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RESEARCH PAPER

Hip joint torques in type II diabetes with and without neuropathy

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KEYWORDS
type II diabetes;
hip;
joint;
torques;
peripheral neuropathy

Abstract *Background:* Patients with diabetes and peripheral neuropathy demonstrate significantly reduced peak torques at the peripheral joints.
Objectives: The aim of this study was to assess isometric and concentric peak torques of the hip joint in people with type II diabetes with and without peripheral neuropathy in comparison with healthy participants.
Methods: 27 patients with type II diabetes including 15 patients without peripheral neuropathy, 12 patients with diabetes and peripheral neuropathy and 15 healthy people participated. Isometric and concentric peak torques of hip flexion, extension, adduction and abduction of the non-dominant leg were measured by motorized dynamometer.
Results: Peak and average peak concentric torques of the hip extension and abduction in patients with diabetes and peripheral neuropathy were lower than those patients with diabetes and control group. Angle of extension peak torque was significantly greater in patients with diabetes and peripheral neuropathy compared with other groups. Angle of flexion peak torque was lower in the patients with diabetes and peripheral neuropathy.
Conclusions: Torque related parameters in patients with type II diabetes with or without peripheral neuropathy, are different from healthy subjects. As a result, patients with diabetes especially with peripheral neuropathy are more susceptible of injury and disability in lower limbs.

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Introduction

Diabetes is one of the causes of death and disability in the world with prevalence of approximately 366 million in the world. Among diabetic patients, 90% of them are diagnosed with type II diabetes and the rest with type I diabetes [1]. Inappropriate control of the disease may lead to various complications; including vascular and musculoskeletal disorder [2]. Progressive muscle weakness is usually considered as the most important musculoskeletal complications of the diabetes which mainly causes the disability [3]. It seems that 30–47% of patients with type II diabetes experience musculoskeletal complications in their life time [4]. Upper and lower weakness is evident in patients with long-term diabetes and there is a controversy that if lower extremity is more affected than upper extremity [3]. Based on magnetic resources imaging finding, patients with diabetes peripheral neuropathy had less muscle mass and cross-sectional area [4] and also double intramuscular fat (an important factor in skeletal muscle function) than the healthy individuals [5].

Proximal muscles of lower limbs play an important role in pelvic stability during walking, running, and standing on one leg or both [6]. During functional movements and sport activities, hip muscles provide stability, prevent falling, and have important roles in hip movements in frontal and horizontal planes [7,8]. Therefore, thigh muscles weakness and changes in the angle of maximum torque production of these muscles may alter functional abilities of the lower limbs [9,10]. However, current information regarding hip muscle strength in patients with type II diabetes is limited.

Patients with DPN experience weakness in skeletal muscles during their life time due to impaired nerve function and lack of physical activities [11]. Approximately, 30–50% decrement of power in ankle and knee muscle groups was evident in patients with DPN [12]. Muscle strength reduction is correlated with the duration of diabetes and severity of peripheral neuropathy [3,11–13]. As a result, ankle muscles (plantar and dorsi flexors) and knee extensors are more affected in patients with long-term type II DPN [3,12]. The extent of muscle power reduction was directly correlated with the severity of peripheral neuropathy [3,12]. On gait analysis, patients with type II diabetes have reduced ankle and knee joint torques and more joint work on walkway, thereby leading to less balance and potential increase in their risk of falling [14]. Furthermore, patients with peripheral neuropathy have less hip extension joints torques than the healthy individuals [14]. However, there is limited evidence about hip joint torques in patients with type II diabetes which are evaluated with isokinetic dynamometer, and this is the first time that hip joint torques have been evaluated in sagittal and frontal planes with isokinetic dynamometer.

Therefore, the aim of this study is to assess the isometric and concentric torques of the hip joint consisting the flexion, extension, abduction, and adduction in patients with DPN and diabetic patients without peripheral neuropathy (DWOPN) compared with healthy individuals. We hypothesised that patients with type II diabetes have less hip joint torques than the healthy individuals, and peripheral neuropathy is a contributing factor for torque reduction of hip joint in patients with type II diabetes.

