Falls among Older Adults with Type 2 Diabetes Mellitus with Peripheral Neuropathy

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ABSTRACT

Objective: The high incidence and prevalence of falls among older people with type 2 diabetes mellitus (ODM) have been documented. The risk factors of falls among ODM were identified as poor diabetic control, diabetic peripheral neuropathy (DPN) and balance impairment. This study aimed to investigate the contribution of DPN to history of falls. The differences of balance performance and lower limb muscle strength among ODM with and without DPN were also explored.

Methods: This cross-sectional study interviewed 112 ODM for their falls occurrences within the previous 6 months. DPN was determined by the score of the Michigan Neuropathy Screening Instrument. Balance performance tests included Clinical Test of Sensory Interaction and Balance (mCTSIB), Functional Reach Test (FRT) and Timed Up and Go Test (TUG). Leg muscle strength was also measured. The logistic regression analysis was performed.

Results: The history of falls was reported 30.6% of ODM with DPN and 10.4% of ODM without DPN. Presenting of DPN influenced falls with odds ratio of 3.46 among ODM. Differences were found of mCTSIB in the condition of eyes closed on firm and foam surfaces, FRT, and TUG between those with and without DPN. Knee extensor strength differed between those with and without DPN.

Conclusion: DPN was more prominent among fallers. Balance performance and leg strength were lower in ones with DPN. Falls prevention programs including balance training and therapeutic exercise to improve balance performance and muscle strength should be emphasized among ODM, especially before the onset of DPN.

Keywords: Balance; diabetic peripheral neuropathy; elderly; falls; type 2 diabetes mellitus (Siriraj Med J 2021; 73: 92-98)

INTRODUCTION

Diabetes mellitus (DM) is a major metabolic condition with several complications causing disabilities among older adults i.e., people with age greater than 60 years. High prevalence of older adults with Type 2 diabetes mellitus (ODM) has been reported globally, 15-22% worldwide[1] and 17.2% in Thailand.[2] Compared with a nondiabetic group, older adults with Type 2 diabetes mellitus (ODM) reported greater falls occurrence[3] and risk of falls.[4] Other important risk factors of falls among ODM include balance impairments and reduced muscle strength.[5] However, studies regarding falls risk among ODM showed inconsistent findings which might be associated with the complications, duration of disease, cognitive function, age and sex differences.[4]

Diabetic peripheral neuropathy (DPN) is a major complication known to be associated with increasing falls and reduced quality of life among ODM.[6] The overall prevalence of DPN among ODM was 28% in the US[7] and 2.82% in Thailand.[8] ODM with DPN exhibited significant deficits in sensory-motor function, postural instability and gait imbalance leading to a high fall incidence.[9] The presence of DPN was associated with poorer balance performance including the Berg Balance

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score (BBS), single leg stance test (SLS) and Timed Up and Go Test (TUG). The severity of DPN reflected by MNSI score was reversely correlated with BBS score and SLS time.[10] Although DPN affects both sensory and motor functions,[11] the sensory deficits specifically exteroception and proprioception are usually more prominent than muscle dysfunction among ODM with DPN.[12] The early clinical picture typically involves altered somatosensory functions, while motor involvement usually manifests in the later stages of DPN.[13] In more severe stages, the motor deterioration presents as unilateral or bilateral muscle weakness and atrophy of the proximal thigh muscles.[14]

The functional fallouts of sensory and motor impairments such as postural instability, unsteady gait and frequent falls were evident among ODM.[10,12,15] These adverse consequences could be inflated in cases of ODM with DPN. However, the effects of DPN concerning falls among ODM still require more evidences. Therefore, this study aimed to determine the contribution of DPN on the history of falls. Balance performance and lower limb muscle strength were also compared between ODM with and without DPN.

MATERIALS AND METHODS

This study employed a cross-sectional, comparative design. The research settings were eight community hospitals in the Mueang, Phuttamonthon, Nakornchaisri and Sampran districts, Nakornpathom province. The inclusion criteria were community dwellers, aged over 60 years and diagnosed with type 2 DM by medical doctors for at least five years. Two hundred and forty-eight (n=247) ODM who were followed up in the diabetes clinics of hospitals nearby their residents were enrolled in the study. All participants were informed about the study procedures and signed informed consent before participating. This study was approved by the Mahidol University Central Institutional Review Board (MU-CIRB 2015/035.0303).

