ISSN: 2345-2897; Health Education and Health Promotion. 2020;8(4):203-208

Assessment of Lower Extremity Muscle Strength in Diabetic Peripheral Neuropathy Patients Measured by Handheld Dynamometer

ARTICLE INFO

Article Type
Original Research

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How to cite this article
Ravanbod R, Eslami N, Ashtiani M.N. Assessment of Lower Extremity Muscle Strength in Diabetic Peripheral Neuropathy Patients Measured by Handheld Dynamometer. Health Education and Health Promotion. 2020 ;8(4):203-208.

ABSTRACT

Aims The aim was to investigate lower extremity muscle strength by a handheld dynamometer and to assess the possible correlation between fear of falling and muscle strength in diabetic peripheral neuropathy.

Materials & Methods In this cross-sectional study, 15 patients with diabetic peripheral neuropathy were evaluated based on the Michigan neuropathy screening instrument, and ten healthy control were enrolled. The study was performed in the clinical and research center of Tarbiat Modares University's movement disorders between February and May 2020. Fall efficacy scale-International was completed to assess fear of falling. Muscle strength of the peroneus longus, tibilalis anterior, gastrosoleus, Hamstring, vastus lateralis, quadriceps femoris, gluteus maximus, and hip abductors of the dominant (right) lower extremity was measured by a handheld dynamometer. SPSS 22 was used for data processing. An independent t-test, Pearson correlation, and regression analysis were used to analyze data.

Findings There was a moderate and negative correlation between fall efficacy scale-International and gastrosoleus time to peak (r=-0.0607; p=0.016), and a strong correlation between fall efficacy scale-International and Michigan neuropathy screening instrument (r=0.709; B=1.829; p=0.003). All the time-to-peak force results were higher in diabetic peripheral neuropathy than healthy control and became significant in tibilalis anterior, quadriceps femoris, and gluteus maximus (p<0.05). The augmented force of the gluteus maximus was significantly lower in diabetic peripheral neuropathy (p=0.021).

Conclusion Gastrosoleus rate of force development has a negative correlation with fear of falling. Fall efficacy scale-International and Michigan neuropathy screening instruments have a strong correlation.

Keywords Diabetic Neuropathies; Muscle Strength; Muscle Strength Dyanamometer; Accidental Falls

CITATION LINKS

[1] IDF diabetes atlas ... [2] Assessment of lower extremity muscle mass ... [3] Prevalence and risk factors of diabetic ... [4] Declining skeletal muscle function ... [5] Geneva: WHO; 2018 [Unknown ... [6] fear of falling is prevalent in older adults ... [7] Influence of the diabetic neuropathy on the ... [8] Muscle strength in diabetics compared to ... [9] Hip joint torques in type II diabetes with and ... [10] comparison between muscle strength ... [11] The effect of peripheral neuropathy ... [12] Lower extremity muscle strength is ... [13] Diabetic polyneuropathy is a risk factor for decline ... [14] Lower-limb muscle strength according to ... [15] Lower-limb muscle strength according to ... [16] Patients with type 2 diabetes show a greater ... [17] Reduced lower-limb muscle strength and volume ... [18] Statistical power analyses using ... [19] Clinical testing in diabetic peripheral ... [20] Cross-cultural validation of ... [21] Development and initial validation ... [22] validity and reliability of tools to ... [23] Muscles: Testing and function with ... [24] Diabetic neuropathy: A review emphasizing ... [25] Muscular atrophy in diabetic neuropathy ... [26] Muscle force distribution of the ... [27] Foot function and strength of patients ... [28] Kinetics and kinematics of diabetic ... [29] Foot kinetic and kinematic profile in ... [30] Reliability and validity of knee extensor ... [31] Validity and reliability of a handheld ... [32] Concurrent validity of a fixated handheld ... [33] Muscular activity of lower limb muscles ... [34] Physiological and methodological aspects ...

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Article History
Received: October 27, 2020
Accepted: January 20, 2021
ePublished: April 04, 2021

Introduction

There are 463 million people with diabetes worldwide and 55 million in the Middle East and South Africa. The international diabetes federation has predicted that 578 million people (10.2% of the population) will have diabetes by 2030 [1]. Growing the aging population throughout the world is a remarkable sociodemographic phenomenon of the 21st century. The number of diabetic patients is also increasing, accordingly. Elderly diabetic patients have lower muscle mass, muscle strength, and motor function than healthy individuals [2]. One of the most common complications of diabetes is diabetic peripheral neuropathy (DPN) [3]. Lower extremity muscle impairment, functional capacity reduction, abnormal gait pattern, balance impairment, and the resultant increase in fall risk could happen following DPN. Bone fractures, poorly healing wounds, and chronic infections are DPN complications after falling [4]. Falls are the second leading cause of accidental or unintentional injury deaths worldwide, according to the world health organization (WHO) [5]. However, Kelly *et al.* reported that while fear of falling (FOF) assessed by fall efficacy scale-International (FES-I) questionnaire is prevalent in older diabetic patients, it is unrelated to the level of the neuropathy [6].

