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ORIGINAL ARTICLE

Which field test should be used to compare the functional exercise capacities of patients with type 2 diabetes mellitus with and without diabetic peripheral neuropathy? Cross-sectional study

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KEYWORDS
Type 2 diabetes mellitus;
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Abstract
Background: The 6-minute step test (6MST) has begun to be used as a simple and effective alternative for assessing functional exercise capacity. There is no study using 6MSTs to evaluate the exercise capacities of patients with type 2 diabetes mellitus (DM) with and without diabetic peripheral neuropathy (DPN).
Objective: To compare the cardiorespiratory responses of the 6-minute walk test (MWT) and the 6MST exercise tests and to analyze the usability of the 6MST in Type 2 DM patients with and without neuropathy.
Methods: 32 non-neuropathic Type 2 DM, 32 neuropathic Type 2 DM patients, and 30 healthy volunteers were included in this cross-sectional study. Functional exercise capacity was evaluated with the 6MWT and the 6MST. The 30-second sit-stand test (30s STS) was used to evaluate general lower extremity muscle strength and function.
Results: There was a significant difference in the results of 6MWT (m), 6MST (number of steps), and 30s STS of the three groups ($p < 0.05$). The 6MST results of patients with neuropathic Type 2 DM were significantly lower than those of non-neuropathic diabetics and those who were healthy (number of steps; 114.07 ± 25.57 vs. 133.48 ± 33.57 vs. 160.35 ± 28.52, respectively) ($p = 0.001$). The change in cardiorespiratory response in systolic blood pressure, heart rate, perceived dyspnea, and leg fatigue severity was significantly higher at 6MST than 6MWT in the three groups ($p < 0.05$). 6MST was correlated with 6MWT ($r = 0.679$, $p = 0.001$), and 30s STS ($r = 0.589$, $p = 0.001$) in patients with Type 2 DM.

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Conclusions: Cardiorespiratory responses increased more in 6MST compared to 6MWT. In patients with Type 2DM, 6MWT and 6MST were moderately correlated with each other. 6MST is an effective and safe assessment method that may better reveal the differences in functional exercise capacity between neuropathic and non-neuropathic individuals in clinics.

PALABRAS CLAVE
Diabetes mellitus tipo 2;
Neuropatía diabética periférica;
Capacidad de ejercicio funcional

¿Qué prueba de campo se debe utilizar para comparar las capacidades de ejercicio funcional de los pacientes con diabetes mellitus tipo 2 con y sin neuropatía diabética periférica? Estudio transversal

Resumen
Antecedentes: La prueba de pasos de 6 minutos (6MST) ha comenzado a utilizarse como una alternativa simple y efectiva para la evaluación de la capacidad de ejercicio funcional. No existe ningún estudio que utilice 6MST para la evaluación de la capacidad de ejercicio de pacientes con diabetes mellitus (DM) tipo2 con y sin neuropatía periférica diabética (DPN).
Objetivo: Comparar las respuestas cardiorrespiratorias de la prueba de caminata de 6 minutos (MWT) y las pruebas de ejercicio 6MST y analizar la usabilidad de la 6MST en pacientes con DM tipo2 neuropática y no neuropática.
Métodos: En este estudio transversal se incluyeron 32 pacientes con DM tipo2 no neuropáticos,32 pacientes con DM tipo2 neuropáticos y 30 voluntarios sanos. El test de sentarse y levantarse durante 30 segundos (30s STS) se utilizó para evaluar la fuerza y función muscular general de las extremidades inferiores.
Resultados: Hubo una diferencia significativa en los resultados de 6MWT (m), 6MST (número de pasos) y 30s STS de los tres grupos ($p < 0,05$). Los resultados de la 6MST de los pacientes con DM tipo 2 neuropática fueron significativamente inferiores a los de los diabéticos no neuropáticos y los que estaban sanos (número de pasos; $114,07 \pm 25,57$ vs. $133,48 \pm 33,57$ vs. $160,35 \pm 28,52$, respectivamente) ($p = 0,001$). El cambio en la respuesta cardiorrespiratoria en la presión arterial sistólica, la frecuencia cardíaca, la disnea percibida y la gravedad de la fatiga de las piernas fue significativamente mayor en 6MST que en 6MWT en los tres grupos ($p < 0,05$). 6MST se correlacionó con 6MWT ($r = 0,679$, $p = 0,001$) y 30s STS ($r = 0,589$, $p = 0,001$) en pacientes con DM tipo 2.
Conclusiones: Las respuestas cardiorrespiratorias aumentaron más en 6MST en comparación con 6MWT. En pacientes con DM tipo2, 6MWT y 6MST se correlacionaron moderadamente entre sí. 6MST es un método de evaluación efectivo y seguro que puede revelar mejor las diferencias en la capacidad de ejercicio funcional entre individuos neuropáticos y no neuropáticos en las consultas.