Methods

Study population

In total, 27 patients with type II diabetes, including 15 DWOPN patients and 12 DPN patients (DPN), and 15 healthy individuals as control group (CG) participated in this study. This sample size was estimated based on the pilot study with 3 individuals in every study group, prior to the main study. In this study, isometric flexion average peak torque was 59.5 $\pm$ 18.02 newton meter (N.M) in CG, 49.04 $\pm$ 15.14 N.M in DWOPN, and 47.73 $\pm$ 12.03 N.M in DPN. Considering $\alpha = 0.05$, power $= 0.8$, and difference in between groups $= 10$, 13 participants were estimated for each study group. To increase the validity of the study, 15 participants were considered in each group. All sample size calculations were performed using the software power sample size calculation 3.1.2.2014 (by William D. Dupont and Walton D. Plummer, Jr.). Medical records of 2000 patients with type II diabetes were assessed in the clinic of internal medicine, and 70 of them were selected to participate in the study based on inclusion and exclusion criteria. Of 70 patients, 30 patients with type II diabetes, including 15 with DWOPN and 15 with DPN, accepted to participate in the study. Next, individually matched control individuals were identified and invited. The individuals in CG were selected among Tabriz University's clerks, and they were matched with DWOPN and DPN groups in terms of age, sex, and body mass index. The inclusion criteria were age of 40–55 years, lasting type II diabetes disease for 5–15 years, ability to follow simple commands, able to walk a distance of 6 m unaided, and full hip range of motion. The exclusion criteria were a history of severe or uncontrolled cardiac disease, other autonomic symptoms, intermittent claudication, central nervous system disorders, current or healed foot ulcers, musculoskeletal disorders, and rheumatoid arthritis in lower extremity. The individuals were also excluded if they showed any autonomic nervous system symptoms (e.g., heart and respiratory rate changes) during the test [13]. All inclusion criteria were considered for CG except that they were not diagnosed with type I and II diabetes. Fifteen DPN patients were diagnosed and referred by an internal physician based on the nerve conduction velocity findings of common peroneal and tibial nerves. Most of these patients were diagnosed by sensory and the others by motor and sensory peripheral neuropathy [15]. However, 3 patients in the DPN group were excluded due to no capability of learning test process, thereby leaving with 12 patients (Figure 1). Informed consent was obtained from all participants, and the protocol was approved by the Medical Ethical Committee of Tabriz University of Medical Sciences.

Testing procedures

HbA1c and fast blood glucose were recorded according to the last blood test. Radial pressure and finger blood glucose

