Original Article

Reliability and validity of an audio signal modified shuttle walk test

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ABSTRACT

Background: The audio signal in the conventionally accepted protocol of shuttle walk test (SWT) is not well-understood by the patients and modification of the audio signal may improve the performance of the test. **Objectives:** The aim of this study is to study the validity and reliability of an audio signal modified SWT, called the Singla-Richa modified SWT (SWT_{SR}), in healthy normal adults. **Patients and Methods:** In $SWT_{SR,}$ the audio signal was modified with the addition of reverse counting to it. A total of 54 healthy normal adults underwent conventional SWT (CSWT) at one instance and two times SWT_{SR} on the same day. The validity was assessed by comparing outcomes of the SWT_{SR} to outcomes of CSWT using the Pearson correlation coefficient and Bland–Altman plot. Test-retest reliability of SWT_{SR} was assessed using the intraclass correlation coefficient (ICC). The acceptability of the modified test in comparison to the conventional test was assessed using Likert scale. **Results:** The distance walked (mean ± standard deviation) in the CSWT and SWT_{SR} test was 853.33 ± 217.33 m and 857.22 ± 219.56 m, respectively (Pearson correlation coefficient - 0.98; $P < 0.001$) indicating SWT_{SR} to be a valid test. The SWT_{SR} was found to be a reliable test with ICC of 0.98 (95% confidence interval: 0.97–0.99). The acceptability of SWT_{SR} was significantly higher than CSWT. **Conclusions:** The SWT_{SR} with modified audio signal with reverse counting is a reliable as well as a valid test when compared with CSWT in healthy normal adults. It better understood by subjects compared to CSWT.

KEY WORDS: Exercise test, reliability, shuttle walk test

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INTRODUCTION

The 6-min walk test (6MWT) is the most common clinical and research tool for the evaluation of functional exercise capacity in chronic pulmonary disabled patients.[1] The incremental shuttle walk test (SWT) was developed by Singh *et al*.[2] to measure disability in patients with chronic obstructive pulmonary disease (COPD). It is an inexpensive tool and has been used to assess exercise capacity in the pulmonary rehabilitation setting for patients with COPD[3-7] as well as for patients with other diseases.[8]

Among the SWT protocols, the modified protocol by Singh *et al*.,[2] (referred here as conventional SWT [CSWT]) is the accepted protocol. However, the authors observed that the audio signal in the protocol was not well-understood by the patients and a modification of the audio signal may help them to understand and perform the test in a

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better way. The modified audio signal has been explained in methods section. This is expected to better guide the patient's adjustment to the speed required during each shuttle. The audio signal modified test was named as Singla-Richa modified SWT (SWT_{SR}) after the names of the authors who have developed this modified protocol. The current study was aimed to study the validity and reliability of $SWT_{SR,}$ in healthy normal adults.

PATIENTS AND METHODS

This study was conducted at a tertiary referral institute of tuberculosis and respiratory diseases, New Delhi. It was planned to evaluate the modified test in healthy normal individuals. The subjects were recruited for the study by incidental sampling. The healthy normal adults were asymptomatic, nonsmoker, and nonobese adults in the age group of 18–60 years with stable vitals, body mass index in the range of 18.5–29.9 kg/m,^{2} absence of any diagnosed cardiac, pulmonary, orthopedic, or neurogenic condition which could decrease their functional capacity and absence of any acute disease during 6 weeks preceding the study. Patients with clinical conditions where the exercise tests are contraindicated were excluded.[9,10]

Study protocol

The subjects were informed about the study through information sheets, and written consent was obtained from all subjects. The study was approved by Research and Ethical Committee of the institute.

Testing was performed in the hospital where a rapid, appropriate response to an emergency was possible, and physician was also available on call whenever any emergency arises.[10,11] All subjects were evaluated by clinical examination, X-ray of the chest, electrocardiogram, and a clinical research performa was filled. Subsequently, spirometry was done. The subjects were familiarized with CSWT as well as the audio signal modified test (SWT_{SR}) under study by verbal commands and by demonstration of an actual test procedure for the first 3 min. No practice session for the entire test protocol was done.