Regarding alterations in muscle activity, Sacco *et al.* demonstrated that electromyography (EMG) activity of tibilalis anterior (TA), vastus lateralis (VL), and lateral gastrocnemius (LG) muscles during treadmill walking had a delay in DPN [7].

It should be mentioned that evaluating muscle strength is divided into manual muscle testing and machine method testing [8]. The latter consists of the small and cheap handheld dynamometer (HHD) and the big and expensive isokinetic devices. HHD is more practical for routine clinical investigations. However, muscle strength has been widely assessed by isokinetic devices in DPN [9-12]. Nevertheless, HHD has also been measured mainly with just a single muscle group assessment like knee extension [8, 13]. Asada et al. reported no difference in muscle force measured with HHD in diabetic patients for knee extension and ankle dorsiflexion [14], contrary to Vongsirinavarat *et al.,* who reported significant differences in knee flexor and ankle plantar flexors [15]. Leenders *et al*. measured muscle strength in diabetic patients with 1 RM in leg press and leg extension machines and reported leg extension strength was significantly lowered in diabetic patients [16]. Concerning the strength loss pattern in DPN, it was reported that the ankle had more strength loss than thigh muscles [4]. However, in another study, the reduced strength of the proximal and distal leg muscles was reported the same and both significant ($p<0.003$) [17]. Rahimi et al. also reported that diabetes affects neither the upper nor the lower extremity muscle force in the elderly [8]. Therefore, while most of the investigations assessed limited muscle groups instead of the more precise measurement of individual muscle strength, no consensus has been achieved regarding muscle strength and the appropriate measurement device in DPN yet.

Preventing falling strategies are prioritizing fall-related research and establishing effective policies to reduce the risk of falling [5]. Knowing the pattern of muscle weakness in DPN patients with a dynamometer could help healthcare providers better guide these patients in strengthening their weakened muscles, preventing muscle imbalance and the resultant risk of falling [4]. Thus, the purpose of the present study was to investigate lower extremity muscle strength by a handheld dynamometer and to assess the possible correlation between fear of falling and muscle strength in diabetic peripheral neuropathy.

Materials and Methods

Fifteen patients with DPN and 10 matched healthy controls (HC) subjects were enrolled in this cross-sectional study. The study was performed in the clinical and research center of Tarbiat Modares University's movement disorders between February and May 2020. Patients were selected according to the convenient sampling method. The sample size was determined as 15 patients given the mean±SD of the knee extension force measured by a handheld dynamometer in DPN reported in Namura *et al*. study [13]. G*Power software was used to calculate the sample size with an alpha level of 0.05, study power of 70%, and calculated effect size of 0.39 for the difference between two independent means (t-test) [18]. Inclusion criteria were age 50-75 years, body mass index (BMI) 25-30, HA1C 5.5-9, MNSI 13-29 (mild to moderate neuropathy), and diabetic duration of 4-12 years. Patients with diabetic ulcers, falling history, using medications affecting muscle, and participating in regular physical training for six months were excluded.

The neuropathy severity was evaluated based on the Michigan neuropathy screening instrument (MNSI). MNSI consisting of yes/no questions was applied to all the patients. 13 items assess symptoms of diabetic peripheral neuropathy, 1 item assesses peripheral vascular disease, and 1 item assesses general asthenia. MNSI has a physical examination part with foot inspection, vibration sensation, muscle stretch reflexes, and monofilament testing [19]. FES-I is a valid and reliable questionnaire that measures falling in daily living activities with 16 items [20]. The total score ranges from 16 to 64, with higher scores indicating more concern about falling [21]. After filling the FES-I in DPN patients, muscle strength, as the dependent variable, was measured by a handheld dynamometer (Model 01165, Lafayette Instrument Company, 3700 Sagamore Parkway North, Lafayette, IN 47904, U.S.A) for peroneus longus (PL), ta, gastrosoleus (gs), hamstring (HAM), VL, quadriceps femoris (QF), gluteus maximus (GM), and hip abductors (HA) muscles of the dominant (right) lower extremity. The validity and reliability of this method were confirmed in previous studies [22]. Outputs were Peak force (PF), time to peak (TP), and augmented force (AF).