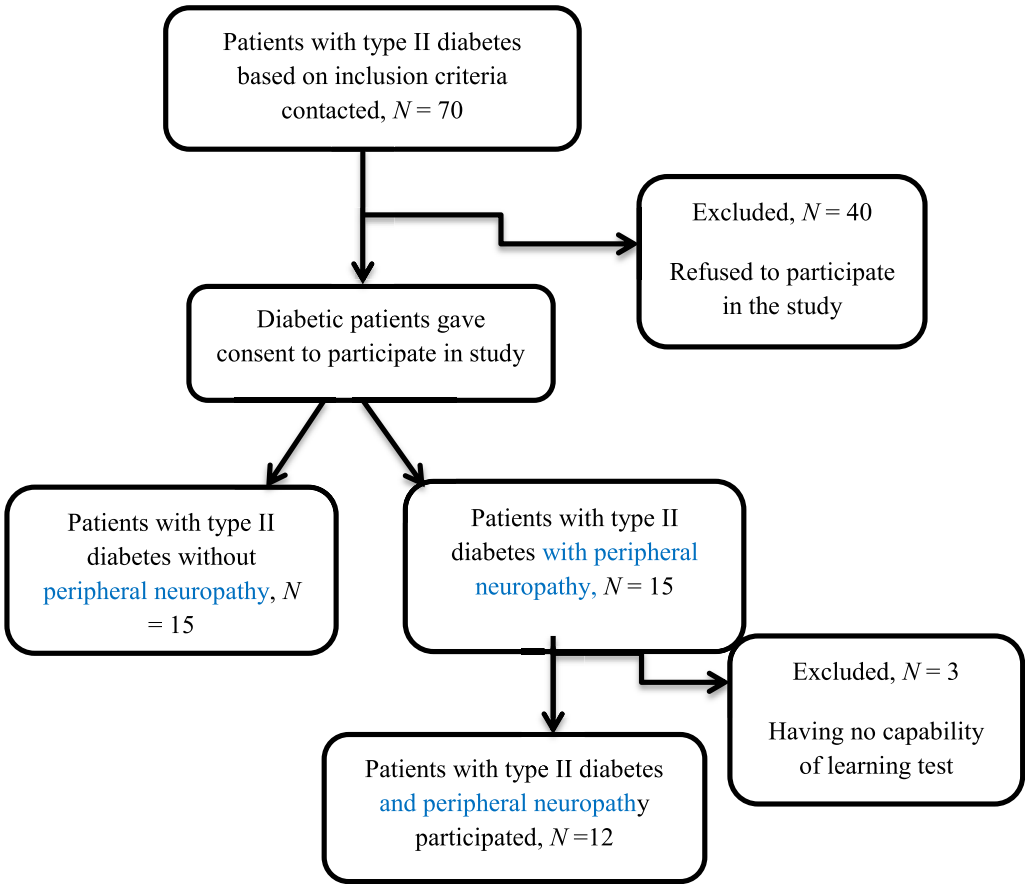

Figure 1. Flow chart presenting the procedure of participant allocation and grouping.

were also measured before test, and patients were asked to take prescribed medications as usual. The tests were performed by an isokinetic dynamometer (Biodex dynamometer system pro 4, USA) [16] in the morning. Test protocol involved hip flexion, extension, adduction, and abduction of the non-dominant leg (the dominant leg was determined by the ball kicking leg) [17]. Before main test, in short, participants were familiarised with the protocols and asked to perform a warm-up session, including two trials of quadriceps and hamstring stretching holding for 30 seconds and 5 minutes of free load ergonomic cycling [13].

Isometric and concentric testing

The first test aim was to determine isometric peak torques for the hip joint flexion, extension, adduction, and abduction. Maximal isometric flexion and extension joint torques were performed at 45 degrees and 15 degrees of hip flexion for flexion and extension, respectively, in supine position. The knee joint was positioned in 90 degrees of flexion and trunk, and the opposite leg was fixed by straps. The centre of rotation of the dynamometer was aligned with participant's greater trochanter. To measure maximum voluntary hip isometric abduction and adduction torques testing, patients were asked to side-lie while the lower extremity was positioned to an angle of 20 degrees of hip abduction for abduction and 15 degrees for adduction movements. The knee joint was in full extension and the opposite leg and trunk was fixed by straps; all joints angles were controlled by mechanical goniometry. During the isometric tests, the participants were provided with a visual feedback of force and encouraged verbally to maintain maximal effort in isometric tests. Participants were asked to press up the lever arm maximally for isometric flexion and abduction tests and press it downward for isometric extension and adduction tests. All tests were done three times. Each effort was kept for 5 seconds, and a rest period of 60 seconds was given between consecutive contractions.

Concentric peak torque tests, composed of three repetitions of hip flexion, extension, abduction, and adduction were set at constant velocity of 60 degrees per second, and the range of motion was set at 0—45 degrees for movements. Fixation of trunk and the other leg was done as in isometric test. Each test was performed separately, and 5-minute rest was considered between tests to prevent fatigue. Participants were instructed to push and pull as hard and fast as possible through the full available range of motion at every repetition without breath holding and resting. Damping was set in hard status [17].

Data collection

All joint torques normalised to body mass and gravity correction were performed in all conditions. Isometric Peak

Torque (IPT), Concentric Peak Torque (CPT), Isometric Peak Torque to Body Weight (IPT/BW), Concentric Peak Torque to Body Weight (CPT/BW), Isometric Average Peak Torque (IAPT), and Concentric Average Peak Torque (CAPT) values of repetitions were recorded from Biodex software in Newton meter unit. Angle of Peak Torque (AOPT) was calculated based on the highest torque values of extracted data in the available range of motion with constant angular velocity then. The ratio of flexor to extensor peak torque and abductor to adductor peak torque was considered for concentric records performed by dynamometer.