Using the systematic random method without bias, either the CSWT or modified SWT (SWT_{SR}) was done first. Both tests protocols have been described below. If the subject had done first the CSWT then he/she was subjected to the modified SWT (SWT_{SR}) later and vice versa. There was a gap of 30 min or when the pulse had returned to baseline, whichever was later, between the two tests.

To assess the reliability of $SWT_{SR,}$ the test was repeated after 30 min of rest or when the baseline parameters returned to normal, whichever was later.[10]

Conventional shuttle walk test

This was the modified protocol of SWT as described by Singh *et al*.[2] It was an externally paced exercise test for maximum 12 min. There was one level in each minute. Each level had multiple shuttles. The subjects were expected to walk a distance of 10 m in a corridor to complete one shuttle and then turn around to start the next shuttle. A cone was kept 0.5 m away from the end of 10 m around which the patient was to turn around to start the next shuttle. The speed of walking was increased in subsequent levels. In the first level, there were three shuttles of 10 m distance to be covered in 20 s each. In the second level, there were four shuttles of 15 s each; in the third level, five shuttles of 12 s each, etc., leading to 14 shuttles of 4.2 s in 12th level as shown in Table 1. The start of test and the speed of walking were guided by a series of prerecorded signals played on a tape cassette, originally generated from a BBC microcomputer. The CD of audio recording was purchased from Dr. S. J. Singh, Glenfield Hospital, Leicester, UK who originally described the test protocol.

The audio signal in the form of a triple bleep indicated when a subject should start a shuttle and another audio signal in the form of single bleep at the completion of a shuttle and giving an indication to the patient to turn around the cone. If the subject reached the cone before the signal, he/she was instructed to wait until the signal indicated to proceed with the next shuttle. At the end of each minute of a level, there was another triple bleep sound to mark the beginning of the next level. There was no audio signal during the shuttle period to guide the patient how much time was left to complete the particular shuttle.

Singla-Richa modified shuttle walk test

Here, the basic protocol of exercise was same as that of CSWT,[2] but the audio signal had been modified (CD available). We used an audio signal with reverse number counting being played on a music system (mobile phone). This audio signal had been calibrated according to the seconds left during each shuttle period. If there was shuttle

Table 1: The speed in each level, number of shuttles, number of seconds per shuttle, distance covered at the end of each level, and the cumulative distance covered at the end of that level

Level	Speed (m/s)	Number of shuttles	Number of seconds per shuttle	Distance per level (m)	Cumulative distance covered at end of level (m)
1	0.50	3	20	30	30 (as every shuttle of 10 m)
2	0.67	4	15	40	70
3	0.84	5	12	50	120
4	1.01	6	10	60	180
5	1.18	7	8.5	70	250
6	1.35	8	7.5	80	330
7	1.52	9	6.6	90	420
8	1.69	10	6	100	520
9	1.86	11	5.45	110	630
10	2.03	12	5	120	750
11	2.20	13	4.6	130	880
12	2.37	14	4.2	140	1020

of 20 s, the audio signal would be playing 20, 19, 18, 17 and so on up to 1 at a constant interval. If there was shuttle of 15 s, the audio signal would be playing 15, 14, 13, 12, and so on up to 1. This would guide the test subject while walking so that the test subject would know how much time was left to complete each shuttle. This would help the subject to adjust speed to complete the shuttle on time as per protocol preventing him/her to reach the end of the shuttle distance too early or too late. Furthermore at the beginning of each next level, the audio signal announced the number of shuttles to be performed in that level again attempting to understand and perform the test better.

