

ORIGINAL ARTICLE

Validity and reliability of the shuttle walk test in people with multiple sclerosis

Multipl sklerozlu bireylerde mekik yürüme testinin geçerliliği ve güvenilirliği

Süfeyla Ulaş COŞKUN¹, Gülbin ERGİN², Beliz Belgen KAYGISIZ³, Didem KARADİBAK⁴

Abstract

Purpose: It is known that people with multiple sclerosis (PwMS) have reduced exercise capacity, and field tests are practical for assessing exercise capacity. This study aims to investigate the reliability, validity, and minimal detectable change (MDC) of the shuttle walk test (SWT) in PwMS.

Methods: This study included people diagnosed with multiple sclerosis according to McDonald's criteria, with an expanded disability status scale (EDSS) ≤ 3 , and with independent walking. The socio-demographic information of 38 participants who met the inclusion criteria was recorded. Six Minute Walk Test (6MWT), SWT I and II were evaluated twice with one-hour rest intervals. At the end of the tests, walking distances were recorded.

Results: PwMS showed strong correlations between vital signs, fatigue, dyspnea, walking distance, and VO₂max values measured after 6MWT and SWT I ($p < 0.05$). Also, there was a moderate agreement between the vital signs, fatigue dyspnea, walking distance, and VO₂max values measured after SWT I and SWT II ($p < 0.05$). MDC value for SWT was 133,62m.

Conclusion: The SWT was reliable and valid in determining exercise capacity in PwMS with EDSS ≤ 3 .

Keywords: Multiple sclerosis, 6-min Walk Test, Shuttle Walk Test.

Öz

Amaç: Multipl sklerozlu bireylerin egzersiz kapasitesinin azaldığı ve saha testlerinin egzersiz kapasitesini değerlendirmek için pratik olduğu bilinmektedir. Bu çalışma, multipl sklerozlu bireylerde mekik yürüme testinin (MYT) güvenilirliğini, geçerliliğini ve minimal klinik anlamlılık değerini (MDC) araştırmayı amaçlamaktadır.

Yöntem: Bu çalışmaya McDonald's kriterlerine göre multipl skleroz tanısı almış, genişletilmiş engellilik durumu ölçeği (EDSS) ≤ 3 olan ve bağımsız yürüyüşe sahip bireyler dahil edildi. Dahil etme kriterlerini karşılayan 38 katılımcının sosyo-demografik bilgileri kaydedildi. Altı Dakika Yürüme Testi (6DYT), MYT I ve II bir saatlik dinlenme aralıklarıyla iki kez değerlendirildi. Testlerin sonunda yürüme mesafeleri kaydedildi.

Bulgular: 6DYT ve MYT I'den sonra ölçülen vital bulgular, yorgunluk, dispne, yürüme mesafesi ve VO₂max değerleri arasında güçlü ilişki vardı ($p < 0,05$). Ayrıca, MYT I ve MYT II'den sonra ölçülen vital bulgular, yorgunluk dispnesi, yürüme mesafesi ve VO₂max değerleri arasında orta düzeyde ilişki olduğu belirlendi ($p < 0,05$). MYT için MDC değeri 133,62m idi.

Tartışma: MYT, EDSS ≤ 3 multipl sklerozlu bireylerde olan egzersiz kapasitesini belirlemede güvenilir ve geçerlidir.

Anahtar Kelimeler: Multipl skleroz, 6 dk Yürüme Testi, Mekik Yürüme Testi.

1: Ankara 29 Mayıs State Hospital, Ankara, Türkiye.

2: İzmir Bakircay University, Faculty of Health Sciences, Department of Physical Therapy and Rehabilitation, İzmir, Türkiye.

3: European University of Lefke, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Lefke, Northern Cyprus.

4: Dokuz Eylül University, School of Physical Therapy and Rehabilitation, İzmir, Türkiye.