Statistical analysis

One-way analysis of variance (ANOVA) was used to determine differences in age, weight, height, HbA1c, FPG, and glucose test among the three groups. We also used one-way ANOVA to compare torque differences among the three groups, and post-hoc multiple comparisons were performed if the overall significance for ANOVA was found for any outcome measures. A p value of <0.05 was considered as significant.

Results

Demographic and diabetes-related variables are presented in Table 1. There was no significant difference in demographic variables among the three groups.

Isometric joint torques

There were no significant differences in isometric variables, including flexion, extension, abduction and adduction IPT, IAPT, and IPT/BW, among the three groups ($p > 0.05$) (Table 2).

Concentric joint torques

Hip flexion torque variables were not significantly different among the three groups, except for AOPT which was lower in the DPN group than in the other two groups ($p = 0.01$). CPT and CPT/BW of the hip extension torque were lower for DPN patients than for DWOPN patients and CG ($p = 0.01$; $p = 0.00$) and CAPT was lower in DPN group than in CG

Table 1 Demographic and blood characteristics of participants and results of ANOVA test to compare these variables among three groups.

	CG ($n = 15$)	DWOPN ($n = 15$)	DPN ($n = 12$)	p
Age	46.0 ± 4.3	49.5 ± 3.8	49.6 ± 5.3	0.20
Weight (kg)	78.2 ± 10.7	79.5 ± 14.5	82.5 ± 12.5	0.71
Height (cm)	163.6 ± 4.9	165.2 ± 8.6	164.5 ± 4.7	0.79
Body mass index	29.43 ± 3.9	28.46 ± 5.8	30.67 ± 4.1	0.10
Diabetes duration (y)	–	8.9 ± 3.9	12 ± 2.9	0.40
HbA1c (milli mole/mole %)	–	8.0 ± 1.1	9.2 ± 1.4	0.38

Data are presented as mean ± standard deviation.
CG = control group; DPN = diabetes with peripheral neuropathy group; DWOPN = diabetes without peripheral neuropathy group.

Table 2 Results of one-way ANOVA to compare the hip flexion, extension, abduction, and adduction isometric torques among three groups and mean and standard deviation of isometric variables.

	CG ($n = 15$)	DWOPN group ($n = 15$)	DPN group ($n = 12$)	p	F	OP
FLEX IPT (N.M)	56.68 ± 12.77	49.14 ± 15.63	46.89 ± 10.56	0.61	0.87	0.40
FLEX IPT/BW(N.M/kg)	65.75 ± 15.54	56.56 ± 12.98	50.82 ± 10.16	0.42	0.87	0.30
FLEX IAPT (N.M)	52.89 ± 11.67	46.14 ± 15.24	41.95 ± 10.48	0.56	0.59	0.75
EXT IPT (N.M)	108.97± 9.27	93.31 ± 18.29	94.49 ± 17.66	0.59	1.04	0.30
EXT IPT/BW(N.M/kg)	131.2 ± 19.54	107.52 ± 6.87	110.25 ± 8.94	0.36	1.04	0.70
EXT IAPT (N.M)	102.49 ± 8.40	88.28 ± 16.85	88.39 ± 7.93	0.59	0.52	0.27
ABD IPT(N.M)	62.73 ± 9.48	57.66 ± 12.37	54.62 ± 2.42	0.63	0.94	0.35
ABD IPT/BW(N.M/kg)	75.23 ± 7.87	67.6 ± 13.56	61.75 ± 12.65	0.40	0.94	0.35
ABD IAPT(N.M)	58.83 ± 9.76	54.32 ± 11.12	50.46 ± 10.56	0.63	0.45	0.25
ADD IPT(N.M)	88.14 ± 14.05	80.79 ± 5.01	88.39 ± 4.030	0.74	0.42	0.15
ADD IPT/BW(N.M/kg)	106.1 ± 15.05	96.06 ± 15.25	104.92 ± 6.43	0.66	0.42	0.11
ADD IAPT(N.M)	83.28 ± 14.07	76.8 ± 15.15	83.25 ± 17.12	0.78	2.44	0.50

