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Postural Stability and Functional Capacity in Recreational Athletes with Type 1 Diabetes Mellitus*

Aims: The aim of this study was to evaluate postural stability and functional capacity in recreational athletes with type 1 diabetes mellitus (T1 DM) and to compare them with healthy recreational athletes.

Materials and Methods: Sixteen recreational athletes with T1 DM (21.4 ± 2.1 years of age, 174.3 ± 7 cm height, 64.5 ± 10.1 kg weight, 10.9 ± 5.3 body fat percentage [BFP]) and 19 healthy recreational athletes (21.9 ± 2.5 years of age, 173.1 ± 5.2 cm height, 66.1 ± 4 kg weight, 14.4 ± 1.5 BFP) participated in this study. Postural stability was measured by using the one leg standing test (OLST) (static test) and single limb hopping course (SLHC) test (dynamic test). Functional capacity was evaluated by using the isokinetic muscle strength test, one-legged and triple-legged hop for distance tests, and six meter (6-m) and cross 6-m hop for time tests. Mann-Whitney U test was used to compare mean values of the diabetic group (DG) with those of the control group (CG).

Results: There was no difference between groups with regards to anthropometric data except in BFP (P < 0.01) and functional capacity tests (P > 0.05). OLST (P < 0.05) and SLHC tests (P < 0.01) were significantly lower in the DG.

Conclusions: These results suggest that diabetic athletes have reduced postural stability.

Key Words: Postural stability, functional capacity, type 1 diabetes mellitus, recreational athletes

Tip 1 Diyabetli Rekreasyonel Sporcularda Postural Stabilite ve Fonksiyonel Kapasite

Amaç: Çalışmanın amacı Tip 1 Diyabeti olan rekreasyonel sporcularda postural stabilite ve fonksiyonel kapasitenin belirlenmesi ve sağlıklı rekreasyonel sporcularla kıyaslanmasıdır.

Metod: Tip 1 diyabeti olan 16 rekreasyonel sporcu (yaş: 21.4 ± 2.1 yıl, boy: 174.3 ± 7 cm , ağırlık: 64.5 ± 10.1 kg, vücut yağ yüzdesi (VYY): 10.9 ± 5.3) ve 19 sağlıklı rekreasyonel sporcu (yaş: 21.9 ± 2.5 yıl, boy: 173.1 ± 5.2 cm, ağırlık: 66.1 ± 4 kg, VYY: 14.4 ± 1.5) çalışmaya katıldı. Postural stabilite tek bacak durma (statik test) ve tek bacak hoplama testi (dinamik test) ile ölçüldü. Fonksiyonel kapasite izokinetik kas kuvveti testi, tek adım ve 3 adım hoplama mesafesi testi, 6 metre ve çapraz 6 metre hoplama zamanı testleri ile değerlendirildi. Diyabet grubu (DG) ve kontrol grubunun (KG) değerleri istatistiksel olarak Mann Whitney U testi kullanılarak karşılaştırıldı.

Bulgular: İki grup arasında antropometrik değerlerden VYY (P < 0.01) ve fonksiyonel kapasite testleri (P > 0.05) haricinde istatistiksel olarak anlamlı fark bulunmadı. Tek bacak durma testi (P < 0.05) ve tek bacak hoplama testi (P < 0.01) DG'de istatistiksel anlamlı olarak daha düşük bulundu.

Sonuç: Elde edilen bulgular ışığında diyabetik sporcularda postural stabilitenin azaldığı söylenebilir.

Anahtar Sözcükler: postural stabilite, fonksiyonel kapasite, Tip 1 diyabet, rekreasyonel sporcular

Introduction

Diabetes mellitus type 1 (T1 DM) is a metabolic disease associated with insulin secretion defect and hyperglycemia. A common complication of DM was defined as diabetic neuropathy (DN) (1). Important limitations of sensory modalities and postural control disturbances are frequently observed in DN (2). The postural control system comprises the vestibular, visual and proprioceptive components controlling the balance of the body (3,4). Peripheral neuropathy has been significantly associated with repetitive

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falls (5). Peripheral neuropathy leading to decreased proprioception has been a possible risk factor of falling (6,7). In T1 DM patients with a long-term neuropathy (over 20 years), the muscle strength at the ankle and knee is impaired (8). Factors that affect falling are balance, muscular strength and endurance. Some studies have addressed the disturbance of postural stability during standing in DN patients (9-11). DN has been related to instability during normal stance (5). In some studies, high correlations were found between instability measurements and the severity of neuropathy (10-12). The onset of postural stability damage after the development of DN is not known. There is no literature study assessing the balance, muscular strength and functional capacities of young recreational athletes diagnosed with short-term diabetes.

