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Correlation of distance walked in audio signal-modified shuttle walk test with six-minute walk test

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Abstract

The literature review suggested that the audio signal-modified shuttle walk test (SWT_{SR}) was equally reliable and valid when compared to the conventional shuttle walk test. A comparison of SWT_{SR} with the six-minute walk test (6MWT), which is considered the gold standard in walk tests, allowed us to evaluate the SWT_{SR} and determine its validity and reliability as an alternative or supplement to the 6MWT. The objective of this study was to determine the correlation between the distances walked during a SWT_{SR} and the 6MWT in healthy, normal adults. The study recruited 42 healthy normal adults who underwent 6MWT and SWTSR on the same day. The correlation was assessed by Pearson's correlation coefficient, and agreement between the tests was assessed using a Bland-Altman plot. Additionally, the acceptability of the modified test in comparison to the 6MWT was assessed by the Likert scale. The distances walked (mean ± standard deviation) in the 6MWT and SWT_{SR} were 693.8±58.3 and 951.4±139.7 m, respectively (Pearson's correlation coefficient of 0.918). The distance covered by the study participants in the 6MWT and SWT_{SR} showed a strong correlation with spirometry results. The SWT_{SR} induced a greater physiological response compared to the 6MWT. The acceptability of the SWT_{SR} was comparable to that of the 6MWT. The distance walked in the SWT_{SR} shows a strong positive correlation with the 6MWT and has comparable acceptability with the 6MWT. The SWT_{SR} may provide a better index of the patient's ability for his activities of daily living and may be a better measure for studying exercise tolerance than the 6MWT in certain clinical settings.

Key words: walk test, exercise test, spirometry, cardio pulmonary exercise testing.

Introduction

Field walk tests are cost-effective and provide straightforward evaluations, useful for a variety of clinical and research purposes. These tests help to assess functional exercise capacities of patients and can be used to evaluate treatment response and prognosis in chronic respiratory diseases. The most widely used are staircase climbing, Six-minute walk test (6MWT), incremental shuttle-walk test (SWT), cardiac stress test (e.g., Bruce protocol) and cardiopulmonary exercise test [1]. Exercise tests like 6MWT and SWT are easy to perform. 6MWT is considered to be the gold standard among field walk tests. SWT is an externally paced maximal exercise test, where the speed of walking is controlled by a series of pre-recorded signals. The accepted protocol for SWT is modified protocol by Singh *et al.* [1]. After observing that the patients were having difficulty in following the pre-recorded audio signals in SWT in form of beeps, the authors devised an audio signal modified protocol for SWT.

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. In a previous study, the authors found that SWT_{SR} was reliable and valid when compared to the conventional SWT [2]. However, as 6MWT is considered to be the gold standard in walk tests, it is important to compare SWT_{SR} with the 6MWT. The current study aimed to study the correlation between distances walked in 6MWT and SWT_{SR}, in healthy normal adults.

Materials and Methods

This study was conducted at National Institute of TB and Respiratory Diseases New Delhi, a tertiary referral institute for chest diseases. Convenience Sampling was used to recruit the subjects for the study. The study sample comprised of healthy adult individuals aged 18 to 60 years who met the following criteria: asymptomatic, non-smoker, and body mass index (BMI) within the range of 18.5kg/m^2-29.9kg/m^2. These individuals had no diagnosed cardiac, pulmonary, orthopedic, or neurogenic conditions that could potentially impact their functional capacity or affect the outcome of the study. Furthermore, they did not experience any acute illnesses during the six weeks prior to the study. Subjects with any clinical conditions that contraindicated exercise testing and those who did not consent to participate were excluded [1,3].

A total of forty-six subjects were screened for the study. Two were found to be smokers who had only recently quit smoking; one had history of recent upper respiratory tract infection, and one refused to give consent to participate in the study. After excluding these four subjects, forty-two healthy normal subjects were recruited for the study,

Study protocol

The subjects were provided with information sheets to gain a comprehensive understanding of the study. Written consent was obtained from all the participants. The study received approval from the research and ethical committee of the institute to ensure that it complied with ethical principles and standards (NITRD/RC/15/4753 dated 12/09/2015 & NITRD/PGEC/2015/7276 dated 02/12/2015 respectively).

