3.0†	.02
Heart rate peak, beats/min	108.2 ± 16.5	107.7 ± 16.6	.67	108.8 ± 16.4	106.1 ± 15.5	.19
Systolic blood pressure peak, mm Hg	143.6 ± 24.0	141.9 ± 23.8	.44	142.2 ± 23.0	139.5 ± 22.3	.24
Diastolic blood pressure peak, mm Hg	73.2 ± 10.6	75.1 ± 10.9	.07	74.5 ± 11.5	77.4 ± 11.6	.060
Nadir S_{pO_2}	89.0 (82.7–91.0)	88.0 (82.7–91.0)	.08	88.5 (82.7–91.0)	85.0 (80.0–87.0)‡	< .001
Borg: dyspnea	3.5 (1.0–5.0)	3.3 ± 2.3	.42	3.5 (1.0–5.0)	3.0 (1.0–4.2)	.07
Borg: fatigue	3.0 (2.0–5.0)	3.3 ± 2.4	.16	3.0 (2.0–5.0)	2.0 (0.3–4.0)‡	< .001

Data are presented as mean ± SD or median (interquartile range).
* $P < .05$ between Test 1 and Test 2 of STVR-6 (rater 1) (paired Student *t* test); $P < .05$ between Test 1 and Test 2 of STVR-6 (Wilcoxon test).
† $P < .05$ between the STVR-6-B and the 6MWT-B (paired Student *t* test).
‡ $P < .05$ between the STVR-6-B and the 6MWT-B (Wilcoxon test).
STVR-6–1/2/B = 6-min stationary walk test associated with virtual reality: Test 1, Test 2, and the Best (Rater 1)
6MWT = 6-min walk test
NA = not applicable
$\dot{V}_{O_2}$ peak = the highest value of oxygen consumption during the test
Nadir S_{pO_2} = lower value of oxygen saturation as measured with pulse oximetry during the test

Table 3. Relative Intra-Rater and Inter-Rater Reproducibility of the STVR-6

	Intra-Rater		Inter-Rater	
	ICC (95% CI)	*P*	ICC (95% CI)	*P*
Number of steps	0.94 (0.89–0.96)	< .001	0.93 (0.87–0.96)	< .001
$\dot{V}_{O_2}$ peak, mL/min/kg	0.80 (0.68–0.89)	< .001	0.57 (0.35–0.73)	< .001

STVR-6 = 6-min stationary walk test associated with virtual reality
ICC = intraclass correlation coefficient
$\dot{V}_{O_2}$ peak = the highest value of oxygen consumption during the test

cause the oxygen cylinder does not need to be transported while carrying out the test.

In this study, we proposed associating the stationary gait test with virtual reality because it may encourage greater patient interaction and motivation, and virtual reality is increasingly used in pulmonary rehabilitation programs. Liu et al[33] proposed a functional capacity assessment test using the Gait Real-Time Analysis Interactive Lab, in which a self-directed treadmill designed on a 180-degree screen was used. This test proved to be reliable and valid for evaluating the elderly and COPD subjects.

The virtual reality may have a direct influence on test performance or exercise practice. In our study, the mean $\dot{V}_{O_2}$ peak obtained in STVR-6 was higher than that in the 6MWT. This may be due to the higher motivation in the virtual reality setting, but it could also be an intrinsic characteristic of STVR-6 because nadir S_{pO_2} and fatigue were significantly higher in this test when compared to the 6MWT. However, we do not know of any studies that performed the stationary gait test without virtual reality with gas analysis to confirm this possibility.

In clinical practice, it is important for the evaluation tool to be reliable, validated, and easy to perform; for this reason, we examined the psychometric properties of functional tests.[34] We found that STVR-6 presented excellent intra-rater reproducibility (ICC values for the various measures were 0.80–0.94), and similar results were found with the 6MWD (ICC 0.93) and changes in the S_{pO_2} (ICC 0.81), heart rate (ICC 0.62), and fatigue sensation on the Borg scale (ICC 0.59).[35] The relative inter-rater reproducibility, on the other hand, presented a good value (ICC 0.57) for the $\dot{V}_{O_2}$ peak and an excellent value (ICC 0.93) for the number of steps. This good relative reproducibility for $\dot{V}_{O_2}$ peak can be accounted for by the fact that the variable is very accurate and has low variability, which lowers the coefficient of variation; therefore, error measurements may be the most accurate method for verifying reproducibility.

