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Investigation of the Effects of Lower Extremity Muscle Oxygenation, Balance, and Strength on Short-Duration Performance Tests

Alt Ekstremite Kas Oksijenasyonu, Denge ve Kas Kuvvetinin Kısa Süreli Performans Testleri Üzerindeki Etkilerinin İncelenmesi

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Abstract

Objective: The aim of this study was to compare changes in lower extremity muscle oxygenation during short-term performance tests and to investigate the effects of muscle oxygenation, muscle strength, and balance on test performance.

Material and Methods: A total of 52 healthy and physically active participants aged 18–35 years were included in the study. Three different short-term performance tests were applied to the participants: the Timed Up and Go Test, the Five Times Sit-to-Stand Test, and the 10-Meter Walk Test. Dorsiflexion and knee extension muscle strength of the dominant extremity were measured. Balance status was assessed using the Berg Balance Scale, while muscle oxygenation was determined using a near-infrared spectroscopy device placed over the rectus femoris muscle. Maximum, minimum, and mean muscle oxygen saturation levels were recorded during the measurements.

Results and Conclusion: No statistically significant differences were found in maximum, minimum, or mean muscle oxygen saturation levels across the tests. These findings suggest that short-term performance tests in healthy individuals may not be directly associated with muscle oxygenation, muscle strength, or balance. The relationship between short-term functional tests and physiological parameters appears to be limited, indicating that test performance cannot be reduced to a single biological determinant.

Keywords: Muscle strength, near-infrared spectroscopy, physical performance tests

Öz

Amaç: Bu çalışmada, kısa süreli performans testleri sırasında alt ekstremite kas oksijenizasyonundaki değişimlerin karşılaştırılması ve kas oksijenizasyonu, kas kuvveti ile dengenin test başarısına etkisinin incelenmesi amaçlanmıştır.

Materyal ve Metod: Çalışmaya 18–35 yaş aralığında 52 sağlıklı ve fiziksel olarak aktif gönüllü dahil edilmiştir. Katılımcılara üç farklı kısa süreli performans testi uygulanmıştır: Süreli Kalk-Yürü Testi, 5 Kez Otur-Kalk Testi ve 10 Metre Yürüme Testi. Dominant ekstremitede dorsifleksiyon ve diz ekstansiyon kuvvetleri ölçülmüştür. Denge durumu Berg Denge Ölçeği ile, kas oksijenizasyonu ise rektus femoris kasının üzerine yerleştirilen yakın kızılötesi spektroskopi cihazı ile belirlenmiştir.

Ölçümler sırasında maksimum, minimum ve ortalama kas oksijen satürasyon düzeyleri kaydedilmiştir.

Bulgular ve Sonuç: Tüm testler sırasında elde edilen maksimum, minimum ve ortalama kas oksijen satürasyonu değerleri arasında istatistiksel olarak anlamlı bir fark bulunmamıştır. Bu bulgular, kısa süreli performans testlerinin sağlıklı bireylerde kas oksijenizasyonu, kas kuvveti ve denge ölçümleri ile doğrudan bağlantılı olmayabileceğini göstermektedir. Sonuç olarak, kısa süreli fonksiyonel testlerin fizyolojik parametrelerle olan ilişkisi sınırlı düzeyde olup, test performansının tek bir biyolojik belirleyiciye indirgenemeyeceği anlaşılmaktadır.

Anahtar Kelimeler: Kas kuvveti, performans testi, yakın kızılötesi spektroskopi

Introduction

Short-term performance tests are widely used methods to assess individuals' physical performance levels. These tests play a crucial role in evaluating the abilities of athletes and physically active individuals. They are designed to provide rapid and efficient results. However, several factors may influence test performance (1).

One of the factors affecting the success of short-term performance tests is muscle strength (2). For example, in a jump test, an individual with low muscle strength may fail to achieve adequate height, thereby negatively affecting the test outcome. Muscle strength refers to the force-generating capacity of muscles and is a critical component in many sports and physical activities. It influences movement control and overall performance efficiency (3).Balance refers to the control of body position and movement. It is a key factor in many sports and physical activities and directly affects performance effectiveness and efficiency. Balance characteristics are often assessed in short-term performance tests, and these evaluations can directly impact test outcomes. For instance, in a running test, an individual with poor balance may have an increased risk of falling, which may adversely affect performance results (2).

Muscle oxygenation refers to the uptake and utilization of oxygen by muscles. Adequate oxygen delivery is essential for energy production and the maintenance of performance. During high-intensity physical activities, a reduction in muscle oxygenation may occur, which can negatively impact performance. Therefore, evaluating lower extremity muscle oxygenation in short-term performance tests is of particular importance (4).