Introduction

Diabetes mellitus (DM) is one of the biggest threats to global health because it is a public health problem with an increasing incidence rate.[1] Among the common complications of Type 2 DM are retinopathy, nephropathy, and diabetic peripheral neuropathy (DPN). A decreased in nociception, impaired perception of position, loss of distal strength, ataxia, and muscle atrophy characterize peripheral neuropathy. These DPN-related disorders affect the ability of patients to be physically active and lead to a decrease in their functional exercise capacity.[3,4]

The exercise capacity of patients with DM can be evaluated objectively by various methods, such as laboratory or field tests. The 6-minute walk test (6MWT) is a widely used method for evaluating the functional exercise capacity of patients with DM in clinics.[6] Since a large area is required for the 6MWT to be performed reliably, it may reduce the applicability of the 6MWT in DM clinics where a large population is screened and where space and time are usually more limited. The 6-minute step test (6MST) requires less time and space. Therefore, 6MST has recently been used as a simple and effective alternative as it requires less physical space than 6MWT.[7]

Lower extremity muscle strength is important in maintaining functional ability in advanced ages.[8] The ability to perform the sit-to-stand (STS) movement is important for maintaining physical independence and can be one of the most important functional measurements of physical capacity.[9] The muscle mass and strength reduction observed in Type 2 DM are related to many factors. In particular, neuropathic processes involving motor neurons are one of

the underlying mechanisms for decreased muscle strength in DM.[10] The 30s STS test has been reported as a reliable method for evaluating functional lower extremity muscle strength and functionality in Type 2 patients with DM.[11]

Previous clinical and observational studies have reported differences in 6-minute walking distance between subjects with neuropathic and non-neuropathic Type 2 DM and healthy control subjects[12–14]; however, there is no study in literature in which 6MST was used to compare the functional exercise capacities of Type 2 DM cases with and without DPN and healthy controls. Additionally, studies showing the change in exercise capacities between neuropathic and non-neuropathic Type 2 DM patients are insufficient. Therefore, this study aims to compare the cardiorespiratory response of the two exercise tests and analyses the usability of the 6MST in Type 2 DM patients with and without neuropathy when 6MWT cannot be performed.

Methods

Subjects

This research is a cross-sectional study conducted at Dokuz Eylul University Faculty of Medicine, Department of Internal Medicine, Department of Endocrinology and Metabolism Diseases, and Dokuz Eylul University Faculty of Physical Therapy and Rehabilitation from May 2019 to March 2020. Patients aged between 45 and 70 diagnosed with Type 2 DM and using antidiabetic drugs for 3 months, with or without diabetic peripheral neuropathy according to the EMG result, without orthopedic-neurological disability that would interfere with the tests, and who agreed to participate in the study were included. Voluntary individuals who had not been diagnosed with Type 2 DM were also included in the control group. Hemodynamically unstable cases, individuals with insufficient consciousness and cooperation, those who did not accept to participate in the study, those with orthopedic or surgical problems that would prevent the tests, those with uncontrolled hypertension and a history of MI in the last month, unstable angina and cardiac problems such as severe heart failure were excluded from the study. The smallest sample size was calculated by looking at a similar study's 6-minute step test parameter. A priori sample size was calculated as 78 participants, 26 for each group, with an estimated effect size of 0.56, an alpha error probability of 0.05, and a power of 0.80 using G*Power Software (Version 3.1.9.2, Dusseldorf University, Dusseldorf, Germany). With a drop-out rate of 20%, 94 participants would be needed. This study was approved by the Dokuz Eylul University Non-invasive Research Ethics Committee (decision number: 2019/08-17). All of the subjects gave written informed consent.