Corresponding Author: Gülbin Ergin: gulbin.ergin@bakircay.edu.tr

ORCID IDs (order of authors): 0000-0002-3819-9364; 0000-0002-0469-6936; 0000-0003-4801-0884; 0000-0003-3129-6417

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INTRODUCTION

Multiple sclerosis (MS) is an autoimmune inflammatory demyelinating central nervous system disease.¹ Neurological deficits differ in each patient according to the location of the demyelinated plaques in the central nervous system and generally cause a wide range of functional limitations.² When the clinical course is examined, muscle tonus, sensory, coordination, and balance disorders observed in people with MS (PwMS) cause the level of physical activity to decrease. Moreover, a decrease in exercise capacity accompanies the progression of the disease; a cycle arises between physical inactivity and reduced exercise capacity.³

Exercise capacity evaluation is essential to exercise prescriptions for PwMS.^{4,5} The most valid and reliable evaluation tool for determining exercise capacity in MS is the cardiopulmonary exercise test (CPET) performed in a laboratory environment on a bicycle ergometer treadmill. Although these laboratory tests are advantageous, expensive equipment and technical expertise are needed.⁶⁻⁹ For this reason, the focus is on field tests, which are low-cost and more practical. Considering the literature, the Six-minute Walk Test (6MWT), one of the field tests, was found to be valid and reliable in PwMS.¹⁰ However, the 6MWT is a submaximal test that requires a long walking path. Walking speed and motivation vary depending on the person, and these cannot be standardized and can affect the level of effort.¹¹

One of the field tests, the Shuttle Walk Test (SWT), is a symptom-limited maximal exercise test and can give information about the limitations of patients.¹² This test is very similar to laboratory tests in that it has an external stimulus orientation and gradual progress, but it is more practical than laboratory tests.¹³ However, the SWT is an externally-paced test; therefore, it is less influenced by therapist encouragement than the 6MWT, so the SWT may be better for assessing the patient's performance. Moreover, the SWT strongly correlates with VO_{2peak} and requires smaller space than the 6MWT.¹³ Due to the advantages, it is seen that SWT has been used frequently in neurological diseases such as stroke in recent

years.^{11,14-16} However, when we analyze today's literature in the databases we can access, there are no studies investigating the applicability of SWT in PwMS. Therefore, we aimed to examine the shuttle walking test's intra-rater reliability, validity, and MDC in determining the exercise capacity of PwMS.

METHODS

The study included 38 PwMS who were recruited from the Cyprus Turkish Multiple Sclerosis Association, met the inclusion criteria, and volunteered to participate. GPower 3.1 software was used to determine the number of samples required for the study. The required sample size was 38, with 95% power (1- β) and an effect of 0.8.^{11,15}

Inclusion criteria: to be diagnosed with MS according to McDonald's criteria, to have an Expanded Disability Status Scale (EDSS) score ≤ 3 , to walk independently without physical assistance, and to get 24 points or more from the mini-mental state test.⁸ **Exclusion criteria:** to have had an MS attack in the past month,⁹ to have an orthopedic, neurological, or cardiopulmonary disease affecting the movement system, to have had a surgical operation involving the movement system, to have hearing loss and to be pregnant.^{16,17} The Ethics Committee of the European University of Lefke approved this study (decision no: 15/02/06/1718/01). Each participant gave consent to participate and signed an informed consent form.

The procedure of the study

The socio-demographic characteristics of all participants were recorded. The physiotherapist evaluated PwMS twice by SWT and once by 6MWT. The 6MWT was performed first. The rest period between each test was one hour. Heart rate, blood pressure, oxygen saturation, dyspnea, and fatigue levels were assessed at the tests' beginning and end.