The test was conducted in a hospital setting, which offered prompt access to emergency medical response and the availability of a physician in the event of an emergency [3,4]. All enrolled healthy individuals were informed about the study and underwent routine investigations, including Chest X-ray, ECG, spirometry, and complete clinical examination. Both the 6MWT and SWT_{SR} were performed by the subjects after a 30-minute gap or when the physiological parameters returned to normal, whichever occurred later. Test allocation, for the type of the test to be performed first, was conducted using a systematic random sampling method.

Six-minute walk test (6MWT)

The 6MWT was conducted according to ATS guidelines 2014 [3].

Before the commencement of the 6MWT, the subjects were instructed to sit on a chair placed near the starting position for a minimum of 10 minutes. During this resting period, the subject's resting heart rate, blood pressure, SpO2, and Rate of Perceived Exertion (RPE) on the Borg scale were recorded. Standardized verbal instructions were provided for the 6MWT. The subjects were required to walk at their own pace from one end to the other of a 30-meter hallway, aiming to cover the maximum distance possible within the designated 6-minute time frame. Standard encouragement was provided to the subjects every 60 seconds using pre-determined phrases. The 6MWT was terminated if any of the following criteria were met: 1) the subject indicated an inability to continue, 2) the subject experienced chest pain, intolerable dyspnea, leg cramps, staggering, diaphoresis, or a pale/ashen appearance, 3) the subject's SpO2 level dropped below 80%. The primary outcome was measured as 6-minute walk distance (6MWD), and the number of laps and additional distance covered were recorded. The total distance walked was calculated, rounded to the nearest meter. The maximal heart rate achieved and SpO2 levels at the end of the test were also recorded.

Singla-Richa Modified shuttle walk test (SWT_{SR})

The protocol for SWT_{SR} was adapted from a previous study conducted by the authors [2]. An audio signal was utilized during the test, played through a music system or mobile phone, which was calibrated according to the seconds remaining during each shuttle period. The audio signal was programmed to play a countdown from the total time allotted for each shuttle, with a constant interval between each count. This enabled the subjects to adjust their speed accordingly and complete the shuttle on time, in adherence to the protocol [2].

Before the test the subject was given the following instruction- "Walk or maybe run, if required, at a steady pace, aiming to turn around when you hear the audio signal in the form of 'end of a count'. 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 the completion of both tests, the total distance walked was calculated, rounded to the nearest meter. The maximal heart rate achieved and SpO2 levels at the end of the test were also recorded. Additionally, all subjects were required to report their level of dyspnea and fatigue on the Borg dyspnea and fatigue scales. The subjects were requested to fill out a questionnaire regarding their perceptions of the tests using the Likert scale. Likert scale evaluated their responses on a five-point scale ranging from strongly disagree to strongly agree. The questionnaire was drafted to assess the ease of completing the test using audio signal as conveyed through the device for the $SWT_{SR.}$

The data was then entered into a Microsoft Excel spreadsheet and analyzed using the Statistical Package for Social Sciences (SPSS) version 21.0.

Results

A total of forty-two healthy normal subjects were recruited for the study, out of which thirty-two were males and ten were females. The mean age (SD) of the participants was 28.69 (8.7) years with a median of 16 and IQR of 8.

Pearson correlation was used to find correlation between distance walked in 6MWT and distance walked in SWT_{SR}. Similarly, correlation coefficient was used to correlate FVC and FEV_1 with distance walked in 6MWT and distance walked in SWT_{SR}. Bland Altman plot was used to assess the agreement between distances walked in 6MWT and distance walked in SWT_{SR}. Quantitative variables were compared using Mann-Whitney Test (as the data sets were not normally

distributed) between the two group and paired T test/Wilcoxon rank sum test was used for comparison between pre and post.