Assessments

Sociodemographic and anthropometric characteristics such as age, gender, weight, height, body mass index (BMI), and marital status of all the individuals included in the study were recorded. The diagnosis times of patients with Type 2 DM and EMG results of patients with neuropathy were obtained from clinical files. Patients who did not have a history of falling in the last 1 year and were followed up with the diagnosis of Type 2 DM were divided into neuropathic and non-neuropathic according to their file information.

The body mass index (BMI) (kg/m^2) and lean body mass (kg) of the participant were measured using a bioelectrical impedance analysis system (Bodystat 1500, Bodystat Ltd., Douglas, UK).[15] Symptom severity in Type 2 DM patients with DPN was evaluated using the ''neuropathy symptom score'' scale. As the neuropathy symptom score increases, the neuropathy symptom severity increases (3–4 points for mild symptoms, 5–6 points for moderate symptoms, and 7–9 points for severe symptoms).[16]

Functional exercise capacity

Six-Minute walk test

The 6MWT was conducted according to the standardized protocol described by the American Thoracic Society guidelines. Blood pressure, heart rate, oxygen saturation (SpO_2), dyspnea, and leg fatigue perception were evaluated before and after the test. A modified Borg scale was used for dyspnea and leg fatigue perception. Heart rate and oxygen saturation (SpO_2) values were measured with a pulse oximeter (Finger Pulse Oximeter, Germany). The maximum distance covered was recorded at the end of the test.[6]

6-Minute step test

A wooden step with a height of 20 cm was used in the 6-minute step test. The participants were instructed to climb up and down at a speed they thought would allow them to perform the maximum number of steps in 6 min. The one cycle of climbing up and down the step was counted as 1 step. They could begin the climbing with whichever lower limb they felt more comfortable with and change it at any time during the test. Thus, the test would be more similar to an activity of daily living.

For better reliability, the test followed the same principles as the 6MWT. Thereby, the same standardized verbal incentives each minute were used, and the participant chose their own pace.[7] Before and after the test, heart rate, blood pressure, and SpO_2 were assessed; dyspnea and leg fatigue were asked using a modified Borg scale (0–10). Heart rate and SpO_2 values were measured with a pulse oximeter (Finger Pulse Oximeter, Germany).

The 30-second sit-to-stand test

The test was administered using a chair without arms. The seat height was adjusted so that the hip and knee angle of all participants was 90°. Arms are crossed at the wrists and held against the chest. Participants were asked to rise from a seated position and sit as quickly and safely as possible in 30 s. The completed number of chair stands within 30 s is counted and recorded for this test.[11]

Statistical analyses

The statistical analysis was performed using IBM SPSS software (Version 24.0, IBM Inc. Chicago, ABD). Since the variables showed normal distribution, using parametric test statistics, continuous variables were expressed as mean ± standard deviation, and categorical variables were

Table 1 Demographic characteristics.

Features	Non-neuropathic Type 2 DM	Neuropathic Type 2 DM	Healthy controls	p	$p^{\dagger}$	$p^{\ddagger}$	$p^{\S}$
Gender							
Female	15 (46.9%)	16 (50.0%)	15(50.0%)	0.961	0.967	0.968	1.000
Male	17 (53.1%)	16 (50.0%)	15 (50.0%)				
Age (yrs)	59.90 ± 6.82	60.31 ± 7.23	56.83 ± 6.42	0.099	0.969	0.186	0.118
Height (cm)	166.50 ± 6.96	166.43 ± 9.91	167.90 ± 8.86	0.757	1.000	0.801	0.785
Weight (kg)	81.43 ± 14.44	86.22 ± 13.13	77.04 ± 11.37	0.026*	0.313	0.387	0.019*
BMI (kg/m^2)	29.47 ± 4.84	31.30 ± 5.13	27.06 ± 3.14	0.002*	0.236	0.93	0.001*
Lean body mass (kg)	55.44 ± 10.95	57.98 ± 12.29	53.10 ± 9.80	0.228	0.632	0.685	0.199
Disease duration (yrs)	10.65 ± 6.31	13.21 ± 9.59	NA	0.212			
Neuropathy symptom score	NA	5.43	NA				
30s STS	13.78 ± 1.96	11.75 ± .78	16.16 ± 2.53	0.001*	0.004*	0.001*	0.001*

One-way ANOVA. Data were expressed as mean ± SD. Disease duration: independent sample t-test, mean ± SD. 30s STS: 30-second sit-to-stand test; NA: not applicable.