Ethic code was obtained from Tarbiat Modares university ethical committee. For the participant's familiarization, one practice trial was performed before commencing the real test procedure. Each muscle contraction lasted for five seconds according to the dynamometer setting. Each muscle's strength was measured according to the manual muscle test method in the specified body and limb positions [23]. The position of the device was standardized for each measurement. For PL, the subject laid side-lying on the left side with the extremity medially rotated. The examiner supported the leg above the ankle joint. Subject everted the foot, with plantar flexion of the ankle joint. The pressure was applied through a padded stirrup of the dynamometer against the lateral border and sole in the direction of inversion of the ankle joint's foot and dorsiflexion. To evaluate TA, the patient sat at the plinth edge with the knee in 90 flexions. The examiner supported the leg just above the ankle joint. The patient performed dorsiflexion of the ankle joint and the foot's inversion, without extension of the great toe. The pressure was applied through the padded stirrup of the dynamometer against the medial side, dorsal surface of the foot, the direction of plantar flexion of the ankle joint, and the foot's eversion. For GS, the subject laid prone and performed plantar flexion while the examiner applied pressure through the device stirrup against the head of the metacarpal bones. In the same prone position, the subject was asked to perform knee flexion, and the pressure was applied above the ankle for testing Ham's muscle. To evaluate, VL and QF subjects sat with the knees over the table's side and held on to the table. The subject performed full extension of the knee joint, without rotation of the thigh and leg for QF and medial rotation of the leg for VL. The pressure was applied against the leg above the ankle. To test GM, the subject laid prone with the knee flexed 90 degrees or more and pressure applied above the knee while the subject performed hip extension. To assess HA, the patient laid side-lying, and the examiner supports pelvic to prevent rotation. The subject performed hip abduction and pressure applied above the knee joint [23]. A standard instruction of 'push as hard as you can' was given to each participant for each test.

The Statistical Package for Social Science version 22 (SPSS Inc, Chicago, IL, USA) was used for data processing. The Shapiro-Wilks test was used to check for normality, and all values were normally distributed. An independent t-test was performed for comparisons of the parameters between two groups. Pearson correlation and regression analysis were done to explore the association between variables. Statistical significance was defined as $p<0.05$.

Findings

Demographic data of the participants are summarized in Table 1. No statistically significant difference was found between the two groups at baseline ($p>0.05$).

Table 1) Mean±SD of demographic data

Group	Healthy Control	DPN
Age (year)	55.90±6.26	55.93±5.92
Height (cm)	169.60±8.38	170.93±9.79
Weight (Kg)	73.05±4.76	74.73±7.09
BMI (kg/m^2)	25.54±2.90	25.51±2.21
Diabetes duration (Year)	-	6.84±1.01
HbA1c	-	8.66±4.44
MNSI	-	19.26±3.75
FES-I	-	20.46±9.67

DPN: Diabetic Peripheral Neuropathy; BMI: Body Mass Index; MNSI: Michigan Neuropathy Screening Instrument; FES: Fall Efficacy Scale-International

Peak force, time to reach muscle activity to the peak force, and augmented force are presented in Diagram 1. All the time-to-peak force results were higher in DPN than HC and became significant in TA, QF, and GM ($p<0.05$). Effect sizes according to Cohen's d classification were 0.80, 0.82, and 0.79, respectively. The augmented force of GM muscle was also significantly lower in DPN ($p=0.021$).

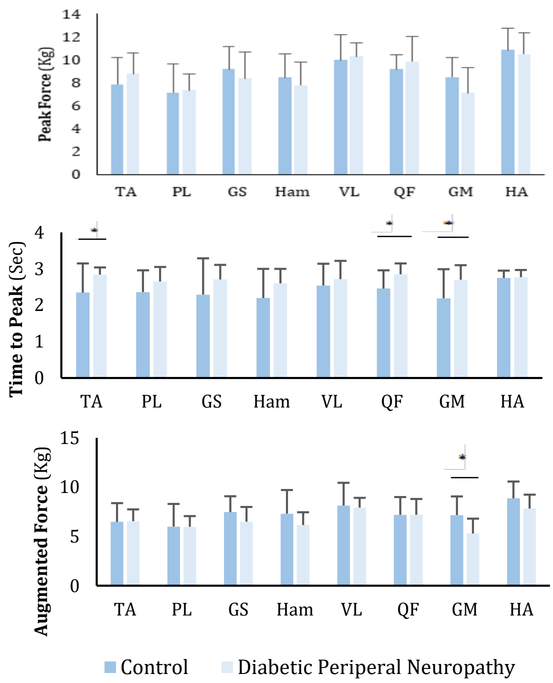

Diagram 1) Dynamometer outcomes including peak force, time to peak, and augmented force in healthy control and diabetic peripheral neuropathy groups; *p<0.05

There was just one moderate and negative correlation between GS time to peak and FES-I (Spearman's r=-0.607, p=0.016). All other correlations between FES-I and muscle strength outcomes were not significant. A strong correlation was found between FES-I and MNSI (r=0.709, p=0.003). The regression analysis showed that the unstandardized coefficient was 1.829.