Data are presented as mean ± standard deviation.
ABD IAPT = abduction isometric average peak torque; ABD IPT = abduction isometric peak torque; ABD IPT/BW = abduction isometric peak torque/body weight; ADD IAPT = adduction isometric average peak torque; ADD IPT = adduction isometric peak torque; ADD IPT/BW = adduction isometric peak torque/body weight; CG = control group; DPN = diabetes with peripheral neuropathy; DWOPN = diabetes without peripheral neuropathy; EXT IAPT = extension isometric average peak torque; EXT IPT = extension isometric peak torque; EXT IPT/BW = extension isometric peak torque/body weight; FLEX IAPT = flexion isometric average peak torque; FLEX IPT = flexion isometric peak torque; FLEX IPT/BW = flexion isometric peak torque/body weight; N.M = Newton meter; N.M/kg = Newton meter per kilogram; OP = observer power.

($p = 0.02$). AOPT of the hip extension torque was significantly greater for DWOPN group than for CG ($p = 0.01$). Moreover, hip flexion to extension ratio was different among three groups, i.e., lowest in CG and highest in DPN group; however, this variable was significantly different between DWOPN and DPN ($p = 0.03$) groups. CPT, CPT/BW, and CAPT of hip abduction were lower in DPN group than in CG ($p = 0.03$, $p = 0.01$, $p = 0.05$). However, there was no significant difference of adduction concentric torque variables among the three groups ($p > 0.05$). Despite the difference in abduction to adduction torque ratio, it was not significantly different among groups ($p = 0.12$) (Table 3).

Discussion

In this study, we investigated the hip joint isometric and concentric torques in patients with type II diabetes. Results showed that concentric torques of hip extension and abduction was lower in DPN patients than in CG. Angle of flexion peak torque in DPN group was the lowest among the three groups. Another finding in our study was that the ratio of flexion to extension torques in all three groups showed a difference, with the most values in DPN group and the least values in CG.

Isometric joint torques

In this study, there was no significant difference among three groups in hip isometric torque variables. Isometric state is a static and non-functional contraction. Also, isometric muscle testing in a specific angle in patients with type II diabetes cannot adequately measure muscle strength in these patients [18].

Concentric joint torques

Our finding about less concentric torques of hip joint in patients with diabetes is consistent with results of previous studies that demonstrated long-term type II diabetes results in a significant decrease in lower extremity joint torques, especially in knee and ankle [3,13] Joint torque is defined as a muscle force and joint reaction force multiplied by lever arm [18]. As previous studies assessed diabetic patients muscle strength by joint torques, lower joint torque represents muscle weakness.

Muscle weakness in type II diabetes may have several reasons, including less muscle mass, cross-sectional area, and double intramuscular fat [4,5]. Moreover, microscopic studies of skeletal muscle in patients with diabetes

Table 3 Results of one-way ANOVA to compare the hip flexion, extension, abduction, and adduction concentric torques among three groups and mean and standard deviation of concentric variables.