* Statistically significant difference ($p < 0.05$).

† Comparison of non-neuropathic and neuropathic Type 2 DM groups.

‡ Comparison of non-neuropathic Type 2 DM and healthy controls.

§ Comparison of neuropathic Type 2 DM and healthy controls.

expressed as numbers and percentages (%). The Chi-square test was used to compare the differences between categorical variables. 'One-way analysis of variance (one-way ANOVA test)' was used to compare the difference between the groups. The complementary Tukey HSD post hoc analysis technique was used to determine the significant difference between which groups was found after a one-way analysis of variance. The 'independent sample t-test' calculated the statistical significance between the values of the two groups. The 'dependent sample t-test' was used to compare groups' responses to the tests within themselves. To determine the relationship between 6MWT, 6MST, and 30s STS, correlations between tests were investigated using Pearson's product–moment correlation coefficient. A correlation coefficient was interpreted as negligible for $r/p = 0.00–0.30$, low for $r/p = 0.30–0.50$, moderate for $r/p = 0.50–0.70$, high for $r/p = 0.70–0.90$ and very high for $r/p = 0.90–1.00$.[17] Statistical significance was deemed at $p < 0.05$.

Results

A total of 94 people aged 45–70 were included in the study; 32 were non-neuropathic Type 2 DM (15 (46.9%) female, 17 (53.1%) male), 32 were neuropathic Type 2 DM patients (16 (50%) female, 16 (50%) male), and 30 were healthy (15 (50%) female, 15 (50%) male). The demographic characteristics and 30s STS results of the groups, and also disease duration and NSS results of the patients with Type 2 DM, are summarized in Table 1. There was no significant difference between the three groups regarding gender, age, height, and lean body mass ($p > 0.05$). There was a significant difference between the three groups regarding body weight and BMI ($p < 0.05$). The body weight and BMI of neuropathic Type 2 DM patients were significantly higher than in the control group ($p < 0.05$). The disease duration in patients with non-neuropathic Type 2 DM was 10.65 ± 6.31 years, and in patients with neuropathic Type 2 DM was 13.21 ± 9.59 years. There was no significant difference between the disease duration of the two groups ($p > 0.05$). The neuropathy severity of patients with neuropathic Type 2 DM was 5.43 moderate intensity. There was a significant difference between the 30s STS results of the three groups ($p < 0.05$).

The 30s STS results of non-neuropathic and neuropathic Type 2 DM patients were significantly lower than the control group ($p < 0.05$). The 30s STS results of the patients with neuropathic Type 2 DM were significantly lower than those with non-neuropathic Type 2 DM ($p < 0.05$).

The results of the 6-minute walk distance and the number of steps in the 6MST between the three groups are presented in Table 2. There was a significant difference in the results of 6MWT (m) and 6MST (number of steps) between the three groups ($p < 0.05$).

The distances of 6MWT (m) of patients with Type 2 DM were significantly lower than in the control group ($p < 0.05$). There was no difference between non-neuropathic and neuropathic Type 2 DM patients in terms of 6MWT (m) distances ($p > 0.05$). There was a significant difference between the 6MST (number of steps) results of the three groups ($p < 0.05$). The number of steps of non-neuropathic and neuropathic Type 2 DM patients was significantly lower than the control group ($p < 0.05$). The number of steps in patients with neuropathic Type 2 DM was significantly lower than in patients with non-neuropathic Type 2 DM ($p < 0.05$).

The comparison of the changes in cardiorespiratory responses within the groups is shown in Table 3. The change in systolic blood pressure, heart rate, perceived dyspnea, and severity of leg fatigue was higher in 6MST than in 6MWT in the three groups ($p < 0.05$). There was no significant difference between the two tests in diastolic blood pressure, oxygen saturation, and general fatigue severity in all groups ($p > 0.05$).

Table 4 shows the correlation between 6MST, 6MWT, and 30s STS results in patients with Type 2 DM. The 6MST were

Table 2 Results of 6MWT and 6MST.

