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Impact of lower limb muscle strength on walking function beyond aging and diabetes

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Abstract

Objective: This study was performed to investigate the influence of lower limb muscle strength on the walking function of advanced-age patients with diabetes.

Methods: In this cross-sectional descriptive study, data were collected from 202 advanced-age patients with diabetes. All patients completed questionnaires, the one-leg stance test, the timed up-and-go test, the 30-s sit-to-stand test, and plantar pressure platform measurements. The patients were divided in two groups according to their lower limb muscle strength: those with declining muscle strength and those with normal muscle strength.

Results: Walking function was significantly abnormal in the patients with declining lower limb muscle strength. The gait trajectories were abnormal, mainly with respect to a shortage of driving force.

Conclusion: The lower limb muscle strength can affect the static balance and dynamic balance in advanced-age patients with declining lower limb muscle strength.

Keywords

Lower limb muscle strength, diabetes, walking performance, questionnaires, aging, balance

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Introduction

The World Health Organization reported that the advanced-age population will triple in the next few decades and is expected to grow to 1.5 billion by 2050.[1] The number of people diagnosed with diabetes mellitus (DM) worldwide has reached 382 million and is expected to reach

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522 million by 2030.[2] Studies have shown that half of the new diagnoses of DM are made in people aged $\geq$60 years.[3]

Walking function, including gait and balance ability, is the major determinant of an independent and productive life.[4] Gait and balance are essential for predicting quality of life, morbidity, and mortality.[5] Aging causes deterioration in the sensory systems and changes the muscle activity patterns, which lead to degradation in gait and balance.[6] Chronic diseases, such as DM and sarcopenia, can accelerate this degradation.[7] Insufficient insulin secretion in patients with type 2 DM results in insufficient synthesis of myoprotein, leading to decreased muscle strength and function.[8] The changes in muscle mass make the skeletal muscle less sensitive to glucose uptake, which leads to metabolic disorders and increased blood glucose.[9] Consequently, declining lower limb muscle strength may serve as a pathway for multiple pathologic processes of poor walking function in older people, and DM may promote the development of these pathologic processes.[10]

The relationship between muscle strength and walking function in patients with DM who have declining lower extremity muscle strength has not been quantified. Therefore, in this study, we monitored the characteristics of foot balance, the center of pressure (COP) trajectories, and the plantar force–time curve. An understanding of these parameters will assist in identifying early deterioration in walking function, which in turn may promote timely intervention.

Materials and methods

Design and sample

This cross-sectional descriptive study took place from March 2017 to February 2018. Patients with declining lower limb muscle strength were recruited from the Changning District Xianxia Street Community Health Service Center, Shanghai, China. The patients were divided in two groups according to their lower limb muscle strength: those with declining muscle strength and those with normal muscle strength.

The inclusion criteria were an age of >60 years, the ability to remain in an orthostatic position without assistance or the use of auxiliary devices, and a diagnosis of DM based on the standard oral glucose tolerance test or previous medical records. The exclusion criteria were a current foot ulcer or bilateral foot amputation, a wheelchair-bound status or the inability to walk, the inability to participate because of severe illness, and psychiatric illness that prevented provision of informed consent.

All patients provided informed consent prior to participating in the study. The Ethics Committee of Huadong Hospital, Fudan University approved the study protocol.

Procedure

When the patients' condition was stable, they completed a general information form and underwent a plantar pressure platform test. All tests were performed under the guidance of six trained DM specialist nurses in the department. The nurses who participated in the study held nurse-in-charge or higher positions and had been working in the hospital for more than 5 years.

Measures

All evaluation procedures were performed by the same examiner, who was not told the aims of the study or to which group the patients were allocated. We used the one-leg stance test (OLS), the timed up-and-go test (TUG), and the 30-s sit-to-stand test (STS) to assess the static and dynamic balance ability and lower extremity muscle strength, respectively. These tests are easy to implement and require no special equipment; thus, they are widely used among community-dwelling patients of advanced age.