Data Collection Tools

Six-Minute Walk Test (6MWT)

6MWT was performed using criteria determined by the American Thoracic Society. After the 30-meter track was marked every three meters, the individual was asked to walk on the track at his walking speed for 6 minutes. The test was terminated in case of chest pain,

dizziness, shortness of breath, excessive fatigue, palpitations, and leg cramps during the test. It was stated during the test that the individual could rest before the stopwatch is closed but should continue until the end command. When the test was completed, the walking distance was recorded in seconds.¹⁸ Before and after the test, blood pressure was recorded with a sphygmomanometer, heart rate, and oxygen saturation were recorded with a pulse oximeter, and fatigue and dyspnea were recorded with the Modified Borg Scale (MBS).¹⁹

The expected value for 6MWT was determined by the formula below:²⁰

Man: $(7.57 \times \text{height-cm}) - (5.02 \times \text{age}) - (1.76 \times \text{Kg}) - 309$

Woman: $(2.11 \times \text{height-cm}) - (2.29 \times \text{Kg}) - (5.78 \times \text{age}) + 667$

According to the 6MWT result, the average VO₂max value, $4.948 + (0.023 \times 6 \text{ minute walking distance (m)})$, was calculated with the formula.²¹

Shuttle Walk Test (SWT)

In a total area of 10 meters, a cone was placed, leaving 0.5 m for turns. With the audible signal loaded on the smartphone, the walking speed was increased every minute. The test was applied to a total of 12 levels. During the test, the participant was not allowed to speak, and if he arrived at the cone before the beep, he was asked to wait until the beep. The test ended when the participant could not continue the test due to dyspnea, chest pain, dizziness, shortness of breath, excessive fatigue, palpitations, and leg cramps or reached 85% of the maximal heart rate. Walking distance and several stages were recorded when the test was completed. Before and after the test, blood pressure was measured with a sphygmomanometer, heart rate, and oxygen saturation were measured with a pulse oximeter, and fatigue and dyspnea were recorded with the Modified Borg Scale (MBS).²²

The expected SWT value was calculated according to the formula given below:

SWT: $1449.701 - (11.735 \times \text{age}) + (241.897 \times \text{gender}) - 5.686 \times \text{body mass index (BMI)}$

(1 is written in the gender part for men and 0 for women).²²

According to the SWT results, the average VO₂max value, $4.19 + (0.025 \times \text{SWT walking distance (m)})$, was calculated using the formula.²¹

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) 25.0 software. Descriptive statistics for discrete and continuous variables in the study were shown as percentages, mean values, standard deviations, and most minor and significant values. Shapiro-Wilk test was used to determine whether the data fit the normal distribution. Nonparametric hypothesis tests were used because the data did not show normal distribution. Wilcoxon test was used to compare the results before and after the test, and Spearman correlation analysis was used for correlations between parameters. The test-retest reliability of individuals was demonstrated by looking at the class correlations (ICC). According to Fleiss, the correlation coefficients for the class were determined to be low if the score was <0.40, medium if it was between 0.40-0.75, and high if the score was >0.75.²³ Standard error measurement (SEM) values were calculated as follows: $SEM = SD \times \sqrt{(1 - ICC)}$, with SD representing the standard deviation of the measure. Minimal detectable change (MDC) values, which reflect the magnitude of change necessary to provide confidence that a change is not the result of random variation or measurement error, were calculated as follows: $MDC = z\text{-score (95\% CI)} \times SEM \times \sqrt{2}$.²⁴

RESULTS

Of the 84 people referred to the study, 38 individuals who met the inclusion/exclusion criteria were included. The average age of the individuals was 42.97 ± 11.86 years, and the average BMI was $26.12 \pm 4.66 \text{ kg/m}^2$. Table 1 gives the socio-demographic and clinical characteristics of individuals.

Table 2 shows descriptive statistics of walking distance and VO₂max parameters of individuals before and after the test.

It was determined that the compliance of the heart rate, SBP, fatigue, dyspnea, and walking distance values of the individuals measured as a result of SWT1 and SWT2 was high, and the compliance of the DBP and oxygen saturation values was moderate (Table 3). The intra-rater reliability and the SEM and MDC values in Table 3 were presented. The intra-

Table 1. Socio-demographic and clinical characteristics of people with MS (N=38).