	Non-neuropathic Type 2 DM	Neuropathic Type 2 DM	Healthy controls	p	$p^{\dagger}$	$p^{\ddagger}$	$p^{\S}$
6MWT (m)	451.26 ± 73.69	416.39 ± 68.63	547.69 ± 81.99	0.001*	0.155	0.001*	0.001*
ΔSBP (mmHg)	4.40 ± 14.40	6.06 ± 12.54	11.63 ± 14.90	0.111	0.884	0.109	0.264
ΔDBP (mmHg)	4.37 ± 4.66	4.10 ± 3.21	6.33 ± 8.11	0.536	0.994	0.618	0.627
ΔHeart rate (beat/min)	10.18 ± 7.56	8.43 ± 8.25	14.0 ± 11.95	0.065	0.737	0.252	0.057
ΔSPO_2 (%)	0.31 ± 0.82	0.43 ± 1.29	0.56 ± 1.30	0.690	0.903	0.665	0.899
ΔDyspnea (M.Borg 0–10)	0.78 ± 1.64	0.56 ± 1.07	0.00 ± 0.00	0.026*	0.726	0.023*	0.135
ΔLeg fatigue (M.Borg 0–10)	1.31 ± 1.53	2.15 ± 1.93	1.36 ± 1.67	0.098	0.128	0.992	0.174
ΔGeneral fatigue (M.Borg 0–10)	0.90 ± 1.39	0.84 ± 1.52	0.56 ± 1.25	0.601	0.983	0.607	0.717
6MST (number of steps)	133.48 ± 33.57	114.07 ± 25.57	160.35 ± 28.52	0.001*	0.026*	0.002*	0.001*
ΔSBP (mmHg)	18.00 ± 18.56	19.31 ± 21.92	20.66 ± 14.02	0.852	0.957	0.839	0.956
ΔDBP (mmHg)	2.12 ± 16.03	−0.65 ± 7.64	1.76 ± 7.57	0.563	0.584	0.991	0.673
ΔHeart rate (beat/min)	23.15 ± 14.93	18.87 ± 10.46	28.63 ± 17.75	0.036*	0.473	0.308	0.027*
ΔSPO_2 (%)	0.37 ± 0.90	0.68 ± 1.20	0.36 ± 0.71	0.328	0.404	0.999	0.397
ΔDyspnea (M.Borg 0–10)	1.46 ± 2.38	1.50 ± 1.72	0.30 ± 0.595	0.012*	0.997	0.027*	0.022*
ΔLeg fatigue (M.Borg 0–10)	3.90 ± 2.77	5.09 ± 2.10	2.53 ± 2.48	0.001*	0.138	0.079	0.001*
ΔGeneral fatigue (M.Borg 0–10)	1.46 ± 2.27	1.40 ± 2.31	1.16 ± 1.82	0.845	0.993	0.846	0.900

One-way ANOVA. Data were expressed as mean ± SD. (SBD: systolic blood pressure; DBD: diastolic blood pressure; HR: heart rate; 6MWT: 6-minute walk test; 6MST: 6-minute stepper test; M.Borg: modified Borg scale.)

* Statistically significant difference ($p < 0.05$).

† Comparison of non-neuropathic and neuropathic Type 2 DM groups.

‡ Comparison of non-neuropathic Type 2 DM and healthy controls.

§ Comparison of neuropathic Type 2 DM and healthy controls.

moderately correlated with 6MWT and 30s STS in patients with Type 2 DM (6MWT, $r = 0.679$, $p = 0.001$; 30s STS, $r = 0.589$, $p = 0.001$) and non-neuropathic Type 2 DM patients (6MWT, $r = 0.604$, $p = 0.001$; 30s STS, $r = 0.559$, $p = 0.001$). The 6MST showed a high correlation with 6MWT ($r = 0.733$, $p = 0.001$) and a moderate correlation with 30s STS ($r = 0.559$, $p = 0.001$) in neuropathic Type 2 DM patients. Also, the 6MWT were moderately correlated with 30s STS in patients with Type 2 DM ($r = 0.507$, $p = 0.001$) and neuropathic Type 2 DM patients ($r = 0.531$, $p = 0.002$). In addition, the 6MWT was lowly correlated with 30s STS in patients with non-neuropathic Type 2 DM ($r = 0.395$, $p = 0.025$).

Discussion

In this study, patients with Type 2 diabetes were found to have significantly lower exercise capacity than healthy controls. The cardiorespiratory responses of the three groups to exercise tests were higher in the 6MST than in the 6MWT. 6MWT, 6MST, and 30s STS were found to be related to each other in patients with Type 2 DM.