In both type of tests, CSWT as well as in $SWT_{SR,}$ the subject was instructed, "Walk or may be run, if required, at a steady pace, aiming to turn around when you hear the audio signal in the form of a bleep or end of a count depending upon the test. You should continue to walk until you feel that you are unable to maintain the required speed, without becoming unduly breathless or fatigue and/or when instructed to stop."

The test was to be terminated by either (a) the patient, when he or she was too breathless to maintain the required speed or (b) the operator, if the patient failed to complete a shuttle in the time allowed (that is, was more than 0.5 m away from the cone when the audio signal sounded).

After performing both the tests, the subjects were asked to fill a questionnaire about the tests, and their perceptions (strongly disagree/disagree/not able to decide/agree/strongly agree) were evaluated by Likert scale. The questionnaire was, "It was easy to complete the test using reverse counting test (SWT_{SR})."

We analyzed the data using Stata version 13.2 (StataCorp, College Station, TX, USA) and MedCalc 12.7 (MedCalc Software, Belgium). Proportions and means (standard deviation [SD]) were calculated for categorical and continuous variables respectively. Scatter plot was drawn between distance walked by CSWT and SWT_{SR}. Correlations between CSWT and SWT_{SR} tests were performed to verify criterion validity, using the criterion of r - 0.7 as a validity marker.[12] The Bland–Altman plot was plotted to compare CSWT and SWT_{SR}. In this graphical method, the differences of both methods was plotted against the reference method, that is, CSWT.[13] To assess test-retest reliability we considered repeated responses within a participant as longitudinal data and computed the intraclass correlation coefficient (ICC) based on a mixed-effects linear model, classifying the values as low (ICC: <0.4), good (ICC: 0.4–0.75), and excellent (ICC: >0.75). We also quantified reliability as the canonical correlation between the two sets of repeated measurements. For internal consistency Cronbach's alpha, a function of the average covariance (or correlation) among all possible combinations of the variable was measured. The acceptability of the SWT_{SR} was assessed by response to the questionnaires on 5 point Likert scale.

RESULTS

A total of 54 healthy normal subjects (male = 37, female = 17) were recruited and evaluated. The mean age (SD) of healthy normal subjects was 30.83 (10.82) years. The demographic profile and the pulmonary function test parameters of healthy normal subjects are shown in Table 2.

The distance walked by CSWT and SWT_{SR} were computed. The performance (mean distance walked ± SD) in the CSWT and SWT_{SR} test was 853.33 ± 217.33 m and 857.22 ± 219.56 m, respectively. Mean difference of distance walked between CSWT and SWT_{SR} was 3.88 m [Table 3]. Scatter plot showed linear correlation (Pearson correlation coefficient - 0.98; $P < 0.001$) between CSWT and SWT_{SR} [Figure 1] indicating SWT_{SR} to be valid test. The Bland–Altman plots showed limits of agreement between the CSWT and SWT_{SR} range from −79.88 to 72.11 m [Figure 2]; 94.4% of the values of SWT_{SR} were within upper and lower limits of agreement [Table 4].

The SWT_{SR} was repeated to evaluate its reliability. Mean (±SD) distance walked in first and repeat SWT_{SR} was 857.22 ± 219.56 m and 864.81 ± 215.64 m, respectively. The ICC showed positive (direct) and statistically significant correlation in distance walked between first and repeat SWT_{SR} (ICC = 0.98, $P < 0.001$) indicating high reliability. Both canonical correlation and Cronbach's alpha also showed high reliability of SWT_{SR} [Table 3].

The response of the subjects regarding the acceptability of the CSWT and SWT_{SR} was assessed on Likert scale with response to questionnaire mentioned above. The SWT_{SR} was found to be more acceptable to the subjects compared to the CSWT.