| | n (%) |
|----------------------------------|-------------------|
| Gender (Woman / Man) | 23 / 15 (61 / 39) |
| Education status | |
| Primary education | 7 (18) |
| High school | 12 (32) |
| Undergraduate/Graduate | 19 (50) |
| Time to diagnosis | |
| 5 years and under | 12 (31-5) |
| 6-10 years | 12 (31-5) |
| 11 years and over | 14 (37) |
| Type of MS | |
| Relapsing-remitting | 35 (92) |
| Relapsing progressive | 1 (3) |
| Secondary progressive | 2 (5) |
| Expanded Disability Status Scale | |
| 0 | 8 (21) |
| 1 | 22 (58) |
| 2 | 2 (5) |
| 3 | 6 (16) |
| Regular exercise (Yes/No) | 15/23 (39/61) |
| Smoking (Yes/No) | 8/30 (21/79) |

Table 2. Descriptive statistics of the test result parameters of people with MS.

| | $\bar{X} \pm SD$ |
|-------------------------------------|-------------------|
| Walking distance (m) | |
| 6MWT | 422.0 \pm 71.7 |
| SWT1 | 632.6 \pm 202.0 |
| SWT2 | 625.5 \pm 210.1 |
| VO _{2max} expected percent | |
| 6MWT | 14.65 \pm 1.65 |
| SWT1 | 20.01 \pm 5.05 |
| SWT2 | 19.83 \pm 5.23 |
| | n (%) |
| 6MWT (%) | |
| Above expected value | 5.3 |
| Below expected value | 94.7 |
| SWT1 (%) | |
| Above expected value | 15.8 |
| Below expected value | 84.2 |
| SWT2 (%) | |
| Above expected value | 18.4 |
| Below expected value | 81.6 |

VO_{2max}: Maximum oxygen consumption. 6MWT: 6 Minutes Walking Test.
SWT1: Shuttle Walking Test 1. SWT2: Shuttle Walking Test 2.

rater reliability was high for SWT.

Heart rate, SBP, fatigue, dyspnea, walking distance, and VO_{2max} values of PwMS in SWT (Test I) result were found to be significantly higher than the 6MWT result ($p < 0.05$) (Table 4).

It was determined that there were statistically significant correlations between the heart rate, SBP, DBP, oxygen saturation, fatigue, dyspnea, walking distance, and VO_{2max} values of individuals as a result of 6MWT and SWT (Test I) ($p < 0.05$). These correlations are positive and robust. Accordingly, if individuals have high heart rate, SBP, DBP, oxygen saturation, fatigue dyspnea, and walking distance values after 6MWT, the values of heart rate, SBP, DBP, oxygen saturation, fatigue dyspnea, and walking distance measured as a result of SWT are also seen high (Table 5).

DISCUSSION

To the best of our knowledge, this is the first time we have established the reliability and validity of the SWT in PwMS. The test-retest reliability of the SWT was high, and the most conservative estimate of the MDC was 133,62m for PwMS. It was also seen that the results of SWT at different times were similar. These results reveal that SWT is a reliable and valid evaluation method for PwMS with an EDSS score ≤ 3 .

Goldman et al. applied 6MWT thrice at one hour in 40 MS individuals with EDSS scores between 0-6.5 and 20 healthy individuals. As a result, they showed that 6MWT is a reliable test in this population. The six-minute walking test has demonstrated its reliability in PwMS.¹⁰ Test-retest reliability in this study was performed between SWT1 and SWT2. The rest period between the two trials was determined as one hour. In our study, participants' compliance with heart rate, SBP, fatigue, shortness of breath, VO_{2max}, and walking distance measured after SWT1 and SWT2 were high. It was determined that the compliance of DBP and oxygen saturation values were moderate. It is known that DBP remains the same or increases slightly in exercise, and oxygen saturation is not a very variable parameter.²⁵ The high immutability against time shows that SWT is a reliable tool.