The distances walked (Mean± SD) in the 6MWT and SWT_{SR} were 693.8 ±58.3 and 951.4±139.7 meters, respectively. A scatter plot indicated a linear correlation (Pearson correlation coefficient-0.918) between 6MWT and SWT_{SR} (Figure 1), which suggested that SWT_{SR} is a valid test. The Bland-Altman plots demonstrated that the limits of agreement between the 6MWT and SWT_{SR} ranged from -432.54 m to -82.69m (Figure 2) and 92.9% of the values of SWT_{SR} were within the upper and lower limits of agreement.

The distance covered in the 6MWT showed a good correlation with forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) with a Pearson's correlation coefficient (r) of 0.617 and 0.779, respectively (Table 1). Similarly, the distance walked in SWT_{SR} showed a good correlation with FVC and FEV1 with Pearson's correlation coefficient (r) of 0.655 and 0.768, respectively (Table 1). This suggested that both tests correlated well with spirometry.

In comparison to the 6MWT, SWT_{SR} induced a greater heart rate response and a significantly higher percentage increase in baseline heart rate (Table 2). The 6MWT did not show any significant change in SpO2 ($p=0.09$), whereas SWT_{SR} showed a significant change in SpO2 post-test in healthy normal adults. Furthermore, SWT_{SR} induced a greater dyspnoea response than 6MWT in healthy normal adults. The difference in dyspnoea score (Post-Pre dyspnoea score) was significantly different in the two tests ($p<0.0001$). SWT_{SR} also induced a greater fatigue response than 6MWT. The difference in fatigue score (Post-Pre fatigue score) was also significantly different in the two tests ($p<0.0001$). Thus, SWT_{SR} induces a statistically significant greater physiologic response in terms of heart rate, SpO2, dyspnoea, and fatigue recorded, when compared to 6MWT. Lastly, as per the Likert scale regarding the acceptability of the 6MWT and SWT_{SR} by the subjects, there was no statistically significant preference depicted for either of the tests.

Discussion

Shuttle walk tests (SWT) are cost-effective tools that have been widely used to assess exercise capacity in patients with COPD exacerbations and in stable COPD in outpatient settings [5,6]. They have also been utilized in cardiac rehabilitation [7] and in patients with both COPD and heart failure [8]. The SWT has proven to be an objective measure of functional capacity in idiopathic pulmonary fibrosis (IPF) patients [9]. The SWT is often preferred over other walk tests because it closely resembles day-to-day activities, requires minimal instruments, and needs less space compared to the 6MWT. It offers a more accurate estimation of peak oxygen consumption

(VO2 max), a critical parameter in assessing respiratory impairment, particularly in diseases like COPD and ILD, where exercise limitation is a significant symptom [10,11]. Studies have shown that the SWT correlates more strongly with peak VO2 than the 6MWT, making it a more reliable tool for assessing functional aerobic capacity [12,13]. The measurement properties and the technical standards for conducting the shuttle walk test have been described recently in two reviews [1,3].

The authors felt that the patients were having difficulty in following the pre-recorded audio signals in SWT, and hence they had devised an audio signal modified protocol for SWT called Singla-Richa modified SWT (SWT_{SR}). In the current study the SWT_{SR} was compared with 6MWT as 6MWT is considered the gold standard among the walk tests.

In the present study we found that distances walked in SWT_{SR} and 6MWT by healthy normal adults had good correlation with a Pearson correlation (r) of 0.918 (Table 1). Bland Altman analysis of distance walked by participants showed an upper limit of -82.7 and lower limit of -432.54 and 92.9% of values were within upper and lower limits, showing SWT_{SR} is in good agreement with 6MWT (Figure 2).