Table 2: Demographic parameters and baseline respiratory parameters of normal healthy subjects (*n*=54)

Parameters	Mean±SD
Age (years)	30.83±10.82
Sex (%)	
Female	17 (31.5%)
Male	37 (68.5%)
Weight (kg)	56.83±9.54
Height (cm)	160.72±8.15
BMI	21.95±2.93
FVC% predicted	88.19±11.07
FEV_1% predicted	83.89±10.06
FEV_1/FVC	81.44±5.46

BMI: Body mass index, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 s, SD: Standard deviation

Table 3: Reliability of Singla-Richa modified shuttle walk test in healthy normal subjects

Reliability measures	95% CI
Intra-class correlation	0.98 (0.97-0.99)
Cronbach's alpha	0.99 (0.97-0.99)
Canonical correlation	0.98 (0.97-0.99)

CI: Confidence interval

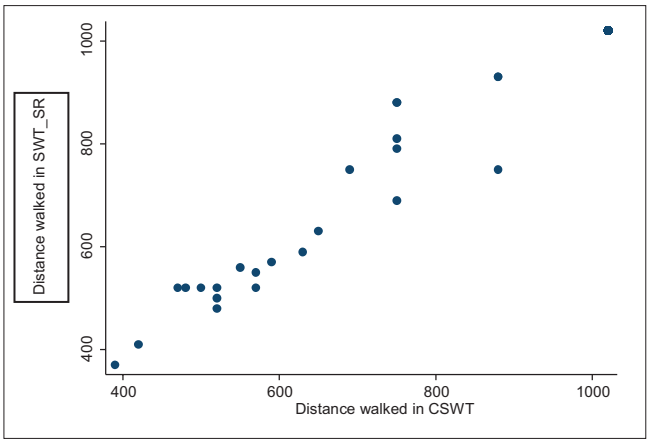

Figure 1: Scatter plot of distance walked in conventional shuttle walk test and Singla-Richa modified shuttle walk test

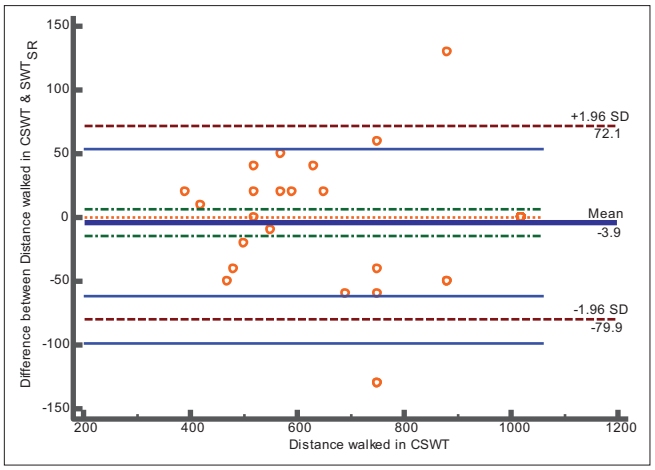

Figure 2: Bland–Altman plot of distance walked in conventional shuttle walk test and Singla-Richa modified shuttle walk test among normal healthy subjects

Table 4: Validity of conventional shuttle walk test and Singla-Richa modified shuttle walk test in healthy normal subjects

Parameters	Difference of distance walked between conventional shuttle walk test and SWT_{SR} done first time
Mean difference (m)	−3.88
95% CI of mean difference (m)	−14.47-6.69
Lower limit of agreement (m)	−79.89
95% CI (m)	−98.08-−61.68
Upper limit of agreement (m)	72.10
95% CI (m)	53.90-90.30

CI: Confidence interval, SWT_{SR}: Singla-Richa modified shuttle walk test

Table 5: Reliability of Singla-Richa modified shuttle walk test during first test and repeat test for some physiological measures

Physiological parameters	ICC (95% CI)	*P*
Dyspnea	0.90 (0.85-0.95)	<0.001
Heart rate	0.65 (0.46-0.78)	<0.001
Fatigue	0.91 (0.85-0.95)	<0.001
SpO_2	0.48 (0.24-0.66)	<0.001

ICC: Intraclass correlation coefficient, CI: Confidence interval

Some physiological measures were reliably assessed when the SWT_{SR} initial test and retest data were compared [Table 5]. ICC values higher than 0.75 ($P < 0.001$) were found between the initial SWT_{SR} and the retest for dyspnea and fatigue, which reflects the existence of excellent reliability for these measures. Moreover, ICC values higher than 0.4 and lower than 0.75 ($P < 0.001$) was found for SpO_2 and heart rate (HR).

