Influence of Diabetic Distal Symmetric Polyneuropathy on the Performance of the Musculoskeletal System of Lower Leg and Foot

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ABSTRACT

Introduction: Complications on the lower extremities are a major cause of morbidity, disability, emotional and physical suffering in people with diabetes. Diabetic neuropathy (DN) is the most frequent complication of both types of diabetes. Lack of performance of the musculoskeletal system of lower leg and foot can result in high focal plantar pressures with increased ulceration risk in patients with neuropathy. Aim: To determine the impact of the severity of distal symmetric polyneuropathy (DSPN) on the foot and ankle muscle strength and the range of motion (ROM) at ankle joint (AJ), subtalar joint (SJ) and first metatarsophalangeal joint (I MTP). Methods: A cross-sectional study was conducted among 100 diabetic patients. The level of DSPN was assessed using the Neuropathy Disability Score. Function of ten foot and ankle muscles has been evaluated by manual muscle testing. Muscle strength was scored by semiquantitative grading system used in the Michigan Diabetic Neuropathy Score. ROM at the AJ, SJ and I MTP was measured with goniometer. Results: The average patient's age was 61.91±10.74 and diabetes duration 12.25±8.60 years. DSPN was present in 45% of patients. The average strength of foot and ankle muscles expressed by muscle score was 11.56±5.08. The average ROM at AJ was 47.85°, at SJ 35.10° and at I MTP 72.70°. Correlations between the severity of the DSPN and muscle function, ROM at AJ, SJ and I MTP were statistically significant. ROM at SJ and I MTP declines significantly with progression of neuropathy but not significant at AJ. Conclusion: The severity of DSPN is significantly associated with foot and ankle muscle weakness and ROM at the SJ and the I MTP, but not significantly with the ROM at the AJ.

Keywords: Diabetes Mellitus, complications, muscles.

1. INTRODUCTION

Diabetes mellitus (DM), or diabetes is the global epidemic of the 21st century and it is now the fourth leading cause of death in most developed countries (1). Diabetes complications on the lower extremities are a major cause of morbidity, disability, emotional and physical suffering in people with DM (2) generating huge economic costs for patients, their families and the entire society (3).

Diabetic neuropathy (DN) is the most frequent complication of both types of DM and is present to some degree in more than 50% of diabetic persons older than 60 years (4, 5). DN affects different sets of lower-limb nerve fibers and leads to a variety of clinical manifestations (5-7). Distal symmetrical polyneuropathy (DSPN) is thought to be the most common variety of DN. The typical DSPN is a chronic, symmetrical, length-dependent sensorimotor polyneuropathy. Internationally agreed definition of DSPN for clinical practice is as follows: the presence of symptoms and/or signs of dysfunction of peripheral nerves in patients with DM after excluding the other possible causes (7).

Limited joint mobility (LJM) at ankle joint (AJ), subtalar joint (SJ), and first metatarsophalangeal joint (I MTP) results in high focal plantar pressures with increased ulceration risk in patients with neuropathy (8). Range of motion (ROM) restriction associated with a lack of protective sensation and foot deformities may even increase the force and mechanical stress exposure under the patient's foot (9). LJM is often overlooked because it causes small disability and is therefore thought to be of little clinical consequence. Determination of the foot and ankle joint mobility is a simple and rather exact test to identify diabetic patients with...
an at-risk foot and, might be useful as a screening tool in diabetic patients to identify those with an at-risk foot because of its price and simplicity (10, 11).

Motor dysfunction in patients with DM can be detected as muscle weakness as well as atrophy of muscular tissue. It is usually found distally in the extremities, primarily in the lower extremities and it is believed to be caused primarily by DN (12). Foot muscle atrophy is closely related to severity of DN. Since DN shows a centripetal pattern of progression, quantification of the more distally situated foot muscles could possibly serve as an early marker for motor dysfunction in DN (13).