SWT_{SR} showed greater heart rate (HR) response compared with 6MWT. There was significant difference between 6MWT and SWT_{SR} in absolute increment from baseline HR and percentage change in pre-exercise baseline HR ($p<0.0001$) (Table 2). One previous study had shown that the maximal heart rate attained in SWT is closer to maximal cycle ergometer tests [14]. In our study we have observed that though the subjects are reaching a statistically significantly greater heart rate as compared to 6MWT they are able to cope up with the demand of the SWT_{SR} and complete the shuttle in time before one could end the test. This shows that SWT_{SR} testing provides a better symptom limited assessment of the exercise response with self-determined termination of the test, an objective determination of functional capacity and impairment and determination of the appropriate intensity needed to perform prolonged exercise. American thoracic Society guidelines for 6MWT accept that the exercise performed in SWT is like a symptom limited, maximal, incremental treadmill test with an advantage that the shuttle walk test correlates better with peak oxygen uptake than the 6MWT [15]. Thus, this test provides an objective measure to assess patient's maximal functional capacity to an externally paced progressive exercise demand, proving to be a better index of patient's ability for his activities of daily living.

*Singh et al.*in 1992, conducted a study on adults with COPD in which they found that 12-level incremental SWT distance significantly related to 6MWT distance but graded cardiovascular response in terms of changes in heart rate were observed with SWT only due to its incremental

nature. Heart Rate on the 12-level incremental SWT strongly correlated with HR on the 6MWT (r= 0.76); however, maximal HR attained with SWT was significantly higher [16]. Thus, from their study too it appears that SWT may be a better measure for studying exercise tolerance than 6MWT in certain clinical settings.

The study also observed that the influence of SWT_{SR} on other physiological responses to exercise such as SpO_2, dyspnea and fatigue variables were greater compared to 6MWT

The strengths of this study include the direct comparison of the SWT_{SR} with the widely accepted gold standard, the 6MWT. The sample size of 42 healthy adults increases the reliability of the findings, and the strong correlation (r = 0.918) between the two tests underscores the robustness of the results. The participant feedback through a Likert scale also offers insights into the acceptability of the SWT_{SR} in comparison to the 6MWT.

A limitation of the study was the reliance on convenience sampling; however, efforts were made to ensure a balanced distribution of participants across age ranges and gender. The study was conducted on healthy adults; therefore, further research is needed to explore the applicability of the results to individuals with underlying health conditions or reduced mobility. The use of a single-day testing protocol may have introduced potential fatigue or learning effects, though efforts were made to reduce these factors.

Conclusions

To conclude, distance walked in 6MWT and SWT_{SR} showed good positive correlations in normal subjects. There was good agreement between the two tests as shown by Bland-Altman analysis. Distance walked in 6MWT and SWT_{SR} by healthy normal adults showed good correlation with spirometry (Table 1). Also, the SWT_{SR} and 6MWT are comparable with respect to acceptability in terms of preference for the test to be done by the subjects. The SWT may provide better index of patient's ability for his activities of daily living and may be a better measure for studying exercise tolerance than 6MWT in certain clinical settings.

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Table 1. Correlation of FVC and FEV1 with distances walked in 6MWT and SWT_{SR}

		Healthy normal		Comparison of r between 6MWT and SWT_{SR}
		Distance walked 6MWT	Distance walked SWT_{SR}	p-value
FVC	Pearson correlation	0.617	0.655	0.778
	p-value	<0.0001	<0.0001	
	N	42	42	
FEV1	Pearson correlation	0.779	0.768	0.904
	p-value	<0.0001	<0.0001	
	N	42	42	

Table 2. Heart rate response in 6MWT and SWT_{SR}

	Sample size	Mean±SD	Median	Min-Max	Inter quartile range	p
HR increment in 6MWT (Post test-Pre test heart rate)	42	39.48±12.88	39.5	11-64	31-51	<.0001
HR increment in SWT_{SR} (Post test-Pre test heart rate)	42	66.98±10.55	66	40-87	61-74	
Percentage change in HR from baseline in 6MWT	42	47.66±15.66	47.31	13.42-80	36.471-60.920	<.0001
Percentage change in HR from baseline in SWT_{SR}	42	77.88±14.07	75.76	47.62-109.21	70.455-86.364	