High values for the error measures of the number of steps were obtained in absolute reproducibility. These measures were obtained with a pedometer, whose reproducibility and accuracy were confirmed in previous studies even at high speeds (eg, during exercise).[36,37] Therefore, this pedometer was not responsible for the error measures obtained. In the Bland-Altman graph, 66% of the sample increased the number of steps between Test 1 and Test 2. In addition, the mean difference was 17 steps. When we relativized the mean difference by the average of the performance in the test, we found an increase of 5.2%. Likewise, other authors observed that the mean difference found in the 6MWT was 27 m, and that they obtained an increase of 7% when they relativized the mean difference by the 6MWD.[35] This demonstrates a learning effect between

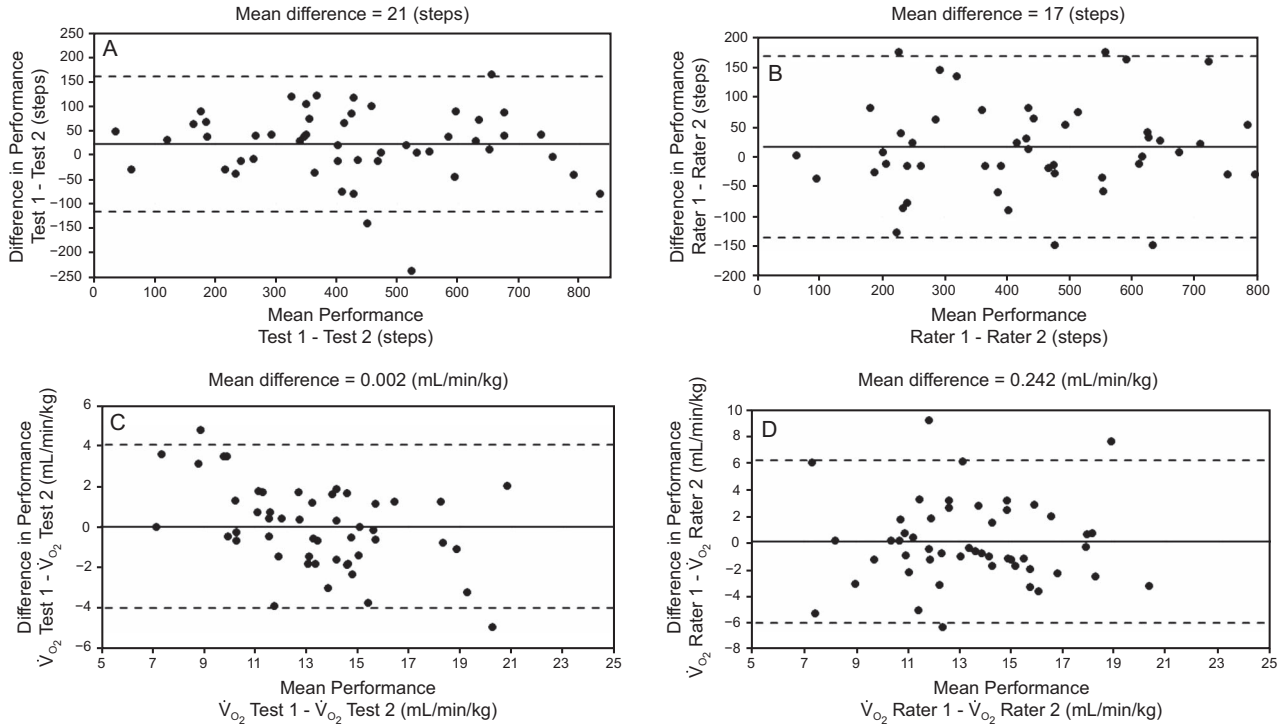

Fig. 4. Bland-Altman graph of the 6-min stationary walk test associated with virtual reality (STVR-6). The horizontal solid line represents the mean of the differences, and the dotted lines represent the 95% CI. (A) Performance between the first (Test 1) and second (Test 2) STVR-6. (B) Performance between the first (Rater 1) and the second (Rater 2) STVR-6 rater. (C) Corrected value of peak oxygen consumption ($\dot{V}_{O_2}$) between the first (Test 1) and second (Test 2) STVR-6. (D) Corrected value of $\dot{V}_{O_2}$ between the first (Rater 1) and the second (Rater 2) rater.

Table 4. Correlation Between Performance and $\dot{V}_{O_2}$ Peak in the STVR-6 and the 6MWT

Distance Traveled, m	STVR-6-1	STVR-6-2	STVR-6-B
6MWT-1	0.66*	0.61*	0.61*
6MWT-2	0.64*	0.58*	0.58*
6MWT-B	0.65*	0.59*	0.59*
$\dot{V}_{O_2}$ Peak, mL/min/kg	STVR-6-1	STVR-6-2	STVR-6-B
6MWT-1	0.66*	0.57*	0.59*
6MWT-2	0.75*	0.68*	0.74*
6MWT-B	0.72*	0.59*	0.65*

* Pearson's correlation (r) ($P < .001$).
STVR-6–1/2/B = 6-min stationary walk test associated with virtual reality, Test 1, Test 2, and the Best (Rater 1)
6MWT-1/2/B = 6-min walk test, Test 1, Test 2, and the Best
$\dot{V}_{O_2}$ peak = the highest value of oxygen consumption during the test

Test 1 and Test 2. We therefore suggest that the STVR-6 should be done at least 2 times, just as the American Thoracic Society has recommended for the 6MWT.[21]