OLS

The OLS is one of the most commonly used methods to assess the static balance ability. It is usually performed to assess older people's ability to maintain balance while standing. Hurvitz et al.[11] reported that the OLS could indicate a decreased balance ability and an increased fall risk due to diabetic peripheral neuropathy (DPN) with high sensitivity (83%) and specificity (71%). Each patient was instructed to stand akimbo (hands on the hips with elbows bowed outward) and then raise one foot and stand on one leg when hearing the order, "ready, go" given by a researcher. The time from one foot leaving the ground to the non-stance foot touching the ground or the stance foot shifting in any way was recorded with a stopwatch. The OLS was performed with eyes open and eyes closed. If the time was longer than 60 s, a second measurement was not required. Each patient performed three tests, and the best result among the three tests was recorded. According to Vellas et al.,[12] a shorter OLS is associated with worse static balance function, and an OLS of <5 s indicates an increased risk of falls.

TUG

The TUG is commonly used to examine dynamic balance ability. This test is a measure of physical mobility and has good intrarater and inter-rater reliability ($\gamma = 0.99$ and 0.98, respectively). Each patient stood up from a chair (approximate seat height of 46 cm) when the researcher gave the order, "ready, go." The patient walked a distance of 3 m to reach the mark, turned around, walked back to the chair, and sat down. The patient wore his or her regular footwear and used his or her customary walking aid (e.g., cane, walker) during the test. No other physical assistance was given. The time was recorded using a stopwatch (from leaving the chair to sitting down again), and the gait was observed. Three trials were performed and averaged. Jernigan et al.[13] showed that a longer TUG was associated with worse dynamic balance function and that a TUG of >10 s indicates that the dynamic balance function is damaged.

30-s STS

The 30-s STS is widely used to evaluate lower extremity muscle strength. The test is easy to implement, and the "sit-to-stand" action is also very common in people's daily life; therefore, this test is suitable for assessing the lower extremity muscle strength and predicting the falling risk in people of advanced age. Alfonso-Rosa et al.[14] also reported that the 30-s STS has good reliability and validity for measuring the muscle strength of the lower extremities in advanced-age patients with DM and can be used to effectively evaluate the lower extremity muscle strength. For this test, each patient in our study was asked to sit in an armless chair (with its back supported against a wall) with his or her arms crossed over the chest. The patient was instructed to stand up and sit down as quickly as possible after receiving the order, "ready, go." The same chair was used for all patients. The number of completed sit–stand cycles within 30 s was counted and recorded. Each patient was tested twice with a 30-minute rest between the two tests. The final result was the average of the two records. Nevitt et al.[15] found that a smaller number of sit–stand cycles within 30 s was associated with weaker lower extremity muscle strength and that <15 sit–stand cycles in the 30-s STS indicates weakened lower extremity muscle strength with an increased risk of falls.

Plantar pressure platform

The pressure platform used in this study was made of a matrix of resistive sensors spaced at 40 × 100 cm with a sensor resolution of four sensors per square centimeter and a sampling frequency of 300 Hz. The parameters were calibrated before measuring. The platform was put in the middle of a wooden walkway that was long enough to guarantee that the data were acquired "at regimen". The patient was trained by a DM specialist nurse to walk barefoot on the walkway at his or her preferred speed in a natural way and to center the active surface with one foot only, without looking down at the platform. The outcome measures were the COP trajectory and the plantar force–time curve.

DPN classification

The Toronto Clinical Scoring System for DPN was used. This scoring system includes assessments of neurological symptoms, nerve reflexes, and sensory function. The total score is 19 points. A score of 6 to 8 indicates mild DPN, 9 to 11 indicates moderate DPN, and 12 to 19 indicates severe DPN.