Table 3. Intraclass correlations between the Shuttle Walking Test 1 and Shuttle Walking Test 2 results of people with MS (N=38).

| | ICC (%95 CI) | SEM | MDC | F | p |
|---------------------------------|------------------|-------|--------|--------|--------|
| Heart rate (beats/min) | 0.94 (0.88-0.97) | 3.59 | 9.96 | 31.504 | <0.001 |
| Systolic Blood Pressure (mmHg) | 0.86 (0.74-0.92) | 3.54 | 9.81 | 12.828 | <0.001 |
| Diastolic Blood Pressure (mmHg) | 0.74 (0.55-0.85) | 2.84 | 7.87 | 6.558 | <0.001 |
| SaO ₂ (%) | 0.49 (0.21-0.70) | 0.39 | 1.08 | 2.934 | 0.001* |
| Fatigue (Modified Borg Scale) | 0.93 (0.87-0.96) | 0.37 | 1.02 | 28.341 | <0.001 |
| Dispne (Modified Borg Scale) | 0.86 (0.75-0.93) | 0.53 | 1.46 | 13.558 | <0.001 |
| Walking distance (m) | 0.89 (0.79-0.94) | 48.21 | 133.62 | 16.595 | <0.001 |
| VO _{2max} (mL/kg/min) | 0.89 (0.79-0.94) | 1.25 | 3.47 | 16.595 | <0.001 |

* p<0.05. SEM: Standard Error of Measurement. MDC: Minimal Detectable Chance. ICC: Intraclass Correlation Coefficient. CI: Confidence Interval.

Table 4. Comparing the differences of 6 Minutes Walking Test (6MWT) and Shuttle Walking Test 1 (SWT1) vital signs of PwMS before and after the test (N=8).

| | 6MWT | SWT1 | z | p |
|--------------------------|------------|-------------|--------|--------|
| | X±SD | X±SD | | |
| Δ Heart rate (beats/min) | 14.74±9.81 | 28.53±19.49 | -3.939 | <0.001 |
| Δ SBP (mmHg) | 9.92±6.72 | 14.97±12.73 | -2.211 | 0.027* |
| Δ DBP (mmHg) | 2.55±6.81 | 4.08±6.43 | -1.093 | 0.274 |
| Δ SaO ₂ (%) | -0.26±0.6 | -0.11±0.92 | -0.821 | 0.825 |

* p<0,05. Δ: difference. SaO₂: Oxyghemoglobin saturation. 6MWT: 6 Minutes Walking Test. SWT1: Shuttle Walking Test 1.

Table 5. Comparison and correlation of 6 Minutes Walking Test (6MWT) and Shuttle Walking Test 1 (SWT1) results of people with MS.

| | 6MWT | SWT1 | z | p | rho |
|---------------------------------|--------------|---------------|--------|--------|--------|
| | X±SD | X±SD | | | |
| Heart rate (beats/min) | 92.61±14.26 | 105.84±20.96 | -4.236 | <0.001 | 0.682* |
| Systolic Blood Pressure (mmHg) | 125.47±11.15 | 132.5±14.85 | -3.139 | 0.002* | 0.647* |
| Diastolic Blood Pressure (mmHg) | 74.63±8.87 | 77.03±8.58 | -1.661 | 0.097 | 0.604* |
| SaO ₂ (%) | 97.66±0.75 | 97.63±0.88 | -0.221 | 0.825 | 0.509* |
| Fatigue (Modified Borg Scale) | 2.74±1.55 | 3.74±2.01 | -3.206 | 0.001* | 0.620* |
| Dispne (Modified Borg Scale) | 2.11±1.33 | 3.03±1.94 | -2.732 | 0.006* | 0.501* |
| Walking distance (m) | 422.03±71.71 | 632.63±201.99 | -5.179 | <0.001 | 0.509* |
| VO _{2max} (mL/kg/min) | 14.65±1.65 | 20.01±5.05 | -5.199 | <0.001 | 0.509* |

* p<0.05. SaO₂: Oxyghemoglobin saturation. 6MWT: 6 Minutes Walking Test. SWT1: Shuttle Walking Test 1.