Functional exercise capacity in patients with Type 2 DM is affected by increased insulin resistance, decreased muscle strength, muscle fiber changes, increased muscle fatigue, and complications related to DM. Functional exercise capacity is a function of cardiorespiratory fitness and is a strong predictor of survival in Type 2 DM.[10] In the literature, 6MWT is widely used to evaluate cardiopulmonary performance in patients with Type 2 DM.[6] Previous studies have shown that patients with neuropathic and non-neuropathic diabetes have a lower walking distance than healthy individuals.[14–16] Our study supports the results of studies showing a decrease in functional exercise capacity in patients with Type 2 DM.

Recently, 6MST has started to be used as a simple and effective alternative because it requires less physical space than 6MWT.[14,18] Only one study was found using 6MST in patients with Type 2 DM in the literature. Jones et al. used 6MST in their study investigating the effect of ethnic differences on the change in exercise capacity and muscle strength in patients with Type 2 DM.[19] Our study is the first to use 6MST to compare functional exercise capacity between neuropathic and non-neuropathic Type 2 DM patients and healthy individuals. In our study, the number of steps in patients with diabetes was lower than in healthy individuals, and the number of steps in our patients with neuropathic diabetes was lower than the number of steps in our patients with non-neuropathic diabetes. Similar to the results in the literature, our 6MST results showed that the exercise capacity of our patients with diabetes decreased compared with healthy individuals. Also, it was determined that the functional exercise capacity of our patients with neuropathic

Table 3 Comparison of cardiorespiratory responses to two test.

	Non-neuropathic Type 2 DM			Neuropathic Type 2 DM			Healthy controls		
	6MWT	6MST	*p*	6MWT	6MST	*p*	6MWT	6MST	*p*
SBP (mmHg)									
Pre-test	130.25 ± 13.64	136.56 ± 17.02	0.051	131.81 ± 18.60	134.03 ± 21.42	0.425	128.90 ± 16.08	131.50 ± 15.74	0.273
Post-test	134.65 ± 16.35	154.56 ± 15.97	0.001*	137.87 ± 21.03	153.34 ± 25.11	0.001*	140.53 ± 17.85	152.16 ± 19.82	0.001*
ΔSBP (mmHg)	4.40 ± 14.40	18.00 ± 18.56	0.004*	6.06 ± 12.54	19.31 ± 21.92	0.004*	11.63 ± 14.90	20.66 ± 14.02	0.020*
DBP (mmHg)									
Pre-test	71.31 ± 6.24	78.93 ± 9.90	0.241	70.50 ± 7.87	79.40 ± 10.64	0.385	79.90 ± 7.47	81.86 ± 9.71	0.815
Post-test	75.68 ± 7,30	81.06 ± 13,76	0.087	74.60 ± 7,39	78.75 ± 12,76	0.181	86.23 ± 11.66	83.63 ± 8.21	0.842
ΔDBP (mmHg)	4.37 ± 4.66	2.12 ± 16.03	0.335	4.10 ± 3.21	0.65 ± 7.64	0.145	6.33 ± 8.11	1.76 ± 7.57	0.967
Heart rate									
Pre-test	82.75 ± 11.40	79.53 ± 11.51	0.034*	83.50 ± 14.70	79.68 ± 13.33	0.001*	79.20 ± 8,65	76.53 ± 8.63	0.113
Post-test	92.93 ± 12.63	102.68 ± 17.73	0.002*	91.93 ± 18.91	98.56 ± 20.39	0.004*	93.20 ± 13.06	105.16 ± 18.15	0.001*
ΔHeart rate (beat/min)	10.18 ± 7.56	23.15 ± 14.93	0.001*	8.43 ± 8.25	18.87 ± 10.46	0.001*	14.00 ± 11.95	28.63 ± 17.75	0.001*
SpO_2 (%)									
Pre-test	96.93 ± 1.21	97.12 ± 1.07	0.226	96.90 ± 1.17	96.81 ± 1.35	0.687	97.03 ± 1.56	97.33 ± 1.06	0.174
Post-test	97.25 ± 0.98	97.50 ± 0.84	0.044*	97.34 ± 1.03	97.50 ± 0.76	0.282	97.60 ± 0.96	97.70 ± 0.70	0.586
ΔSpO_2 (%)	0.31 ± 0.82	0.37 ± 0.90	0.690	0.43 ± 1.29	0.68 ± 1.20	0.340	0.56 ± 1.30	0.36 ± 0.71	0.415
Dyspnea				*(M.Borg 0–10)*					
Pre-test	0.12 ± 0.70	0.00 ± 0.00	0.325	0.09 ± 0.39	0.00 ± 0.00	0.184	0.00 ± 0.00	0.00 ± 0.00	–
Post-test	0.90 ± 2.13	1.46 ± 2.38	0.007*	0.65 ± 1.18	1.50 ± 1.72	0.001*	0.00 ± 0.00	0.30 ± 0.59	0.010*
ΔDyspnea (M.Borg 0–10)	0.78 ± 1.64	1.46 ± 2.38	0.004*	0.56 ± 1.07	1.50 ± 1.72	0.002*	0.00 ± 0.00	0.30 ± 0.59	0.010*
ΔLeg fatigue M.Borg 0–10)									
Pre-test	0.93 ± 1.99	0.59 ± 1.29	0.362	1.40 ± 2.28	1.18 ± 1.76	0.418	0.10 ± 0.54	0.10 ± 0.54	
Post-test	2.25 ± 2.92	4.50 ± 2.94	0.001*	3.56 ± 2.52	6.28 ± 2.34	0.002*	1.40 ± 1.85	2.63 ± 2.56	0.018*
ΔLeg fatigue (M.Borg 0–10)	1.31 ± 1.53	3.90 ± 2.77	0.001*	2.15 ± 1.93	5.09 ± 2.10	0.001*	1.36 ± 1.67	2.53 ± 2.48	0.018*
ΔGeneral fatigue									
Pre-test	1.06 ± 2.24	0.84 ± 1.86	0.370	0.93 ± 1.79	1,00 ± 2.21	0.798	0.10 ± 0.54	0.20 ± 0.76	0.326
Post-test	1.96 ± 3.02	2.53 ± 3.33	0.037*	1.78 ± 2.23	2.40 ± 3.26	0.108	0.66 ± 1.47	1.36 ± 1.95	0.099
ΔGeneral fatigue (M.Borg 0–10)	0.90 ± 1.39	1.69 ± 2.27	0.077	0.84 ± 1.52	1.40 ± 2.31	0.179	0.56 ± 1.25	1.16 ± 1.82	0.147