The aim of this study was to evaluate postural stability and functional capacity in recreational athletes with T1 DM and to compare them with healthy recreational athletes.

Materials and Methods

Subjects

Thirty-five volunteer male adult recreational athletes were divided by the Gülhane Military Academy of Medicine (GATA) sports medicine staff into two groups: T1 DM group (DG) (n=16), 21.4 ± 2.1 years of age, 174.3 ± 7 cm height, 64.5 ± 10.1 kg weight, and 10.9 ± 5.3 body fat percentage (BFP) (Tanita Body Composition Analyzer Type TBF-410 MA, JAPAN), and healthy recreational athletes (CG) (n=19), 21.9 ± 2.5 years of age, 173.1 ± 5.2 cm height, 66.1 ± 4 kg weight, and BFP 14.4 ± 1.5. T1 DM participants were diagnosed at a mean of 6.1 ± 6.8 months. The CG was selected to match the DG characteristics in terms of age, weight, height, BFP and sex. All subjects were pre-screened to exclude individuals using medication, since it would have affected balance, and individuals with knee, ankle or hip injuries or other postural instabilities not related to DM. All subjects were physically examined by the physician, and no symptoms such as hyperesthesia, paresthesia, dysesthesia, or sensations of numbness, tingling, sharpness and burning that began in the feet and spread proximally were detected.

Exclusion criteria for both groups were vision impairment, peripheral vascular disease, somatosensory impairments, visual and/or vestibular dysfunction history, any neurological, muscular, or rheumatic disease outside the scope of the diabetes etiology, history of alcohol intake, and at least one reported fall in the past six months. All subjects were regularly exercising at a sports club at the time of diagnosis. The exercise program consisted of 30-45 minutes submaximal running, 30-50 times shuttle, 20-30 times push-up, and 5-10 times horizontal bar exercising, three times a week. For comparison purposes, the dominant extremities in the CG and DG were used. Three subjects in the DG and 4 subjects in the CG had a dominant left foot established by history. After being informed about the study, the test procedures and possible risks and discomfort that might ensue, written informed consent of the participants was obtained in accordance with the Helsinki Declaration.

Postural Stability Tests

To evaluate the postural stability of the athletes, two different tests, the one leg standing test (OLST) (static test) and single limb hopping course (SLHC) test (dynamic test) were used.

One Leg Standing Test (OLST)

This test evaluates the subject's ability to maintain his/her balance while standing on one leg. We performed this test not on a hard surface, but on a medium-density polyfoam mat, and with eyes closed to increase the failure rate. The subjects stood on the test side limb with their stance foot centered on the mat and their knees slightly flexed. They were instructed to lift the limb that was not being tested by bending the knee, holding it in approximately 90° of knee flexion. Once the subjects were in this position with eyes closed, and said they were ready, data collection was initiated. The OLST measurement was performed for one minute. During the test duration, each surface contact with the contralateral leg, moving the test foot, or swaying the body excessively out from midline in any direction to obtain a balanced stance, was counted as one failure point. The subjects performed the tests without shoes and socks to negate any extraneous skin sensation from clothing touching the foot area. The outcome measure was averaged over two trials. The interclass correlation coefficient (ICC) for the OLST was 0.92 (see data analysis).

Single Limb Hopping Course (SLHC) Test

This test is especially useful to document the function of the ankle on an uneven surface and was previously

used by researchers (13,14). The jumping course consisted of eight squares: four of them were even, one had a 15º increase, another had a 15º decrease, and two showed a 15º lateral inclination. The volunteers were asked to jump across this course on one leg by touching each area once as fast as possible without leaving the course. The test result was quantified by seconds used to pass the course. Each failure added an extra second to the time taken to complete the course. The ICC for this test was 0.96 (see data analysis).

Functional Tests

We evaluated the functional ability of the athletes using five different tests. The tests performed were isokinetic muscle strength test, one-legged hop for distance, triple-legged hop for distance, six meter (6-m) hop for time (s) and cross 6-m hop for time (s).