Discussion

The present study aimed to evaluate lower extremity muscle strength with HHD in DPN patients. HHD was chosen as an easy-to-apply instrument that could be added to the routine clinical practice of the DPN patients and hence could prevent some of the complications of DPN, including muscle weakness and the resultant balance disturbances like falling leading to increase the health state of these patients. The usefulness of diagnostic methods in the clinical setting is of great importance for preventive strategies in diabetes [24].

Contrary to Kelly *et al.*, a strong and significant correlation was found between FES-I and MNIS in the present study [6]. It showed that by one score increase in MNSI, the FES-I increased by 1.829. The difference may be attributed to different utilized neuropathy assessment instruments. They assessed neuropathy with just vibration perception threshold while MNIS, which includes many other aspects of both subjective and objective parameters were utilized in the present study.

Among the eight muscles investigated in the present study, GM augmented force was significantly lower than the healthy control group. In previous studies, either very limited muscles were investigated [8, 13], or reported atrophy was more predominated distally in DPN [25]. As indicated, Rahimi *et al.* also reported that diabetes mellitus affected neither the upper nor the lower extremity muscle force in the elderly while they also assessed just handgrip in upper and QF in lower limb [8]. These selected and limited muscle assessments cannot provide a real understanding of muscle strength patterns in DPN.

Bavaresco *et al.* compared muscle strength of the knee and ankle in diabetic, DPN, and non-diabetic patients with an isokinetic dynamometer. Comparing diabetic with non-diabetic patients, significant reductions in knee flexion torque on the left limb at a 120° angular velocity in diabetes, dorsiflexion at a 60° angular, and knee flexion deficit among DPN when compared with non-neuropathic were reported [10]. They did not explore hip muscles like the present study, and the significant reduction of the knee flexion and ankle dorsiflexion was revealed in the dynamic movement of muscle groups while we studied static maximal strength of individual muscles. Gomes et al. investigated a more comprehensive muscle force distribution of diabetic patients with and without neuropathy during the gait cycle, but they estimated muscle force distribution using static optimization and observed no difference in GM [26]. Pressure platform was also used to assess foot strength in diabetes but in standing position when all muscle body forces can influence the results.

Meanwhile, no difference was reported in toes and hallux strength of the foot between normal and DPN [27]. A systematic review and meta-analysis regarding Kinetics and kinematics of diabetic foot showed no significant peak knee extension and hip flexion moment between diabetes with and without peripheral neuropathy. This review in 2016 found that the sample size in some studies was not statistically significant to perform the meta-analysis and report a strong conclusion [28]. In 2019, Hazari *et al.* evaluated motor neuropathy and muscle weakness by manual muscle test [29]. Finally, we found significantly decreased GM augmented force in DPN by HHD. Consequently, a valid, reliable, and easy-to-apply diagnostic method for measuring muscle strength has not been introduced for diabetes patients yet [30-32]. It should be mentioned that, although the effect sizes of the significant muscle strength differences were high, as a limitation of the present study, further investigations with a higher number of participants could provide a better understanding of the muscle strength pattern of diabetes individuals with and without neuropathy with HHD.

Time to reach the peak force, or in other words, the rate of force development, was lower in DPN in comparison to HC in a harmonic pattern in all the investigated muscles. It became significant in TA, QF, and GM (p<0.05), which are important muscles for upright posture and locomotion [33]. The high rate of force development plays an important role in performing rapid and forceful movements, both in athletes and in elderly individuals who need to control unexpected perturbations in postural balance [34]. Therefore, reducing this variable in DPN with high effect sizes is alarming evidence that these patients might need strength training programs to prevent further complications. GS's significant negative correlation with FES-1 confirms the need for rapid and forceful movement training in these patients. This evidence could be explored by an easy-to-apply device like an HHD available in any diabetes clinic.

This study was performed on mild to moderate DPN. It could also be assessed on severe DPN patients with more muscle strength complications.

Conclusion

Gastrosoleus rate of force development has a negative correlation with fear of falling. Fall efficacy scale-International and Michigan neuropathy screening instruments have a strong correlation.

Acknowledgments: The authors would like to thank the Vice-Chancellor for Research Affairs of Tarbiat Modares University of Medical Sciences, Tehran, Iran, for financial support.

Ethical Permissions: Ethics code of 1397.265 was obtained from Tarbiat Modares University ethical committee.

Conflict of Interests: The present manuscript was extracted from the MSc thesis by Eslami N.

Authors' Contributions: Ravanbod R. (First author), Introduction author/Methodologist/Original researcher/ Statistical analyst/Discussion author (34%); Eslami N. (Second author), Methodologist/Assistant researcher (33%); Ashtiani M.N. (Third author), Methodologist/ Assistant researcher (33%).

Funding/Sources: Fund was obtained from Tarbiat Modares University.

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