

Title: Evaluation of knee proprioception and kinesthesia in patients with type 2 diabetes mellitus

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Abstract

Background: Diabetes is a highly significant public health problem in Iran with a prevalence of 5% to 8%. Proprioception plays an important role in orientation and limb movement in space. Diabetic neuropathy decreases sensory function and causes gait instabilities.

Objective: The present study evaluated knee proprioception and kinesthesia in patients with type 2 diabetes with and without neuropathy in comparison to healthy subjects.

Methods: The subjects were ten patients with type 2 diabetes mellitus associated with neuropathy, ten patients with diabetes without neuropathy and ten healthy subjects as the control group. Data were collected by a physical examination and a questionnaire. Special tests included manual muscle testing of the knee musculature, Achilles and patellar reflexes, and knee proprioception and kinesthesia. Data were analyzed using one-way ANOVA and the Tukey test.

Results: The results show that knee proprioception and kinesthesia were significantly decreased in patients with type 2 diabetes mellitus in comparison with healthy people, and there was a greater decline in patients with diabetes associated with neuropathy than in patients with diabetes without neuropathy. Also, knee musculature strength was significantly lower in subjects with diabetes in comparison with healthy subjects, and the attenuation was greater in neuropathic patients than in non-neuropathic patients.

Conclusions: Patients with type 2 diabetes, especially those with neuropathy, suffer from proprioception deficits. Proprioception training may prevent secondary problems that occur as a result of proprioception impairment in patients with type 2 diabetes.

Key Words: Type 2 diabetes, Neuropathy, Proprioception, Kinesthesia, Continuous Passive Motion

Introduction

Diabetes mellitus is a highly significant public health problem in Iran, with a prevalence of 5% to 8% (Larejani, 2002). Its prevalence is higher among persons of Hispanic, African American and Native American heritage than among persons of non-Hispanic, white origins. The incidence of type 2 diabetes mellitus (T2DM) is a public health problem that threatens to spiral out of control in the twenty-first century. Early intervention can greatly mitigate the serious socioeconomic impact of the disease, which is driven largely by disabling microvascular complications and cardiovascular disease. Diabetes mellitus (DM) affects over 8% of the US population between the ages of 20 and 74. This amounts to 21 million Americans suffering from diabetes (~90% are T2DM), and 2,500 new diagnoses of diabetes are made every day. It is now evident that T2DM is reaching epidemic proportions in the United States and worldwide (Boyle, et al., 2001; Regensteiner 2009). DM has many complications. One of the more important of these is neuropathy. Peripheral neuropathy is a common problem in persons with DM and occurs in about one-third of persons with DM (Hijmans, et al., 2008). Longer disease duration is one of the factors associated with a higher incidence of neuropathy (Young, et al., 1993). Individuals with cutaneous sensory loss secondary to diabetic neuropathy demonstrated loss of movement perception at the ankle (Simoneau, et al., 1994). The somatosensory system can be subdivided into the tactile and proprioceptive systems. Feedback from both these systems plays a part in the control of balance (Bloem, et al., 2000; Kavounoudias, Roll, and Roll, 2001; Maurer, Mergner, and Peterka 2006). The proprioceptive system provides the central nervous system (CNS) with information concerning angles and angular changes of joints. Muscle spindles, Golgi tendon organs and joint afferents play a part in the detection of joint angles and angular velocities during both the stance and swing phases of walking (Bloem, et al., 2000).

When problems arise in the conduction of somatosensory information to the CNS from the periphery, problems in balance control are likely to occur, especially when the availability of compensatory mechanisms is limited. In persons with neuropathy, conduction of both kinesthesia and proprioceptive information to the CNS is impaired when compared to persons without neuropathy. This may result in increased risk of falling (Simoneau, et al., 1994; Uccioli, et al., 1995; Horak, Dickstein, and Peterka, 2002).

Most studies have evaluated ankle proprioception of patients with diabetes with or without neuropathy, and there is not enough knowledge about knee proprioception changes in such patients. Thus the aim of the current study was to compare knee proprioception and kinesthesia of individuals with diabetes with and without neuropathy to that of healthy subjects.

Methods

We evaluated knee proprioception and kinesthesia of patients with T2DM with and without neuropathy and compared the results with those of healthy subjects. The study was approved by the Ethics Committee of Shiraz University of Medical Sciences in accordance with the Declaration of Helsinki. Informed consent was obtained for each subject prior to participation.

Participants

Ten women with type 2 diabetes associated with peripheral neuropathy were recruited from the Diabetes Clinic of one hospital, together with 10 age- and gender-matched T2DM patients without peripheral neuropathy and 10 age- and gender-matched healthy subjects, who acted as the control group. All the subjects were asked to provide their complete medical history and were subjected to a thorough neurological examination. The age range of all participants was 40-65 years. They did not participate in any special sport activity apart from their routine

Activities of Daily Living (ADLs) and were not using any medications that might have affected the study.