The association among ROM, restriction, muscle strength and function loss can lead to altered foot rollover during gait, as their integrity is needed to enable proper load absorption (9). Elevated plantar pressure coupled with a longer period of time spent in support phase in DN patients contributes to the susceptibility for skin damage through the prolonged mechanical load on tissue leading to skin breakdown and ulceration (14).

Keeping in mind serious consequences that complications of DM on the lower extremities make on a personal and social level, inevitably raises the question what can be done to reduce their rate and severity. The implementation of simple and low-cost strategies can reduce the rate of diabetic complications on the lower extremities (15, 16). Proper metabolic control of both types of DM may delay the onset and progression of diabetic complications (17).

2. AIM
To determine the impact of the severity of DSPN on the foot and ankle muscle strength and the ROM at AJ, STJ and I MTP.

3. METHODS
A cross-sectional study was conducted among diabetic patients (both type DM) registered at the family physicians in the Public Primary Health Centre Banja Luka, Bosnia and Herzegovina, during the 2014. The study included 100 diabetic patients. The sample was formed in a way that the patients who approached family doctor for a prescription for insulin or oral antidiabetic drugs in 10 family medicine ambulances were over the time successively asked to enter the study. The survey included: review of medical records, history-taking, measurement and testing.

Medical records were source of personal data, data on DM-type, therapy and HbA1c value not older than 6 months. History-taking data were entered in the anamnestic list and included information about the duration and the past treatment of DM (18, 19). The clinical examinations of muscles and joints were performed routinely by the same observer.

The level of DSPN was assessed by using the Neuropathy Disability Score (NDS) (20, 21, 22). The NDS was derived from examination of ankle reflexes using a tendon hammer, vibration perception on the great toe using a 128-Hz tuning fork, pin-prick perception using standard neotroits on the dorsal surface of the great toe, and temperature perception on the dorsal surface of the metatarsal heads using warm and cool rods. The sensory modalities were scored as either present (score of 0) or reduced/absent (score of 1) for each side, and reflexes as normal (score of 0), present with reinforcement (score of 1), or absent (score of 2) per side. The maximum score is 10, whereas a score of 0 represents a totally normal peripheral nervous system examination, a score of 3-5 represents mild neuropathy, a score of 6-8 moderate neuropathy and a score of 9-10 represents severe neuropathy (21, 23, 24). Patients were diagnosed as having DSPN if they had NDS ≥6 (24).

Muscle function of the foot and ankle muscles has been evaluated by manual muscle testing (MMT) on the dominant leg applying the scoring system as used in the Michigan Diabetic Neuropathy Score (MDNS) (9, 22, 25). MMT means assessing ability of the muscle to produce active movement against the examiner’s resistance. Muscle weakness was scored as 0 for normal muscle strength, 1 for mild, 2 for severe weakness, and 3 for complete loss of strength. A muscle score (MS) was, therefore, obtained for each set of muscles examined. Higher values for this score represented increased muscle weakness (25, 26). In the positions described for manually clinical assessment (27) the function of the following muscles was evaluated: triceps surae, tibialis anterior, interosseus, lumbrical, flexor hallucis brevis, extensor digitorum brevis, extensor digitorum longus, flexor digitorum brevis, extensor hallucis longus and extensor hallucis brevis (9).

Joint mobility at the AJ, SJ and I MTP was measured with a goniometer on the dominant leg (10, 11, 28, 29).

At the AJ range of motion (ROM) was measured with the patient supine and goniometer set with immobile prong in line with calf, mobile prong in line with external edge of the foot and center of goniometer above the joint center. The maximum range of active talar flexion and extension in was measured and the sum of the values was recorded as ROM at the AJ (10).

At the SJ ROM was measured with the patient prone; a vertical line was marked on the patient’s skin from heel to midsch; goniometer set with immobile prong in line with the line on the calf, mobile prong in line with the line on the heel and center of goniometer above the joint center; the maximum range of active calcaneal inversion and eversion was measured with a goniometer and the sum of the values was recorded as ROM at the SJ (10, 11).