Statistical analyses

We used the software program SPSS 24.0 (IBM Corp., Armonk, NY, USA) to conduct the statistical analysis. Continuous variables are expressed as mean ± standard deviation, and categorical variables are expressed as a percentage (%). For comparisons of two variables, each value was compared by the t-test when each datum conformed to a normal distribution, while non-normally distributed continuous data were compared using non-parametric tests. Count data were evaluated using the chi-square test. A P value of <0.05 was considered statistically significant.

Results

Patients' general characteristics

In total, 202 advanced-age patients with declining lower limb muscle strength were recruited in this study. These patients ranged in age from 60 to 88 years (mean, 73.56 ± 8.11 years). The baseline characteristics were not significantly different between the two study groups (Table 1). Additionally, there was no significant difference in the proportion of each classification group of DPN between the two groups (Table 2).

Changes in static and dynamic balance. Static balance was assessed by the OLS, and dynamic balance was assessed by the TUG. There was no significant difference in the proportions of patients with abnormal balance in the eyes-closed OLS (Table 3). In the eyes-open OLS and TUG, the proportion of patients with abnormal balance was significantly lower in the normal muscle strength group than in the declining muscle strength group ($P < 0.05$) (Table 3).

There was no significant difference in the mean time required to complete the eyes-open OLS between the two groups (Table 4). The time required to complete the eyes-closed OLS and TUG was significantly longer in the declining muscle strength group than in the normal muscle strength group ($P < 0.05$ for both) (Table 4).

COP. There was no significant difference in the proportions of patients with an abnormal starting point, lift-off point, and fold back between the two groups (Table 5).

Table 1. Comparison of basic information between the two groups (n = 202).

	Declining muscle strength (n = 102)	Normal muscle strength (n = 100)	P
Age, years	73.62 ± 8.67	73.50 ± 7.54	0.768
Sex	36/66	45/55	0.160
Duration of DM, years	18.72 ± 9.39	18.62 ± 6.31	0.931
DPN classification	3.26 ± 0.49	3.27 ± 0.49	0.936

Data are presented as mean ± standard deviation or number of patients.
DM, diabetes mellitus; DPN, diabetic peripheral neuropathy.

Table 2. Comparison of classifications of diabetic peripheral neuropathy between the two groups.

Group	Mild peripheral neuropathy	Moderate peripheral neuropathy	Severe peripheral neuropathy	P
Normal muscle strength (n = 100)	75 (75.0)	23 (23.0)	2 (2.0)	0.997
Declining muscle strength (n = 102)	77 (75.5)	23 (22.5)	2 (2.0)	

Data are presented as number (percentage) of affected patients.

Table 3. Comparison of abnormal static and dynamic balance between the two groups.

Group	Normal muscle strength (n = 100)	Declining muscle strength (n = 102)	P
Eyes-open OLS	8 (8.0)	18 (17.6)	0.041*
Eyes-closed OLS	52 (52.0)	66 (64.7)	0.067
TUG	15 (15.0)	35 (34.3)	0.001***

Data are presented as number (percentage) of patients with abnormal balance.
OLS, one-leg stance test; TUG, timed up-and-go test.
*$P < 0.05$, ***$P < 0.001$.

Table 4. Comparison of static and dynamic balance between the two groups.

Group	Normal muscle strength (n = 100)	Declining muscle strength (n = 102)	P
Eyes-open OLS	12.63 ± 11.37	14.36 ± 11.22	0.069
Eyes-closed OLS	4.18 ± 3.10	6.44 ± 6.29	0.022*
TUG	8.82 ± 1.71	10.39 ± 3.59	0.003**

Data are presented as mean ± standard deviation seconds required to complete the test.
OLS, one-leg stance test; TUG, timed up-and-go test.
*$P < 0.05$, **$P < 0.01$.

Table 5. Proportions of abnormal COP trajectory between the two groups.

	Normal muscle strength (n = 100)	Declining muscle strength (n = 102)	P
Starting point	30 (30.0)	30 (29.4)	0.927
Lift-off point	56 (56.0)	66 (64.7)	0.206
Fold back	51 (51.0)	62 (60.8)	0.161
COP	67 (67.0)	83 (81.4)	0.019*

Data are presented as number (percentage) of patients.
COP, center of pressure.
*P < 0.05.