Peripheral neuropathy was diagnosed by a specialist using Hoffmann's reflex and electromyography with a Nihon-Kohden Neuropack, which evaluated the latency and amplitude of the response of a peripheral nerve to an electrical stimulus of increasing intensity applied to the tibial nerve (Kandel, 2000).

Exclusion criteria were: smoking, presence of other forms of neuropathy (such as mononeuropathies, radiculopathies) or anamnesis indicative of exposure to conditions predisposing to the development of forms of polyneuropathies other than those associated with diabetes, regular or recent training exercise, alcohol consumption, presence of other evolved chronic diabetic complications, recent episodes of ketoacidosis or of hypoglycemic crises requiring other interventions and any drug use that might affect the results.

Measurements, including (i) knee proprioception, (ii) knee kinesthesia, (iii) knee range of motion, (iv) Achilles and patellar reflexes, and (v) manual muscle testing (MMT) of the knee musculature were performed as follows. Participants sat on a chair in a quiet place, with 6 to 10 centimeters between the posterior of the knee and the chair edge. All participants were blindfolded and their ears covered with a pad so they could not hear any sounds. The measurements were performed at 15- and 45-degree angles on the non-dominant leg in an open kinematic chain.

To evaluate knee proprioception, participants were asked to reconstruct an angle. Participants sat on the chair as described above. A custom-built knee electrogoniometer was fixed lateral to the knee with the motion axis coinciding with the lateral femoral condyle and was calibrated. The examiner took hold of the participants' ankles and passively moved the leg to 15- and 45-degree angles from the start position (knee flexion of 90 degrees). Each angle was

maintained for 5 seconds and then the leg was returned to the initial position. After 5 seconds, participants were asked to reconstruct the angle. Absolute error was defined as the difference between the reference angle and the reconstructed angle. Each angle was reconstructed three times, and the mean of the three trials was calculated.

To evaluate knee kinesthesia, participants' legs were fixed to a continuous passive motion (CPM) system (Toronto Medical, Toronto, Canada) that flexed their legs at a velocity of 30 degrees per minute. The participants verbally indicated to the examiner when they sensed the movement, at which point the CPM was stopped and the angle was measured with an electrogoniometer.

Knee range of motion was recorded using a goniometer. Achilles and patellar reflexes were evaluated with a reflex hammer (SL05-012C, China). Reflexes were graded according to the "deep tendon reflex grading" system (Magee, 1997). Quadriceps and hamstring strengths were measured by the conventional MMT method.

Data Analysis

Continuous data are expressed as the mean (standard deviation). Data were analyzed using a commercially available statistical software program (SPSS 12.0, SPSS Inc, Chicago, IL, USA). All data were analyzed using one-way ANOVA and the Tukey test. Values of $p < 0.05$ were accepted as significant.

Results

Demographic data of all participants are presented in Table 1.

We studied 10 subjects with T2DM with peripheral neuropathy, 10 subjects with diabetes without neuropathy and 10 healthy individuals as the control group. The three groups were matched for age and gender and other demographic data.

Table 1. Demographic data of participants.

Variable	DM with Neuropathy			DM without Neuropathy			Control Group		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Height (cm)	172	159	165	176	155	160.8	173	147	159.8
Weight (Kg)	75	57	64.6	83.5	61	68.15	85	47	65

Key: DM: Diabetes mellitus

Among the subjects with diabetes associated with peripheral neuropathy, 2 subjects had a normal (grade 2) Achilles tendon reflex whereas 8 had a diminished (grade 1) Achilles tendon reflex. Among the subjects with diabetes without neuropathy, 9 had a normal Achilles tendon reflex while only 1 had a diminished reflex. In the control group, all participants had a normal reflex. There were significant differences between subjects with diabetes associated with neuropathy and the other two groups ($F(2, 27) = 20.52, p=0.00$). Results for evaluation of the patellar reflex were the same as for the Achilles tendon reflex. When quadriceps muscle strength was measured with MMT, 6 subjects had grade 4 whereas 4 subjects had grade 3 in the group with diabetes associated with neuropathy. Six subjects had grade 5 while 4 had grade 4 in the group with diabetes without neuropathy. In the control group, 9 participants had grade 5 and 1 had grade 4. There were significant differences between the group with diabetes associated with neuropathy and the other two groups; there was also a significant difference between the subjects with diabetes without neuropathy and the control group. There were no significant differences in knee range of motion among the three groups ($F(2, 27) = 7.74, p= 0.002$).

Table 2 summarizes data related to knee proprioception and kinesthesia and compares them among the three groups. Significant differences were seen for all parameters shown except

for proprioception at a 45° angle for which a significant difference was seen only between the diabetic group with neuropathy and the control group ($p=0.011$).