For validation, we correlated 6MWT variables because there are studies that have demonstrated the criterion and construct validity of this test for subjects with COPD, which are considered functional capacity assessment,[38] as well as a relationship with the maximum exercise capacity.[4] In addition, 6MWD has been shown to be a good predictor of mortality.[39] It also shows the similarities of the tests regarding the duration and characteristic of free cadence.

In our study, there was a high to moderate and significant positive correlation between the tests. Similar values were found to validate the 6MWT (0.4–0.93), and the highest correlations were between measurements of maximum physical performance and physical activity.[3] Similarly, a high correlation of 0.78 between maximum $\dot{V}_{O_2}$ in the cardiopulmonary exercise test and the 6MWD has been reported in the literature, as well as a correlation of 0.85 between the 6MWD and the $\dot{V}_{O_2}$ peak in the 6MWT.[39-41]

Because the $\dot{V}_{O_2}$ peak values were highly correlated between the tests, this variable was selected as the main one to confirm validity, as has been done in other studies.[42] Thus, STVR-6 is a functional capacity assessment test and may be an alternative to the 6MWT, considering some negative aspects of the 6MWT, such as the physical space needed.

One limitation to consider in our study is the use of a convenience sample by selecting subjects from the city of São Carlos. Consequently, our study does not have as many subjects as other stratifications in disease severity or

in different levels of physical activity. Another limitation is that we did not evaluate subjects, who, because they are elderly, could experience some impairment in this function and thus interfere with the stationary gait. In addition, we did not measure the length of the subjects' steps, which might relate to the distance covered in the STVR-6 and could be correlated with the 6MWD.

Conclusion

The STVR-6 had excellent intra-rater reproducibility and has excellent to good inter-rater reproducibility, but high values of error measurements demonstrate that there is a learning effect and each subject should perform the test twice. The STVR-6 had a high correlation with the 6MWT with regard to $\dot{V}_{O_2}$ peak and a moderate correlation with the number of steps. Thus, the STVR-6 proved reproducible and valid to evaluate the functional capacity of subjects with COPD and may be an alternative to the 6MWT.

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