The participants were included if their vital signs including heart rate, blood pressure and respiratory rate were in normal range. The letter chart and visual acuity conversation was used to confirm that all participants had normal vision. They also had no complaints of vertigo and dizziness, could understand and follow verbal instruction and could walk independently at least 10 meters. The exclusion criteria were a history of central nervous system dysfunction, cognitive impairment, lower limb amputation or joint replacement and symptoms affecting walking. One hundred and thirteen ODM were finally included in the study and divided into ODM with DPN (n=36) and ODM without DPN (n=77) groups for analysis. Fig 1 presents the flow of participants.

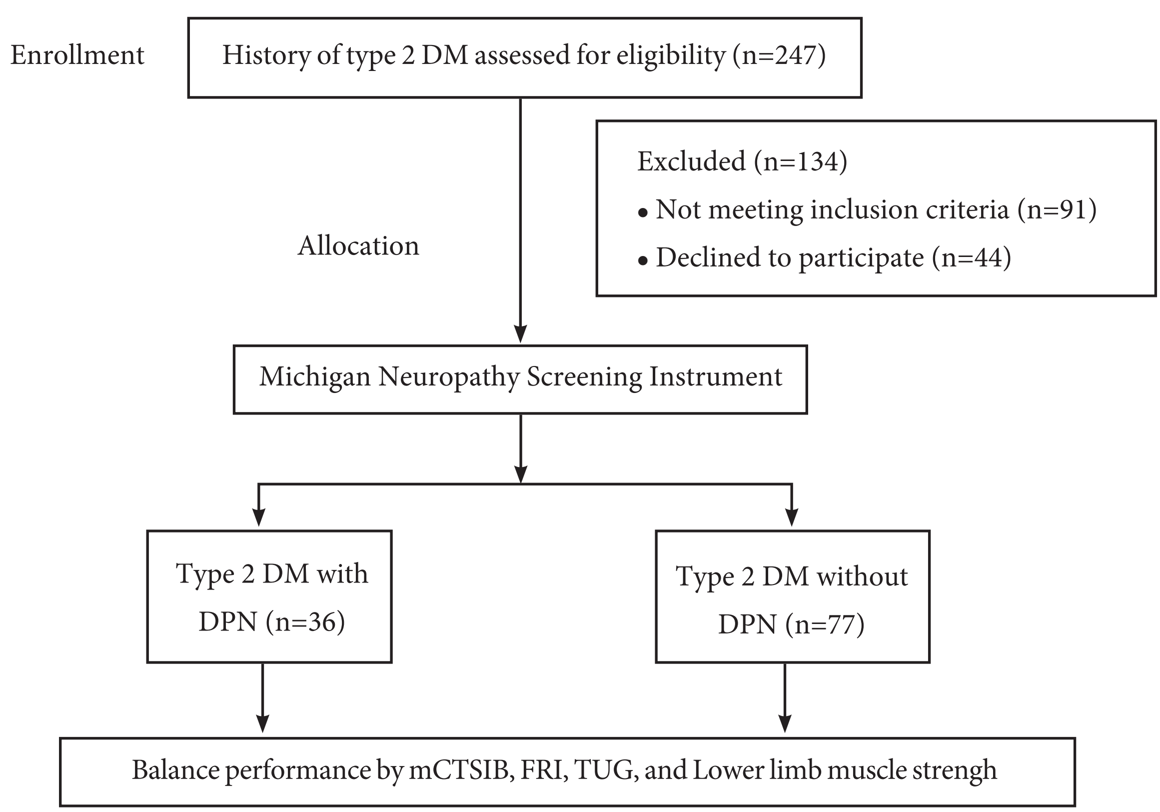

Fig 1. Flow of Participants

Procedures

An experienced physical therapist recruited and screened all participants. The data collection was undertaken by four physical therapists trained by the investigators. A handout for interview and assessment protocols was used to ensure the consistency. Before collecting data, the reliability was monitored using the participants aged 60 and over. A minimum of 0.75 was achieved for the values of Intraclass Correlation Coefficient (ICC) intertester and intratester reliability for all tests.