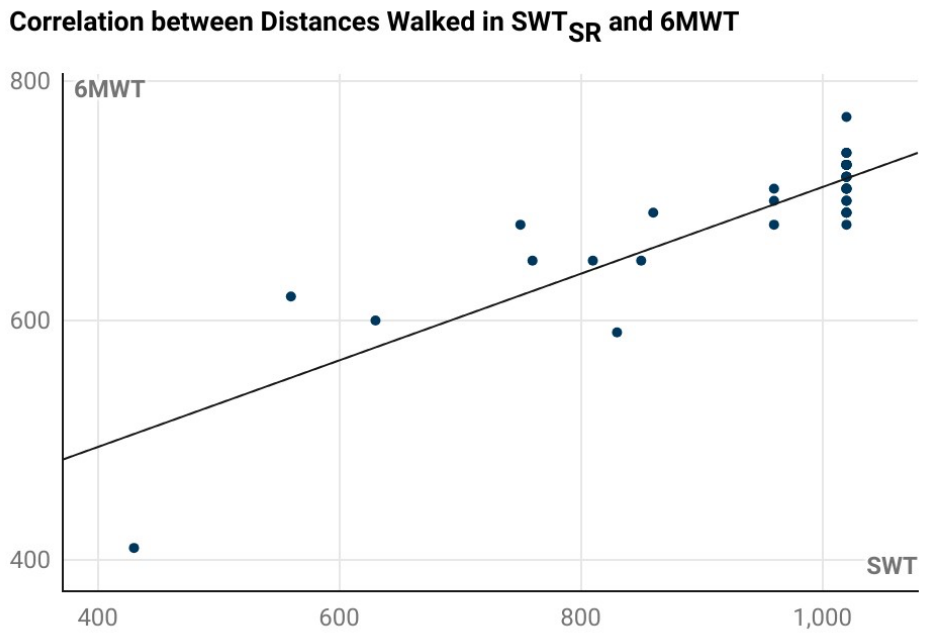

Figure 1. Scatter plot of distances walked in SWT$_{SR}$ and 6MWT.

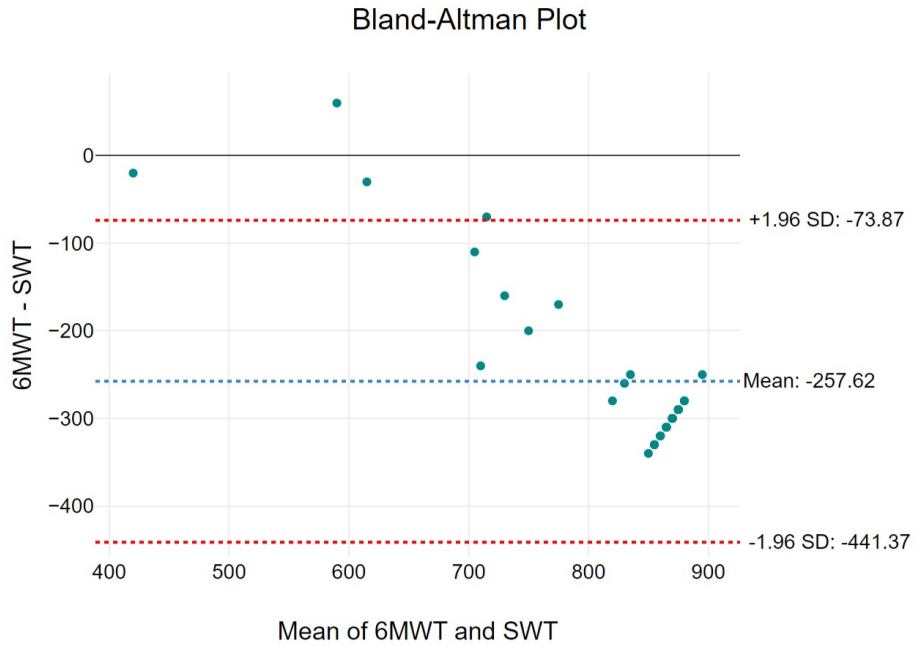

Figure 2. Bland Altman analysis of distances walked in 6MWT and SWT$_{SR}$ in healthy normal adults.