One-way ANOVA. Data were expressed as mean ± SD. (SBD: systolic blood pressure; DBD: diastolic blood pressure; HR: heart rate; 6MWT: 6-minute walk test; 6MST: 6-minute stepper test; M.Borg: modified Borg scale.)

* Statistically significant difference ($p < 0.05$).

Table 4 Correlation between 6MST, 6MWT and 30s STS tests.

	Type 2 DM				Non-neuropathic Type 2 DM				Neuropathic Type 2 DM			
	6MWT (m)		30s STS (*n*)		6MWT (m)		30s STS (*n*)		6MWT (m)		30s STS (*n*)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
6MST (number of steps)	0.679	0.001*	0.589	0.001*	0.604	0.001*	0.559	0.001*	0.733	0.001*	0.531	0.002*

Pearson correlation coefficients. 6MST: 6-Minute stepper test; 6MWT: 6-minute walk test; 30s STS: 30-second sit-to-stand test.
* Statistically significant difference ($p < 0.05$).

diabetes decreased more significantly than our patients with non-neuropathic diabetes.

Chehere et al., in the study of subjects with interstitial lung disease comparing the cardiovascular responses in 6MWT and 6MST, reported that the subjects perceived more leg fatigue severity and showed higher ventilation response after the step test compared to the walking test.[20] Teodorczyk et al., in the study that applied the 2-minute step test and the 6MWT to cases with systolic heart failure, no difference was found between the hemodynamic responses between the tests but the leg fatigue evaluated after the tests were higher in the 2MST than in the 6MWT. In our study, according to the exercise responses of the three groups at the end of 6MWT, our patients with non-neuropathic diabetes had more change in the severity of dyspnea perceived than in the control group. This was because the walking distance of non-neuropathic patients with diabetes was more than those of neuropathic patients with diabetes and less than those of the control group. When the responses of all the patients to exercise were compared at 6MST, it was found that the change in the severity of heart rate, perceived dyspnea, and leg fatigue in patients with neuropathic diabetes was more affected than in the control group. Only the change in the perceived severity of dyspnea in our non-neuropathic diabetic patients was higher than in the control group. The groups' blood pressure, heart rate, oxygen saturation, and general fatigue response parameters were found to have similar results. When we compared the cardiorespiratory responses of each group to exercise at the end of 6MWT and 6MST, the change in systolic blood pressure, heart rate, perceived dyspnea, and leg fatigue severity in the three groups was higher in the step test than in the walking test. These results show that our patients with neuropathy cause more effort in 6MST than in 6MWT compared to the other two groups.