Participants' information regarding age, sex, history of type 2 DM and duration of DM exposure were recorded. Venous blood was drawn on the day of testing to determine fasting blood sugar (FBS) and hemoglobin A1c (HbA1c).

History of falls within the previous six months based on participant recollection was monitored. Falls was defined as an event resulting to a person coming to rest inadvertently on the ground or floor or other lower level.[16] The Thai version of the Montreal cognitive assessment (MOCA) was used for screening cognitive impairment. This tool had good criterion validity and good internal consistency (cronbach's alpha = 0.914).[17]

The Michigan Neuropathy Screening Instrument (MNSI) Thai version, was used to identify DPN.[18] This instruments has good test-retest reliability (ICC=0.830) and intertester reliability (ICC=0.780-0.869).[18] Positive DPN was determined in cases scoring greater than 2 of 8 of the physical examination part, not including the monofilament test.[19]

Balance performances were evaluated by the modified Clinical Test of Sensory Interaction and Balance (mCTSIB), Functional Reach Test (FRT) and TUG test. The procedures of all measurements were also described as following.

The mCTSIB involves observing a participant's attempt to maintain static balance for 30 seconds. Participants were asked to stand with feet together and hands at sides in four conditions including eyes open (EO) on a firm surface, eyes closed (EC) on a firm surface, EO on a foam surface, and EC on a foam surface. The foam was medium density, 24 inches in width and length and 4 inches in height (SunMate Dynamic System Inc., Leicester, USA). Three trials were performed under each condition.[20] The participants were allowed 60 seconds rest between each condition to diminish the effects of fatigue. Sway was defined as inability to stand with feet together, moving upper extremity, opening eyes, flexing one or both knees, toes, or heels raised from the floor and attempting to hold onto the tester during test execution. This test had good interrater agreements (Kappa = 0.57-0.72).[21]

For the FRT, barefoot participants stood with their right side close to a wall. The feet were apart at shoulder width. The right shoulder was flexed at 90 degrees with the elbow extended. The 3rd metacarpal bone was the landmark used to measure the distance between starting and ending points. The participants were asked to reach forward as far as possible without taking a step. They were allowed to practice once and performed the FRT twice. The reaching distance comprised the averaged value.[22] The FRT had been reported excellent test-retest reliability (ICC=0.89-0.92) in community dwelling older adults.[23]

For the TUG, the participants sat on a 46-cm height armchair with their back contacting the chair back support. They were asked to stand up, walk 3 meters as quickly and safely as possible, turn around, walk back and sit down. They were allowed to use a gait assistive device as preferred. The timing was started at the instruction "go" and stopped when the participants sat with their back touching back support. They performed the TUG twice, as a practice session and the latter as the test.[24] This test has been reported excellent test-retest reliability (ICC = 0:96-0.98).[25]

For muscle strength, knee extensors, knee flexors, ankle plantar flexors and ankle dorsiflexors were measured using a hand-held dynamometer (Lafayette Instrument Company, IN, USA). All muscle groups were tested in midrange of joint motion. One practice trial was given before measuring each movement. The average of three trials was recorded.

Statistical analysis

Statistical analysis was performed using SPSS version 18 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov Goodness of Fit test was used to test the distribution of the data. Demographic data and health information were compared between groups. The Mann-Whitney U test was used to examine differences of non-normal distributed data, while the independent t-test was used to determine differences of the normal distributed data. The value of $p<0.05$ was considered statistically significant.

The univariate logistic regression model was constructed to identify the association between DPN and the history of falls among ODM. The association of categorical independent variables with balance impairment was assessed using the Chi-square test, and the calibration was performed using the Hosmer-Lemeshow goodness of fit test. Discrimination was determined using the area under the receiver operating characteristics (AUROC) to evaluate overall predictive accuracy of the model.

RESULTS

The characteristics of participants with and without DPN are presented in Table 1. They did not differ in terms of age, proportion of sex, duration of DM, levels of FBS and HbA1C and cognitive function scores. The overall prevalence of falls among ODM was 17.7%. The prevalence of falls in the groups with and without DPN was 30.6% and 11.7%, respectively (Table 1). Statistically, the DPN had contribution on the fall occurrences among ODM with Odds ratio of 3.46 (95% CI: 1.28-9.38, p = 0.015) with the AUROC value of 0.645.