	CG ($n = 15$)	DWOPN group ($n = 15$)	DPN group ($n = 12$)	p	F	OP
FLEX CPT (N.M)	60.85 ± 12.8	59.06 ± 12.25	47.20 ± 7.18	0.27	1.32	0.26
FLEX CPT/BW(N.M/kg)	77.62 ± 13.45	72.32 ± 4.87	54.16 ± 12.96	0.06	3.02	0.55
FLEX CAPT (N.M)	54.19 ± 8.00	49.47 ± 11.63	41.53 ± 11.65	0.31	1.18	0.40
FLEX AOPT(degrees)	27.40 ± 14.20	24.60 ± 10.9	11.61 ± 4.50	0.01*£€	5.21	0.80
EXT CPT (N.M)	98.90 ± 20.20	95.12 ± 6.30	56.42 ± 1.00	0.01*£€	4.72	0.75
EXT CPT/BW(N.M/kg)	124.4 ± 29.10	118.84 ± 1.80	70.23 ± 1.40	0.00*£€	5.30	0.80
EXT CAPT (N.M)	87.64 ± 18.68	84.63 ± 12.44	50.67 ± 13.67	0.02*£	4.01	0.70
EXT AOPT(degrees)	20.80 ± 8.00	27.80 ± 6.70	20.80 ± 6.00	0.01*∞	4.92	0.77
FLEX/EXT ratio (%)	68.22 ± 3.80	73.81 ± 5.5	89.63 ± 5.70	0.03*€	3.77	0.65
ABD CPT(N.M)	60.51 ± 4.50	49.31 ± 8.90	38.11 ± 0.20	0.03*£	3.73	0.65
ABD CPT/BW(N.M/kg)	78.25 ± 9.23	61.8 ± 6.43	48.21 ± 4.65	0.01*£	4.68	0.75
ABD CAPT(N.M)	53.22 ± 8.33	45.18 ± 8.15	34.01 ± 7.35	0.05*£	3.16	0.65
ABD AOPT(degrees)	30.60 ± 8.03	26.81 ± 1.10	25.59 ± 2.60	0.28	1.30	0.36
ADD CPT(N.M)	78.78 ± 10.98	78.12 ± 10.20	61.55 ± 11.65	0.27	1.34	0.27
ADD CPT/BW(N.M/kg)	100.37 ± 5.34	97.19 ± 7.78	79.28 ± 12.34	0.28	1.29	0.36
ADD CAPT(N.M)	73.51±19.15	71.17 ± 15.89	55.93 ± 14.48	0.24	1.47	0.30
ADD AOPT(N.M)	16.20 ± 8.08	18.90 ± 7.30	20.40±7.50	0.64	0.43	0.11
ABD/ADD ratio (%)	82.33 ± 12.09	63.73 ± 13.6	67.21 ± 12.04	0.12	2.22	0.50

Data are presented as mean ± standard deviation.
ABD AOPT = abduction angle of peak torque; ABD CAPT = abduction concentric average peak torque; ABD CPT = abduction concentric peak torque; ABD CPT/BW = abduction concentric peak torque/body weight; ABD/ADD ratio = abduction to adduction ratio; ADD AOPT = adduction angle of peak torque; ADD CAPT = adduction concentric average peak torque; ADD CPT = adduction concentric peak torque; ADD CPT/BW = adduction concentric peak torque/body weight; CG = control group; DPN = diabetes with peripheral neuropathy; DWOPN = diabetes without peripheral neuropathy; EXT AOPT = extension angle of peak torque; EXT CAPT = extension concentric average peak torque; EXT CPT = extension concentric peak torque; EXT CPT/BW = extension concentric peak torque/body weight; FLEX AOPT = flexion angle of peak torque; FLEX CAPT = flexion concentric average peak torque; FLEX CPT = flexion concentric peak torque; FLEX CPT/BW = flexion concentric peak torque/body weight; FLEX/EXT ratio = flexion to extension ratio; N.M = Newton meter; N.M/kg = Newton meter per kilogram; OP = observer power.
*Means significantly different between groups; ∞ means post hoc between CG and DWOPN group; £ means post hoc between CG and DPN group; € means post hoc between DWOPN group and DPN group.

revealed less oxidative enzyme [19] and limited function of mitochondria [20]. Gene representation of neurotrophic factor is also low in patients with diabetes [21]. In addition, fat to water ratio is higher in these patients than in healthy individuals [22]. Furthermore, muscle fibres type I to type II changes in patients with diabetes results in decreased oxidative capacity of the skeletal muscle [23]. Nevertheless, diabetes itself does not affect the hip muscle, except in extension AOPT in our study, since other extension and abduction concentric torque variables in this study were different between CG and DPN group. As our results indicate, DPN patients are more susceptible of muscle weakness in lower limbs.