DISCUSSION

To evaluate the exercise capacity of the individuals among the various walk tests, the SWT is one of the preferred tests as it resembles the day to day activity of the individuals and requires minimum instruments and also requires lesser space compared to other walk test such as 6MWT. The measurement properties and the technical standards for conducting the SWT have been described recently in two reviews.[9,10]

Currently, the modified SWT protocol by Singh *et al.*[2] (referred here as CSWT) is the accepted protocol. In the CSWT protocol, the subjects are blinded towards the time left to complete the particular shuttle. As a result, the subject may reach the end of the shuttle too early or too late even if the subject was not exhausted. Furthermore, there was no audio signal guiding the patient about the number of shuttles expected to be covered in a particular level requiring a particular speed as each next level requires the speed to be increased.

In the current study, the audio signal in the CSWT described by Singh *et al.*[2] was modified with the addition of reverse counting during the test indicating the approximate time left to complete a given shuttle. This audio signal modified SWT was named as SWT_{SR}. In the audio signal modified protocol (SWT_{SR}), the reverse counting signal would guide the subject about approximately how much time was left to complete each shuttle and is likely to make the comprehension of the test easier. This would also help the subject to maintain the required speed to complete the shuttle as per protocol preventing him/her to reach the end of the shuttle distance too early or too late. This would also help in giving graded increase in exertion ideally required in the test protocol.

In the current study, the distance walked (mean ± SD) in the CSWT and SWT_{SR} test was 853.33 ± 217.33 m and 857.22 ± 219.56 m, respectively (pearson correlation coefficient - 0.988; $P < 0.001$). On repeating the test the SWT_{SR} showed ICC of 0.98 (95% confidence interval: 0.97–0.99). The acceptability of SWT_{SR} was significantly higher than CSWT.

Comparing the distance walked between CSWT and SWT_{SR} by linear correlation and Bland–Altman plots, the SWT_{SR} was found to be a valid test indicating that it is comparable to CSWT for assessing the exercise capacity of the individuals.

The current study also evaluated the reliability of the audio signal modified SWT_{SR}. In our study, the ICC between the distance walked during the first test and repeat SWT_{SR} were very consistent and promising (0.988) indicating that SWT_{SR} is a very reliable test. Our observations are also in agreement with the other previous studies,[12,14-17] which have shown that the ICCs between test and retest SWT was high ranging from 0.76 to 0.99.

In the current study, the acceptability of this SWT_{SR} with a modified audio signal in comparison to the CSWT was also assessed on Likert scale. It was found that compared to CSWT, the SWT_{SR} was highly acceptable to the subjects. This was possibly due to modified audio signal helping them to understand and perform the test with more ease and accuracy.

However, limitation of the study was the use of a convenience sampling in the study, although caution was taken concerning the number of participants in each age range, as well as the proportion of male and female subjects.

The study also observed that the influence of SWT_{SR} on various physiological responses to exercise such as heart rate, SpO_2, dyspnea, and fatigue variables were similar to CSWT, showing close association between the conventional and the modified SWT_{SR} in measuring the exercise capacity of the subjects.[18]

CONCLUSIONS

From this study, we conclude that the SWT_{SR} with modified audio signal with reverse counting is a reliable as well as a valid test when compared with CSWT in healthy normal adults. It is better understood by subjects compared to CSWT and can be considered for routine use in clinical practice.

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Conflicts of interest

There are no conflicts of interest.

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