Differences between ODM with and without DPN were observed in two conditions of the mCTSIB, eye close on a firm surface ($p < 0.001$) and eye close on a foam surface ($p = 0.039$), as well as the FRT ($p = 0.022$) and TUG ($p< 0.001$) (Table 2). Of all lower limb muscles tested, only knee extensors strength differed between groups ($p = 0.031$) (Table 2).

DISCUSSION

This study aimed to explore the contribution of DPN on the occurrence of falls and to compare the balance performances and lower limb strengths among ODM with and without DPN. The results showed that DPN was a contributing factor of the history of falls. Poorer balance performances and less knee extensor strength were also observed among ODM with DPN compared with those without DPN.

The history of falls within the previous six months differed between ODM with and without DPN. Statistically, DPN was a significant predictor of falls. ODM with DPN had the odds of having history of falls 3.46 times more than the odds for ODM without DPN with 64.5% prediction accuracy. The results agreed with a previous longitudinal study reporting higher falls occurrences among older adults with neuropathy compared with a matched nonneuropathy group.[26] Other than DPN, patients with diabetes usually developed retinopathy, vestibular dysfunction, cognitive impairment and hypoglycemic events with insulin use which might also contribute to falls.[4] However, the participants in our study had normal visual acuity, no cognitive impairment and did not complain of vertigo and dizziness. Therefore, falls prevalence and balance impairment would be associated with their DPN condition. The phenomenon of increased falls also reportedly presented 3 to 5 years before the neuropathy diagnosis and worsened rapidly over time, rising from 23 to 56% over the course of a longitudinal study.[26] Thus, falls is a crucial problem which should be addressed in the management plan of ODM.

TABLE 1. Characteristics of older adults with type 2 DM with and without DPN (n=113).

Parameters		DPN Yes (n=36)	DPN No (n=77)
Age (years)		70.42 ± 5.96	68.42 ± 7.10
Sex:	male	12 (33.3%)	21 (27.3%)
	female	24 (66.7%)	56 (72.7%)
Duration of DM (years)		12.44 ± 6.39	10.68 ± 5.98
FBS (mg/dL)		153.78 ± 64.95	141.38 ± 40.86
HbA1C (%)		8.10 ± 1.63	7.50 ± 1.43
MOCA		20.22 ± 4.329	18.69 ± 3.345
History of falls:	Yes	11 (30.6%)	9 (11.7%)
	No	25 (69.4%)	68 (88.3%)

Values are presented as mean ± standard deviation or numbers and percentage. *p-value <0.05 significant difference pairwise comparison without DPN group.

Abbreviations: DM, diabetes mellitus; DPN, diabetic peripheral neuropathy; FBS, fasting blood sugar; HBA1c, hemoglobin A1c (glycated hemoglobin); MOCA, Montreal cognitive assessment score

TABLE 2. Lower limb muscle strength and balance performance among older adults with Type 2 DM with and without DPN (n=113).

Parameters	DPN	
	Yes (n=36)	No (n=77)
Muscle strength (kg)		
Knee extensors	15.01 ± 5.02*	16.93 ± 5.07
Knee flexors	11.06 ± 2.94	10.92 ± 3.36
Ankle plantar flexors	15.51 ± 3.57	16.90 ± 4.87
Ankle dorsiflexors	11.33 ± 2.88	11.78 ± 3.26
Balance performance		
mCTSIB (s)		
Condition 1	28.72 ± 4.90	29.91 ± 0.75
Condition 2	22.39 ± 11.26**	28.93 ± 4.47
Condition 3	22.37 ± 11.37	25.44 ± 8.43
Condition 4	10.15 ± 11.75*	14.63 ± 11.92
FRT (inches)	8.99 ± 2.79*	10.38 ± 3.06
TUG (s)	16.14 ± 6.59**	11.76 ± 3.45

Values are presented as mean ± standard deviation. *p-value <0.05 significant difference pairwise comparison without DPN group. **p-value <0.001 significant difference pairwise comparison without DPN group.
Abbreviations: DM, diabetes mellitus; DPN, diabetic peripheral neuropathy; mCTSIB, modified Clinical Test of Sensory Interaction and Balance; FRT, Functional Reach Test; TUG, Timed Up and Go Test.