At the I MTP range of active extension to plantar flexion was measured with the patient in the supine position; horizontal line was drawn from the first toe to the heel in line with medial edge of the foot; goniometer center set above the joint center, immobile prong in line with proximal part of drawn line and mobile prong in line with the distal part of the line; the sum of maximal extension and flexion was recorded as ROM at I MTP (10, 11).

The statistical analyses were done using the software package “IBM SPSS Statistics”. To test the statistical significance between variables the ANOVA and the Tukey post-hoc test were applied. The relationship and the relationship strength of various parameters were assessed by
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Figure 1. Pearson’s correlation between the severity of the DSPN and muscle function, ROM at AJ, SJ and I MTP joint. Pearson coefficient is statistically significant in all relationships that were observed, except for relations between ROM at AJ and SJ. *p<0.05. DSPN – distal symmetrical polyneuropathy, AJ – ankle joint, SJ – subtalar joint, I MTP – first metatarsophalangeal joint, ROM – range of motion

Figure 2. Foot and ankle muscle strength in groups of patients with different stages of diabetic neuropathy. Strength of ankle and foot muscle significantly declines with progression of neuropathy; p<0,05. ** post-hoc Tukey test p<0,05

Figure 3. Range of motion at ankle joint in groups of patients with different stages of diabetic neuropathy. Range of motion at ankle joint in groups of patients with different stages of neuropathy declines with progression of neuropathy, but not significantly; p>0,05.

Figure 4. Range of motion at subtalar joint in groups of patients with different stages of diabetic neuropathy. Range of motion at subtalar joint in groups of patients with different stages of neuropathy significantly declines with progression of neuropathy; p<0,05. ** post-hoc Tukey test p<0,05

4. RESULTS

In the study group were more women (53%) than men (47%). The average age of the patients was 61,91±10,74 years. The majority of patients (94%) had DM type 2 and type 1 DM had 6% of them. The average diabetes duration was 12,25±8,60 years. The even number of patients was treated with insulin and antidiabetic drugs (46%), and combined therapy with insulin and the antidiabetic drugs had 8% of patients.

DSPN was present in 45% of patients. The average foot and ankle muscles expressed by MS was 11,56±5,05. Average ROM at AJ was 47,85±11,1, at SJ 35,10±8,55 and at I MTP 72,70±21. There were statistically significant correlations between the severity of the DSPN and muscle function, ROM at AJ, SJ and I MTP. Pearson coefficient is statistically significant in all relationships that were observed, except for relations between ROM at AJ and SJ that is shown on Figure 1.

The average muscle strength in the group of patients without neuropathy (NDS < 2) was 7,28±4,12. Muscle strength in the group of patients who had mild neuropathy (NDS 3-5) was 10,94±4,23, in the group pf patients who had moderate neuropathy (NDS 6-8) was 13,22±4,01 and in the group of patients who had severe neuropathy (NDS 9-10) muscle strength was 17,22±3,93. Strength of ankle and foot muscle significantly declines with progression of neuropathy that is shown on Figure 2.

The average ROM at AJ in the group of patients without neuropathy (NDS < 2) was 52,86±12,9. ROM at AJ in the group of patients who had mild neuropathy (NDS 3-5) was 47,06±9,5, in the group pf patients who had moderate neuropathy (NDS 6-8) was 46,53±11,10 and in the group of patients who had severe neuropathy (NDS 9-10) ROM at AJ was 44,44±11. ROM at AJ declines with progression of neuropathy but not significantly as it is shown on Figure 3.

The average ROM at SJ in the group of patients without neuropathy (NDS < 2) was 40,24±9,1. ROM at SJ in the group of patients who had mild neuropathy (NDS 3-5) was 35,88±7, in the group pf patients who had moderate neuropathy (NDS 6-8) was 32,78±7,9 and in the group of patients who had severe neuropathy (NDS 9-10) ROM at SJ was 29,44±10,7. ROM at SJ significantly declines with progression of neuropathy that is shown on Figure 4.
Data from this study are consistent with the results of research that has been done by Andersen [12]. And the most of patients (23%) had mild muscle weakness, 26% of patients had severe muscle weakness, none of them had complete loss of strength, while the most of patients (64%) had mild muscle weakness. Data from this study have shown that the average muscle strength of the foot and ankle muscles in the group of patients who had severe neuropathy (NDS 9-10) ROM at I MTP was 60° ± 29.7. ROM at I MTP significantly declines with progression of neuropathy that is shown at Figure 5.