Isokinetic Muscle Measurement

Isokinetic dynamometry was performed to evaluate quadriceps and hamstring peak torque and work capacity. Maximal concentric force was measured by determining maximal concentric force moment (peak torque) during flexion and extension. The Cybex dynamometer was calibrated as part of the regular schedule for maintenance of equipment used for this testing device.*

The knee to be tested was placed on the knee flexion-extension plate of the Cybex Norm device, according to the manufacturer's instructions for isolating knee flexion and knee extension, and was secured with Velcro straps*. The length of the dynamometer was adapted to the length of the knee of each subject. To familiarize themselves with the testing device, subjects were instructed to perform three active repetitions of knee movement ranging from maximal flexion to maximal extension. Standard stabilization strapping was placed across the distal thigh and chest, and placements were limited to grasping the waist stabilization strap. Before the testing session started, the subject was allowed a 10-minute warm-up at a light intensity (less than 50 W) on a cycle ergometer, followed by a 30-second stretch of the quadriceps and hamstring muscles. Selection of the extremity was random. The same investigator performed all the tests. Subjects were instructed to give 100%

effort and received positive feedback during testing. They were allowed three submaximal contractions of the quadriceps and hamstring muscle group at the beginning of the test condition for the purpose of familiarization. They were given 30 maximal contractions at 180°/s for test condition. The best peak torque and power contraction of the 30 contractions under test condition were collected for data analysis. Between each condition, the subjects were allowed to rest for two minutes and gravitational corrections were performed.

One-Legged and Triple-Legged Hop for Distance

Patients were asked to make one and three forceful hopping movements forward as large as they could. The distance between the starting point and the end point was measured. Two tests were performed and the average distance was measured for each test. The ICCs for one-legged and triple- legged hop for distance were 0.97 and 0.98, respectively (see data analysis).

Six-meter and cross 6-m hop for time

This is a timed test performed over a distance of 6 meters. Each subject was encouraged to use linear, large, forceful one-legged hopping motions and crosswise, large, forceful one-legged hopping motions across a line with a 10 cm width to propel his body toward the measured distance as quickly as possible. Two tests were performed and the average time was measured for each test. The ICCs for 6-m and cross 6-m hop for time were 0.91 and 0.89, respectively (see data analysis).

Data Analysis

SPSS Windows 9.0 statistical program was used for all statistical analyses. Results were presented as mean standard deviation (SD). Data regarding the DG and CG characteristics were analyzed using Mann-Whitney U test. Findings with an error probability value of less than .05 were considered as statistically significant.

Postural stability tests and functional tests were repeated twice at 3-5 day intervals for reliability analysis in 20 healthy subjects. ICC was used to determine the reliability of these tests. The ICC was accepted as clinically meaningful if values were equal or greater than 0.80 (15).

Results

There were no anthropometric differences between the DG and CG regarding the variables measured except for BFP. There was a statistically significant difference in the BFP values of the two groups (P=0.004) (Table 1). The SLHC (P=0.006) and OLST (P=0.017) tests resulted in a statistically significant difference between CG and DG (Table 2). Peak torque, power, work and functional test scores of the knee flexor and extensor muscle groups in the DG were found similar to CG (Table 2).

Discussion

In this study, muscle strength measurements were carried out on the knee flexor and extensor muscle groups. The intensive use of these two muscle groups in daily and recreational activities was the reason for doing so. In a study with elderly diabetic subjects, knee and ankle muscle strengths were measured. A significant decrease in ankle and knee muscle strength was recorded (8). Knee muscle strength of recreational young diabetic subjects has not been studied yet.

Table 1. Anthropometric data and glycemia values (mean ± SD) of the DG and CG.

Characteristics	DG (N=16)	CG (N=19)	P-value
Age (year)	21.4 ± 2.1	21.9 ± 2.5	0.423
Height (cm)	174.3 ± 7	173.1 ± 5.2	0.511
Weight (kg)	64.5 ± 10.1	66.1 ± 4	0.417
BFP (%)	10.9 ± 5.3*	14.4 ± 1.5	0.004
Glycemia (mg/dl)	170.9 ± 54.1	-	-
HbA1c (%)	12.3 ± 3.8	-	-

BFP: body fat percent; DG: Diabetic Group; CG: Control Group. *P<0.005

Table 2. Postural stability and functional test scores (mean ± SD) of the DG and CG.