In this study, the effects of clinical characteristics such as muscle oxygenation, muscle strength, and balance on the performance outcomes of short-term performance tests were investigated. Additionally, changes in muscle oxygen saturation (SmO_2) were examined during these tests. To the best of our knowledge, this is the first study to investigate lower extremity muscle oxygenation changes during short-term performance tests. The findings of this study may contribute to a better understanding of physiological responses during short-term functional performance tests.

Materials and Methods

This single-center crossover experimental study was conducted between January 2024 and May 2024. Ethical approval was obtained from the local ethics committee (Approval Date: 01/12/2023; Approval No: 2022-248), and the study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

The study included participants aged 18–35 years without any known systemic disease or health problem. Participants with peripheral arterial disease affecting muscle oxygenation, orthopedic or neurological conditions impairing balance, skin problems preventing device placement, and smokers were excluded. A total of 60 volunteers were initially assessed for eligibility. Eight participants were excluded because they did not meet the inclusion criteria, and the study was completed with 52 participants (26 females and 26 males). Existing comorbidities among participants included Familial Mediterranean Fever, allergic rhinitis, asthma, goiter, mitral valve insufficiency, polycystic kidney disease, scoliosis, and vertigo.

The sample size was determined through G*Power analysis. Based on SmO_2 (%) values reported in a similar study, with a type I error of 0.05 and a statistical power of 0.95, the minimum required sample size to detect differences between groups was calculated as 52 (5).

Demographic characteristics, including age, sex, height, and body weight, were recorded using a standardized data collection form. Muscle strength of the dominant lower extremity was assessed using a digital dynamometer (Lafayette, IN, US) for knee extension and ankle dorsiflexion. Knee extension strength was measured in a seated position with the knee flexed, while force was applied to the distal tibia during active extension (6). Ankle dorsiflexion strength was evaluated in a seated position with the device placed on the dorsal aspect of the foot (7).

Balance was evaluated using the Berg Balance Scale (BBS), which consists of 14 items scored between 0 and 4, with total scores ranging from 0 to 56. According to the total score, balance was classified as poor (0–20), moderate (21–40), or good (41–56) (8).

Muscle oxygenation was continuously measured using a MOXY (MOXY Monitor, Fortiori Design LLC, Hutchinson, MN, USA) device placed on the rectus femoris muscle, and maximum, minimum, and mean values were recorded throughout all tests. Functional performance was assessed using the Timed Up and Go Test (TUG), Five Times Sit-to-Stand Test (5STS), and 10-Meter Walk Test (10MWT). The order of test administration was randomized, and a rest period of up to 5 minutes was provided between tests to ensure recovery.

During the TUG test, participants stood up from a seated position, walked 3 meters, turned around, returned, and sat down, with the total time recorded in seconds (9). In the 5STS, participants performed five consecutive sit-to-stand movements, and the duration was recorded (10).

In the 10MWT, participants walked at their normal speed over a 10-meter distance, and the elapsed time was recorded in seconds (11).

All measurements were systematically recorded and documented for subsequent analysis.

Statistical Analysis

Statistical analysis was performed using SPSS version 25. The normality of data distribution was assessed using the Shapiro–Wilk test. Categorical variables were presented as percentages and frequencies, whereas continuous variables were expressed as mean ± standard deviation. Differences among the parameters measured during the exercise tests were analyzed using One-Way Analysis of Variance (ANOVA), and the correlations among parameters were examined using Pearson's Correlation Analysis. In this study, the type I error rate (α) was set at 0.05.

Results

A total of 52 participants (26 females and 26 males) with a mean age of 21.94 years were included in the study. The demographic and clinical characteristics of the participants are presented in Table 1. Muscle total hemoglobin (THb) values were similar between male and female participants ($p > 0.05$).

Table 1. Demographic and Clinical Characteristics of the Participants

Demographic and Clinical Variables	**Mean**	**SD**
Age (years)	21.94	5.70
BMI (kg/m²)	22.99	3.67
Ankle Dorsiflexion Strength	48.97	9.33
Knee Extension Strength	51.6	9.02
Berg Balance Score	51.5	0.33
Categorical Variables	**n (%)**	
Sex		
Female	26 (50)	
Male	26 (50)	
Smoking Status		
Yes	-	
No	52 (100)	

BMI: Body Mass Index

Comparisons of muscle oxygenation values between tests are presented in Table 2. No statistically significant differences were found in the maximum, minimum, or mean SmO_2 values obtained during the TUG, 10MWT, and 5STS tests ($p > 0.05$). These findings indicate that the short-term performance tests applied have similar effects on muscle oxygen saturation values.