Peripheral neuropathy may lead to motor dysfunction; thus, patients with DPN are more susceptible to muscle weakness than patients with DWOPN [3,12]. There is evidence in animal and human studies that the number of type II muscle fibres not only decrease with age but also in the setting of denervation [24]. As a whole, decreased physical activity of patients with peripheral neuropathy may reduce the strength of muscles over the time [12], and a direct relationship is seen between the duration of diabetes and muscle weakness in these patients [3]. Based on our results, patients with DPN are more susceptible to muscle weakness in hip extensors and abductors.

Brown et al [14] calculated hip, knee, and ankle joints torques during walking in DPN and DWOPN patients. They reported lower peak joint torques at the ankle and knee in DPN patients. At the hip joint, they only observed significant differences for extension peak torque in DPN and DWOPN compared with CG. Their findings for the hip joint are in agreement with our results but with methodological differences. They calculated joint torques during walking using the process of diverse dynamics in sagittal plane; however, we used dynamometer to directly measure torque around the hip joint in sagittal and frontal planes. They normalised peak torque values of the knee and ankle to the values obtained from dynamometry, but they did not perform this operation for hip joint torques. Therefore, their result about the hip joint should be interpreted with caution. The other difference is the test condition (gait analysis vs. dynamometry).

Angle of peak torque

Interestingly, the results for angle of flexion peak torque demonstrate that in the absence of specific flexor muscle weakness in patients with DPN, these muscles produce maximal torque in short length of hip flexion. As a result, length-tension relationship change in DPN patients may predispose them to muscle weakness and strain in comparison with healthy individuals. Also, lower angle of flexion peak torque production in long time puts hip flexor muscles in shortened length and makes them susceptible to damage, especially caused by sudden eccentric contraction and flexion contracture at hip joint [25]. In addition, in patients with type II diabetes, more angle of extension peak torque with less joint torques than CG indicates that hip extensor muscles in these patients are able to produce peak torque mostly in lengthened positions [26].

Joint torques ratios

In this study, more flexion to extension concentric torque ratio in DPN patients indicates that these patients cannot produce enough force in hip extensor muscles versus flexor muscles which can lead to their lower limb dysfunction [27]. The results of hip flexion to extension peak torque ratio of CG in our study (68%) is in agreement with other studies (65%) [28]. Concentric peak torque ratio of hip joints is an important factor to predict chronic lower limb joints instability, patellofemoral pain, and ligamentous injuries [27].

Limitations

This study had several limitations. First, the sample size of our study was small due to our limited access to patients with peripheral neuropathy in the location of the study. However, it was based on power $= 0.8$ in pilot study, which estimated 13 participants for each study group. Second, patients with peripheral neuropathy were not classified based on the severity of developing peripheral neuropathy, whereas Andersen et al [3] revealed that muscle strength reduction is in correlation with the severity of peripheral neuropathy [3]. Third, we assessed one leg irrespective of bilateral differences. Finally, we did not assess concentric hip joint torques in different velocities. It has been suggested that concentric hip joint torque of different velocities in both legs and eccentric hip joint torques in patients with type II diabetes must be investigated.

Conclusions

Patients with DPN had less hip abduction and extension concentric joint torques. Our results showed no significant differences of isometric peak torques among three study groups. Therefore, patients with type II diabetes isometric strength cannot explore whole strength characteristics of hip muscles alone. Furthermore, the ratio of flexion to extension torques in patients with DPN was higher. Another finding in our study was that the angle of flexion peak torque in patients with DPN was the lowest among the three groups. As a result, patients with DPN are more susceptible to injury and disability in lower limbs.

Clinical Implication

Identification of musculoskeletal dysfunction in DPN patients would be a key element for diabetes complications prevention. It is recommended to prescribe appropriate exercise program for hip muscles for patients with DPN to prevent possible dysfunctions, injuries, and functional limitations in lower extremity.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Authors' contributions

Laleh Abadi: conception and design of study, acquisition of data, analysis of data, drafting the manuscript; Zahra Salahzadeh: conception and design of study, interpretation of data, revising the manuscript, approve and submitting the manuscript; Mandana Rezaei: conception and design of study, interpretation of data, acquisition of data, revising the manuscript; Ali E. Oskouei: conception and design of study, revising the manuscript; Mahmood Reza. Azghani: conception and design of study, acquisition of data, interpretation of data.

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