Heart rate is an objective parameter for determining the physiological response of the cardiorespiratory system.[22] In this study, both field tests revealed heart rate responses, but the increase in end-test heart rates was higher in the step test compared to the walking test. The higher responses to exercise in the step test indicate that the step test requires more effort and that neuropathy cases can give a more significant result in showing the change in exercise capacity compared to non-neuropathies. Consistent with our results, a study by ACSM (American Academy of Sports Medicine) stated that 6MST requires more work against gravity, causes higher oxygen demands due to different body movements, and requires more energy than 6MWT.[23]

Lower extremity muscle strength is important in maintaining functional ability in advanced ages. Studies show that sit-stand tests are a very reliable and valid test for evaluating general lower extremity muscle strength and physical function.[9] In addition, sit-stand tests are widely used to evaluate balance control, lower extremity function, and strength.[24] Nevitt et al. reported that <15 sit-stand cycles in 30 s were associated with weaker lower extremity muscle strength.[25] In our study, the 30s STS results of our patients with diabetes were below 15 repetitions. In addition, the sit-stand numbers of our neuropathic cases are lower than those of our non-neuropathic cases. Gurses et al., in their study on healthy individuals, stated that all sit-to-stand tests have a statistically significant correlation with the 6MWT, sit-to-stand tests can be used to evaluate functional performance in healthy young adults.[26]

Grosbois et al. reported that 6MST shows a significant correlation with 6MWT in the evaluation of exercise capacities of patients with COPD, and 6MST is a clinically valid and usable test.[27] Gurses et al. reported a moderate correlation between 6MWT and 30s STS in their study on healthy individuals.[26] When we look at the results of our study, similar to previous studies, walking distance, number of steps, and sit-to-stand test results of our patients with diabetes were correlated. When we look at the correlations between the tests of our non-neuropathic and neuropathic diabetic cases separately, the number of steps, walking distance, and sit-to-stand test results of our non-neuropathic cases affect each other. As our neuropathic patients' steps increase, the walking distance improves. We observed a correlation between our neuropathic patients' sit-to-stand, step test, and walking distance results.

The present study has some limitations. Postural instability may develop in patients due to sensory and motor loss seen in diabetic peripheral neuropathy. The risk of falling increases in patients with loss of balance. Thus, it reduces the physical functions of individuals. Therefore, balance assessment is an important issue in cases with neuropathy. Roongbenjawan et al. showed that 30s STS could detect changes in balance over time in older adults.[24] Although we did not perform a specific balance assessment for our neuropathic diabetic patients in our study, we thought that the 30s STS might help interpret the balance relatively according to the results of the studies used in the literature to evaluate balance control. In addition, the absence of a history of falls in the last year of our cases indicates no severe balance effects. According to the NSS, another factor was that our patients with neuropathic diabetes had moderate neuropathy. In the literature, balance disorder has not been

shown in patients with DPN diagnosed with moderate neuropathy symptom scores. New studies are expected to be conducted in patients with neuropathy symptom scores of different severity to better guide this issue.

In summary, the findings in this study were that the functional exercise capacity of patients with Type 2 DM was significantly lower than those of healthy individuals. Cardiopulmonary exercise responses increased more in 6MST compared to 6MWT. In patients with Type 2 DM, 6MWT and 6MST were moderately correlated. In conclusion, our study showed that measuring functional exercise capacity with 6MST is an effective and safe assessment method that can better reveal the differences in exercise capacity between neuropathic and non-neuropathic individuals in clinics. We think this study is important and instructive in terms of outcome measures to determine and evaluate the effectiveness of physiotherapy and rehabilitation programs for physiotherapists working with diabetes patients and individuals with Type 2 DM.

Conflicts of interest

None declared.

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