Table 2. Changes in Muscle Oxygenation Values During the Tests

	TUG (n=52)	**10MWT (n=52)**	**5STS (n=52)**	**P***
SmO_2				
Maksimum	55.15±18.20	57.23±17.90	55.69±17.68	0.829
Minimum	49.33±19.83	50.26±19.61	50.65±18.99	0.938
Mean	51.96±18.79	53.78±18.46	53.46±17.78	0.864

SmO_2: Muscle Oxygen Saturation; TUG: Timed Up and Go Test; 10MWT: 10-Meter Walk Test; 5STS: Five Times Sit-to-Stand Test.

The results of the Pearson correlation analysis conducted to evaluate the relationships among the three different short-term performance tests applied in the study are presented in Table 3. A very weak negative correlation was observed between the TUG and 5STS ($r = -0.066$); however, this relationship was not statistically significant ($p = 0.643$). Similarly, no significant correlations were found between TUG and 10MWT ($r = -0.001$, $p = 0.992$) or between 5STS and 10MWT ($r = -0.132$, $p = 0.352$). These findings suggest that the tests may assess distinct and independent components of physical performance.

Table 3. Correlation Analysis Between the Tests

Between Tests (n=52)	**r**	**p**
TUG – 5STS	-0.066	0.643
TUG – 10MWT	-0.001	0.992
5STS – 10MWT	-0.132	0.352

TUG: Timed Up and Go Test; 10MWT: 10-Meter Walk Test; 5STS: Five Times Sit-to-Stand Test.

The relationships between the exercise tests and muscle oxygenation (SmO_2 maximum, minimum, and mean), knee extensor strength, ankle dorsiflexion strength, and BBS were examined (Table 4). According to the correlation analyses, weak correlations were observed among all variables ($r < 0.3$), and none of these relationships were statistically significant ($p > 0.05$). These findings suggest that muscle oxygenation, strength, and balance parameters may not have a determining effect on performance outcomes in the applied exercise tests.

Table 4. Relationship Between Exercise Test Results and Muscle Oxygenation, Muscle Strength, and Balance

Table 4. Relationship Between Exercise Test Results and Muscle Oxygenation, Muscle Strength, and Balance

	SmO_2 Max	SmO_2 Min	SmO_2 Mean	Knee Ext.	DF	BBS
TUG (n=52)						
r	0.137	0.189	0.162	0.124	0.165	0.159
p	0.333	0.18	0.252	0.381	0,242	0.259
10MWT						
(n=52)	0.189	0.235	0.205	0.169	0.209	0.15
r	0.179	0.94	0.146	0.232	0.137	0.29
p						
5STS (n=52)						
r	0.146	0.184	0.158	0.178	0.219	0.138
p	0.302	0.191	0.262	0.208	0.119	0.329

TUG: Timed Up and Go Test; 10MWT: 10-Meter Walk Test; 5STS: Five Times Sit-to-Stand Test; SmO_2: Muscle Oxygen Saturation; Knee Ext.: Knee Extensor Muscle Strength; DF: Ankle Dorsiflexion Strength; BBS: Berg Balance Scale.

Discussion

This study demonstrated that short-term performance tests in healthy participants produce similar effects on muscle oxygen saturation levels. The lack of significant correlations between the tests suggests that each assesses different components of physical capacity. Additionally, no significant relationships were found between muscle oxygenation, muscle strength, balance parameters, and test performance, indicating that these tests may be used as independent assessment tools.

Previous studies have shown that SmO_2 varies depending on exercise type, with low-intensity isometric exercise not significantly affecting muscle perfusion or oxygenation (12). Consistent with this, no significant changes in rectus femoris oxygenation were observed in the present study, likely due to the short duration and low intensity of the applied tests.

Although agreement between different NIRS devices has been reported, their interchangeable use is not recommended (13). In this study, all measurements were performed using the same device, ensuring consistency. Furthermore, no significant relationship was found between dorsiflexor strength and rectus femoris oxygenation, possibly due to the sufficient muscle strength of healthy participants (14).

In older and sedentary populations, muscle oxygenation and hemoglobin dynamics are more variable (15,16). In contrast, the stable SmO_2 values observed in this study may be explained by the high peripheral circulation capacity of young, active individuals.

The relationship between muscle strength and balance remains inconsistent in the literature. Similar to previous findings (17), no significant association was found between dorsiflexor strength and balance performance. This supports the view that balance is a multifactorial function involving multiple systems rather than a single muscle group (18,19).

Although resistance exercise has been associated with decreased SmO_2 (20), no such change was observed in this study, likely due to the submaximal nature of the tests. Similarly, while functional test performance such as 5STS may depend on balance in certain populations (21,22), no such relationships were found in this healthy cohort.

In conclusion, short-term performance tests reflect different aspects of physical capacity and may be used as independent tools. However, the inclusion of only young, healthy individuals and the use of a single device limit generalizability, highlighting the need for further studies in diverse populations.

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