Table 6. Comparison of peak composition in foot pressure curve between the two groups.

Group	Single peak	Double peaks	More than two peaks	P
Normal muscle strength (n = 100)	17 (17.0)	45 (45.0)	38 (38.0)	0.032*
Declining muscle strength (n = 102)	25 (24.5)	28 (27.5)	49 (48.0)	

Data are presented as number (percentage) of patients.
*P < 0.05.

The proportion of patients with an abnormal COP trajectory was significantly lower in the normal muscle strength group than in the declining muscle strength group ($P < 0.05$) (Table 5).

Plantar force–time curve. There was a significant difference in the peak composition between the two groups ($P < 0.05$) (Table 6). The normal double peaks dominated the normal muscle strength group, while multiple peaks dominated the declining muscle strength group (Table 6).

Discussion

In the present study, the walking function of advanced-age patients with DM who had declining lower muscle strength was significantly abnormal. The gait trajectories were abnormal, mainly with respect to a shortage of driving force.

Poor dynamic and static balance function in advanced-age patients with DM and declining lower extremity muscle strength

This study showed that the dynamic and static balance function in advanced-age patients with DM and declining lower extremity muscle strength was significantly decreased. According to Wang et al.,[16] 3 weeks of lower extremity muscle strength exercises in advanced-age patients with DPN significantly improved the static and dynamic balance. Patients with DM tend to have DPN, which can lead to decreased blood flow and perfusion.[17] This decrease in blood flow and perfusion will lead to decreased muscular endurance, which results in decreased strength of muscles such as the ankle extensors (dorsiflexion), ankle plantar flexors, knee extensors, and knee flexors.[18] This leads to decreased ankle range of motion, decreased muscle strength, a prolonged joint muscle response time, and eventually decreased balance.

Shortage of driving force in advanced-age patients with DM and declining lower extremity muscle strength

This study showed that the COP trajectories in advanced-age patients with DM and declining lower extremity muscle strength were significantly abnormal and that the plantar force–time curve was significantly abnormal with multiple peaks. DPN affects the sensory and walking nerves, mainly in the feet and lower limbs.[19] It damages the perception of foot contact by changing the sensory and walking nerves, thereby affecting sensory feedback and balance control. Walking neuropathy damages muscle strength through impaired walking nerve function, thereby affecting lower limb joints, causing torques around them and ultimately affecting gait.[20] However, studies have shown that even before the formation of DPN, non-enzymatic glycosylation of DM can impair muscle function, affect gait, and increase the risk of falls in daily life by acting on the contraction mechanism of muscles.[21]

Walking function deterioration in advanced-age patients with DM and declining lower extremity muscle strength. This study provided objective data to support that declining lower extremity muscle strength among advanced-age people with DM might lead to walking function deterioration. Without timely intervention, walking function deterioration among advanced-age patients with DM and declining lower extremity muscle strength may lead to serious adverse outcomes, including foot ulcers, amputation, and early frailty and might increase the risk of falling and loss of independence, thus further complicating their clinical condition.[22]

Limitations

This study had several limitations. First, this was not a randomized controlled trial. Second, this was only a single-center trial and the sample size was limited. Third, the clinical follow-up was short; in future studies, it will be necessary to observe the clinical long-term prognosis. Finally, we did not have enough data for adjustment for potential confounders in the logistic regression analysis, which should also be investigated in further research.

Conclusion

Advanced-age patients with DM and declining lower extremity muscle strength have poor dynamic and static balance function. Moreover, the walking strategy in these patients is abnormal, including a shortage of driving force. Future research should include larger samples in long-term, double-blinded randomized clinical trials to comprehensively study the effects of exercise on the walking function of advanced-age patients with DM and declining lower extremity muscle strength. We should also develop more suitable exercises for these patients.

Declaration of conflicting interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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