It is known that SWT and 6MWT were widely used in cardiopulmonary rehabilitation. However, there are limited studies on the reliability and validity of SWT and 6MWT in

neurological patients, and the validity, reliability, or MDC of SWT in PwMS has not been studied. Singh et al. studied SWT in patients with COPD and found that MDC was

36,1m.²⁶ Houchen-Wolloff et al. determined that the MDC of SWT was 36,65m in patients undergoing cardiac rehabilitation.²⁷ Quintino et al. investigated incremental SWT after stroke and found that MDC was 114,63m.²⁸ Like stroke patients, our study's MDC in the MS population was 133,62m. If clinicians detect a change of more than 133,62m with SWT in a patient, they can assume it is an actual change in PwMS. Remarkably, the MDC values of the SWT test are higher in neurological patients. This situation may be associated with the symptoms affecting mobilization in neurological diseases, but studies on this subject are needed.

It is known that there is a relationship between 6MWT scores and limited daily life activities, increased resting heart rate, and fatigue perception in PwMS.²⁹ While walking distance is predicted to be 600m for healthy individuals at 6MWT, the length decreases by 50m every ten years of age.³⁰ Chetta et al. evaluated the functional exercise capacity with 6MWT in 11 PwMS with EDSS <4. They indicated that the walking distance was 384 m on average and showed a significant decrease compared to healthy individuals.³¹ Wetzel et al. (2011) determined 6MWT results according to their EDSS scores and stated that those with EDSS <4 walked an average of 402.4m while participants with EDSS 4-6.5 walked 193.7m.³² However, Goldman et al. classified 40 PwMS according to EDSS score as 0-2.5 (n:15), 3-4 (n:19), and 4.5-6.5 (n:6), and they determined that their 6MWT scores were 603m, 507m, and 387m, respectively.¹⁰ In our study, in parallel with the literature, it was seen that the distance walked at 6MWT and SWT was lower in individuals with EDSS ≤ 3 . These results support the validity of SWT in determining the functional walking distance.

When we searched the studies where SWT is applied in individuals with neurologic diseases, Van Bloemendaal et al. investigated the validity and reliability of SWT in determining the functional walking capacity of individuals with stroke. Participants were divided into two groups according to their walking speed (those who walked slower than 0.8m/s and those who walked faster than 0.8m/s. 6MWT and modified SWT (with a starting speed of 0.5m/s every minute, increasing by 0.06m/s, reaching a maximum speed of 2.0m/sec in 23 minutes were applied. Considering the walking

distances, the 6MWT score was 472 m, and the SWT score was 878 m.¹¹ Similar to our results, they showed a significant relationship between 6MWT and SWT regarding heart rate, dyspnea, fatigue, and walking distance in favor of SWT. They also reported that SWT validates functional gait in stroke patients with high walking speed.¹¹ An essential point in our study is that SWT was applied as in the original version. We determined that the SWT application procedure accepted in the literature applies to individuals with MS.

Clague-Baker et al. (2018) investigated the reliability and validity of 6MWT and SWT in individuals with stroke who are in the subacute stage.¹⁴ Forty participants who walked 10m with or without an assistive device were evaluated. Each participant was first subjected to an increasingly severe bicycle test, and then 6MWT and SWT were applied twice. As a result, they stated that SWT could be used as an alternative indicator where laboratory tests cannot be utilized. However, the fact that the participant's mental state was not evaluated and the application of 6MWT individually but SWT as a group were shown among the crucial limitations.¹⁴ In our study, the mental status assessment of participants and the completion of each person's 6MWT and SWT individually increase the reliability of the study.

Accurate evaluation of exercise capacity is essential in planning treatment programs in PwMS. When we look at the literature, the fact that SWT is applied for the first time in PwMS increases the value of this study.

Limitations

The limitations of this study were that the reliability of the inter-rater has not been tested, and the analysis could not be performed during the same period of the day because some participants were working. Fatigue was not evaluated periodically during the recovery period. In addition, since patients with EDSS ≤ 3 were included in the study, it is not possible to generalize the results to all MS patients.

Conclusion

In conclusion, SWT, one of the field tests, was a reliable and valid evaluation tool for determining the maximal exercise capacity in PwMS with an EDSS score of ≤ 3 . For health professionals, it can be preferred as a field test to evaluate maximal exercise capacity in both academic studies and clinical practice.

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