Sensory impairment and lower limb muscle weakness are possibly the underlying causes of increased falls in DPN. Somatosensory, visual function and vestibular inputs play an important role in balance control.[27] Due to impaired somatosensory and motor outputs, patients with DPN demonstrated postural instability and gait imbalance leading to higher fall incidence.[9,28] The nerve damage in DPN is characterized by the development of vascular abnormalities with a subsequent decline in oxygen tension and hypoxia.[11] The mutilation progressively alters the sensory and autonomic axons, and later the motor axons, leading to sensory, autonomic as well as motor losses.[11] Other than falls, patients with DPN could also injure themselves from the reduced sensitivity of touch and pain leading to foot ulceration, which could become infected and lead to amputation.[10] However, the diagnosis of DPN is often delayed by the fact that neuropathy often develops slowly over time.[26] Consistent monitoring of glycemic control and the complications are therefore crucial concerns in ODM.

The ODM with DPN in this study also exhibited less knee extensor strength compared with those without DPN. The declined muscle strength of the knee and ankle were reported among people with T2DM with and without DPN compared with the nonDM control group.[29] The isometric performance of the knee extensors was also suggested to be an assessment for fall risk among ODM.[30]

Poorer static and functional balance was observed among ODM with DPN identified by mCTSIB, FRT and TUG. These impairments might also contribute to the increased prevalence of falls in this study. During the mCTSIB, differences in dependency on sensory inputs were identified, i.e., somatosensory during EO and EC on a foam surface,[31] visual during EC on firm and foam surfaces[32] and vestibular by EC standing on a foam surface.[33] ODM were found to be somatosensory dependent because they presented impaired postural control during somatosensory disruption[34,35] while ODM with DPN lost their balance during deprived visual input.[34] Our results implied an assumption similar to related studies,[34,36] i.e., ODM with DPN were visual dependent because they tended to rely more on visual inputs to compensate for their declined somatosensory inputs. These patients might be able to achieve acceptable postural control using an appropriate compensatory strategy.[37] However, in cases of the other sensory input limitations such as dim light, an irregular trail or presenting of retinopathy and vestibulopathy, the risk of fall among these patients would be even higher.

The static balance reflected by the FRT significantly differed between ODM with and without DPN. Lower FRT values were observed among ODM with somatosensory impairment.[38] The sensory threshold of hallux was reported to be a predictor of reach distance and center of mass displacement among patients with DM.[38] Considering the manner of FRT performance, the strength of lower limb muscles would also influence the test results. In this study, knee extensor muscle strength was reduced among ODM with DPN. The ankle plantar flexors, reported to significantly contribute to the center of mass displacement during forward reach, also had a trend of decreased strength among ODM with DPN.[38]

In this study, the TUG significantly differed between groups. The TUG is a gait-based functional test with the purpose to measure mobility, balance, walking ability, locomotor performance and falls risk among older people.[24] In addition to the reduced proprioception, the dynamic balance impairment among the participants with DPN might have been associated with lower limb muscle weakness reflected by the reduced strength of knee extensors. The correlation of TUG and knee extensor muscle strength has been highlighted among older people.[35]

In conclusion, this study presented the contribution of DNP on higher fall occurrence among ODM with DPN. The poorer performances of static and dynamic balance as well as less knee extensor strength were also found among ODM with DPN. The results suggested that clinicians should systematically monitor and control these impairments as an approach to prevent falls among ODM.

This study had some limitations. The fall occurrence data in this study was based on the interviews. Recall bias is likely especially regarding self-reported falls among ODM. Other factors reported to affect balance and falls in DM including body mass index, medications, depression and fear of falling were not assessed. We also did not monitor the occurrence of hypoglycaemia and the severity of the neuropathic pain. These DM associated conditions were postulated to lead to falls among individuals with DM due to their effects on the attention deficit, slow psychomotor speed as well as orthostatic hypotension.

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