Parameters	DG (N=16)	CG (N=19)	P-value
OLST	13.4 ± 7.5*	7.7 ± 4.1	0.017
SLHC (sec)	12.5 ± 4.5*	8.9 ± 2.5	0.006
Ex-PT (Nm)	78.9 ± 23.2	80.5 ± 18	0.337
Flex–PT (Nm)	44.8 ± 12.7	46.8 ± 13.2	0.352
Ex-W (Joule)	1758.5 ± 627.3	1991.3 ± 356.7	0.421
Flex-W (Joule)	785.2 ± 462.1	900 ± 405	0.523
Ex-P (Watt)	126.1 ± 37.3	137.6 ± 32	0.491
Flex-P (Watt)	71.8 ± 34.2	81.9 ± 28.4	0.522
OLHD (cm)	124.8 ± 37.1	135 ± 18.38	0.485
TLHD (cm)	411.1 ± 119	436.5 ± 114.8	0.562
SMHT (sec)	3 ± 0.9	2.8 ± 1	0.753
CSMHT (sec)	3.6 ± 1.3	2.8 ± 0.7	0.656

DG: Diabetic Group; CG: Control Group; OLST: one leg standing test; SLHC: single limb hopping course; Ex: extensor; Flex: flexor; PT: peak torque; W: work; P: power, Nm: Newton meter; OLHD/TLHD: one- and triple-legged hop for distance; SMHT/CSMHT: 6-m and cross 6-m hop for time.
*P<0.05 (between groups)

Peripheral neuropathy and axonal losses in diabetic patients cause atrophy and reduced muscle strength, especially in ankle dorsi-flexion and plantar-flexion, knee flexion, and extension (16). Diabetic patients with a long history of illness have been reported to have reduced all leg muscle strength (mainly quadriceps femoris and tibialis anterior) and enhanced endurance (16). In one study, contrary to the study of Andersen (16), diabetic patients' endurance also decreased (17).

Most clinicians and investigators feel that DN is primarily a distal process and should affect distal sensation and strength. In another study, however, weakness in trunk and proximal limb muscles was detected (17). In our study, lower extremity muscle strength and endurance were found normal.

Type 2 diabetic patients have low functional capacity (17). This may be related to reduced physical activities and the effect of hyperglycemia on pathogenesis (18). Related studies have shown that immobility and lack of training induced a reduction of muscle strength and functional capacity (19). In our cases, muscle strength and functional capacity were normal. This difference could stem from the recent diagnosis and the sports activities, which were continued by the participants at diagnosis. Secondly, the hyperglycemia might not have been of sufficient duration to affect muscle strength and functional capacity. In fact, literature shows that, if diabetic patients exercise regularly, their muscle strength and functional capacity normalize (20).

In our study, the OLST and SLHC tests used for postural stability measurement showed a significant difference between the groups. Proprioceptive information transmitted from peripheral areas to the upper proprioceptive center via myelinated group 2 axons plays an important role (21). During peripheral neuropathy, hyperglycemia delays sensory-neural transmission by reducing inositol phosphate, thus affecting sodium channels. Peripheral neuropathy disturbs the balance by affecting the flow of information (22).

In all balance tests, we observed that DG participants were significantly worse than the CG. DG participants were more successful in static standing on one leg than in the dynamic test. In CG participants, the dynamic balance reduction ratio was higher than the static balance reduction ratio. This result may be associated with lack of exercise involving balance and coordination during the subjects' daily exercise.

Why postural stability is damaged, after DN develops, is unknown. Since participants were diagnosed in up to a maximum of two years, one might argue that loss of balance could have occurred. However, considering the existence of diabetes possibly prior to time of diagnosis, one cannot be sure.

In our study, the BFP of the DG was found as 10.9 ± 5.3, while that of the CG was 14.4 ± 1.5. The reason for the low BFP in the DG can be explained as a disturbance of glucose metabolism and failure of the insulin to affect the glucose – free fatty acid cycle.

In the present study, the physical examination of subjects was normal from the peripheral neuropathy aspect. Electromyography (EMG) was not conducted. However, failure of the subjects in the postural stability tests could be an early sign of peripheral neuropathy. This could mean that early balance testing in recreational young subjects might render information on peripheral neuropathy.

We recognize certain limitations of our study. We know that polyneuropathy can be detected in patients with T1 DM approximately 70% of the time, even in the ''preclinical period'', by electrophysiologic methods (nerve conduction studies, EMG, etc.). We did not use electrophysiologic methods, as they were not targeted by our study. Electrophysiologic methods require specialized staff and time, carry a high cost and are not easy to conduct.

In conclusion, we can say that the functional capacity of recreational athletes with T1 DM is normal; however, they have a declined postural stability. In this sense, we recommend that such athletes do additional balance training. Whether or not decreased postural stability is an early indicator of peripheric neuropathy has to be corroborated by new studies.

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