**DISCUSSION**

Muscle strength of the foot and ankle muscles in this study has been evaluated in ten muscles applying the scoring system as used in the MDNS. Mean MS of evaluated muscles was 11.56±5.05 and represents mild muscle weakness in the study group. Only 13% of patients had preserved muscle strength, 23% of patients had severe muscle weakness, none of them had complete loss of strength, while the most of patients (64%) had mild muscle weakness. Data from this study are consistent with the results of research that has been done by Andersen [12,30], Andreassen [20], Giacomozzi [31] and Camargo [32] that confirmed the existence of a decrease in muscle strength in people with DM, especially in the region of ankle and knee. The muscle weakness in the lower leg can be explained by the presence of the typical DSPN that is length-dependent and more severe in the distal part of the leg [5].

This study has proved a strong relationship between the presence of the DSPN and the foot and ankle muscle weakness. This relationship was confirmed by numerous studies as led by Andreassen [29,33] and by Andersen [12,13,30]. Muscle weakness is associated with the atrophy of ankle and foot muscles due to denervation caused by loss of motor axons combined with insufficient reinnervation more than demyelination process [20], and the same was found by Balducci [34]. Van Shie and his associates also found that the muscle weakness in patients with DM is caused by incomplete reinnervation after axonal degeneration [25]. Andreassen found a correlation between isokinetic muscle strength in ankle and DSPN evaluated by standardized clinical examination, while in the prospective study found that people with DM have a more rapid decline in muscle strength over time compared with those suffering from DM without neuropathy and healthy individuals. Decrease in muscle strength in patients with DM is 3-4% per year and is related to the severity of neuropathy [20]. In another study Andreassen and his associates, following long-term effects of DN on the muscular system, confirmed that in patients with DN there is an apparent distal-proximal gradient with a significant loss of muscle mass in distal segment of the lower extremities, and that in patients with DM there is a correlation between the presence of neuropathies and decreased muscle strength [33].

Data from this study have shown that the average ROM at ankle joint reduces with the increase of the NDS score, i.e., with the severity of DSPN but not significantly, while the relationship between the severity of the DSPN and the ROM at subtalar and I MTP is significantly correlated that is consistent with data from the literature. By her research on ankle mobility during foot rollover in DN patients Sacco confirmed that people with DSPN have reduced active ankle range of motion and dynamic ankle flexion at heel-strike as well as reduced amplitude (flexion–extension) when compared to non-diabetic subjects [35]. Lazaro-Martinez has found that in patients with DM neuropathy presence significantly affects the ROM at I MTP [36]. Hajrasouliha has proved that ROM at ankle joint is one of the late complications of DM [37]. ROM at AJ and I MTP is essentially seen as a risk factors for foot ulceration because it plays an important role in the redistribution of pressure during the support phase of gait [10]. Sacco has found that anterior areas of the foot in patients with DN had altered role receiving higher loads at push-off phase that were probably due to smaller ankle flexion at support phase. This data may explain the higher loads in anterior areas of the foot observed in DN patients [35] and give an opportunity to minimize the consequences of the DM complication on the lower extremities through an active approach in prevention and treatment using evidence based physical and medical exercise therapy [38,39]. In patients with DSPN physiotherapy discreetly changed the foot rollover towards a more physiological process, supported by improved plantar pressure distribution and better functional condition of the foot ankle complex [39]. Specific gait and balance training in combination with functionally oriented strengthening may improve gait and balance, muscle strength, and increase the joints mobility in patients with DM [39,40].

**CONCLUSION**

The severity of diabetic symmetric polyneuropathy is significantly associated with foot and ankle muscle weakness and range of motion at the subtalar joint and the first metatarsophalangeal joint, but not significantly with the range of motion at the ankle.
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