Table 2. Summary of proprioception and kinesthesia data.

Variable	Angle (degree)	Group 1	Group 2	Group 3
		Mean±SD	Mean±SD	Mean±SD
Proprioception	15	7.01±3.43 *	2.49±1.62 *	1.14±0.56 *
	45	7.1±3.43 *	3.48±1.17	2.69±2.00 *
Kinesthesia	15	2.77±1.38 *	0.89±0.86 *	0.22±0.11 *
	45	2.98±1.59 *	1.03±0.81 *	0.23±0.11 *

Key: Group 1: patients with diabetes associated with neuropathy, Group 2: patients with diabetes without neuropathy, Group 3: control group, *: significant difference ($p<0.05$) according to Tukey's test

Discussion

This study evaluated and compared knee proprioception and kinesthesia among 10 subjects with diabetes associated with peripheral neuropathy, 10 subjects with diabetes without neuropathy and a control group of healthy age- and gender-matched individuals.

To evaluate proprioception, we used only knee angles of 15 and 45 degrees. Since joint receptors are active in the end ranges of joint motion (0-25 degrees), 15 degrees is an angle at which proprioceptive activity would be expected. We also used a knee angle of 45° because at this angle the anterior cruciate ligament (ACL) does not send any proprioceptive signal to the CNS (Levangie and Norkin, 2001). Since individuals with the dominant hand affected following stroke demonstrate less impairment than those with the non-dominant hand affected (Harris and Eng, 2006), we used the non-dominant limb for our measurements.

Our results demonstrated that proprioception and kinesthesia senses were decreased in the subjects with T2DM, especially in those with peripheral neuropathy. This is in agreement with the study by Andersen and Jacobsen (1997) that showed that knee and ankle proprioception were reduced in patients with diabetes. These results were confirmed by

Katoulis and colleagues who attributed reduced walking speed to diminished proprioception (Katoulis, et al., 1997).

Imbalance is commonly found in patients with polyneuropathy due to impaired proprioception and motor functions (Voorhees, 1990; Shepard, Telian, and Smith-Wheelock, 1990). The afferent sensory input from the proprioceptors as well as the efferent motor nerves must be intact in order to maintain balance (Nashner, 1976). Most, but not all, studies of older adults with DM have shown that peripheral neuropathy is a risk factor for falls (Richardson and Hurvitz 1995; Strotmeyer, et al., 2005; Volpato, et al., 2005).

There were significant differences among the three groups in the results for Achilles and patellar tendon reflexes. This is in agreement with Andersen, et al (2004) who reported diminished reflexes in patients with diabetes. Bloem and colleagues showed that patients with diabetes associated with neuropathy had Achilles and patellar tendon reflexes that were either absent or diminished (Bloem, et al. 2000). Bilaterally absent Achilles tendon reflexes are rare in healthy subjects and are nearly always seen as an early feature of peripheral neuropathy (Frijns, et al., 1997). Quadriceps muscle strength was lower in the patients with diabetes than in healthy people in our study, and the decline in strength was more evident in the patients with neuropathy. Andersen and colleagues' findings were in line with our study, but Bloem did not find a significant difference in knee muscle strength between patients with diabetes and healthy individuals (Andersen, et al., 2004; Bloem, et al., 2000). Andersen and coworkers (2004) showed that patients with T2DM have muscle weakness at the ankle and knee joints. In their study, muscle strength at the ankle and knee was related to the severity of neuropathy rather than to the degree of nephropathy, the degree of retinopathy or metabolic variables. The distribution of muscular weakness indicates that a distal neuropathic process underlies the impaired motor performance. This assumption is supported by the observation that muscular strength at the ankle and knee is related to the severity of neuropathy and not to the

degree of nephropathy or retinopathy or the metabolic abnormalities associated with diabetes (Andersen et al., 2004). Muscle strength in neuropathic patients is usually evaluated clinically using MMT. Detection and grading of mild symmetrical muscle weakness using MMT is difficult because the examiner must take into consideration the normal variation in strength in relation to age, weight, height and gender (Andersen and Jakobsen, 1997). Bloem et al. (2000) used a different method, which may account for our differing results, and it appears better to use other methods, such as electromyography, to evaluate the strength of muscles. We did not find any significant difference in knee range of motion among the groups. This is in agreement with a study by Andersen and Jakobsen (1997) that showed that T2DM with or without neuropathy does not affect knee range of motion.

Conclusion

In conclusion, T2DM, especially with peripheral neuropathy, can impair knee proprioception and muscle strength, which may make patients prone to recurrent falls and subsequent fractures with increases in morbidity and mortality. Proprioception and balance training might be beneficial for patients with diabetes, especially for those with peripheral neuropathy, and this should be considered as a part of the rehabilitation program for these patients.

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Conflict of interest: None declared

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