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Cut-Off Point of the Unipedal Stance Test for Detecting Diabetic Peripheral Neuropathy in Patients with Type 2 Diabetes Mellitus

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ABSTRACT

Diabetic peripheral neuropathy (DPN) is a common chronic complication of diabetes mellitus that may impair postural control and increase the risk of falls. The Unipedal Stance Test (UPST) is a simple clinical measure of static balance, but its ability to identify DPN according to leg dominance and visual condition requires further evaluation. This study aimed to determine the differences and cut-off points of UPST performed on the dominant and non-dominant legs with eyes open and closed in patients with type 2 diabetes mellitus (T2DM) with and without DPN. A cross-sectional study was conducted at Hasan Sadikin Hospital, Bandung, Indonesia, from May to July 2013, involving 62 patients with T2DM aged 41–60 years. DPN was assessed using the Diabetic Neuropathy Examination (DNE), with a total score >3 indicating DPN and ≤3 indicating no DPN. Static balance was assessed using the UPST on both the dominant and non-dominant legs under eyes-open and eyes-closed conditions. Receiver operating characteristic (ROC) curve analysis was used to determine the UPST cut-off points, followed by chi-square analysis to evaluate differences between patients with and without DPN. The ROC-derived cut-off points were 42.64 seconds for the dominant leg and 30.52 seconds for the non-dominant leg with eyes open, and 6.32 seconds and 5.35 seconds, respectively, with eyes closed. UPST performance with eyes closed showed significant differences between patients with and without DPN for both the dominant leg (p=0.029) and non-dominant leg (p=0.021), whereas no significant differences were observed under the eyes-open condition for either the dominant leg (p=0.347) or non-dominant leg (p=0.219). The prevalence ratios for DPN were 2.84 (95% CI, 1.09–7.38) for the dominant leg and 2.42 (95% CI, 1.19–4.92) for the non-dominant leg under the eyes-closed condition. In conclusion, UPST performed with the eyes closed demonstrated a significant difference between patients with and without DPN, with cut-off points of 6.32 seconds for the dominant leg and 5.35 seconds for the non-dominant leg. These findings suggest that the eyes-closed UPST may be useful as a simple clinical assessment of static balance associated with DPN in patients with T2DM.

Keywords: *Diabetic Peripheral Neuropathy; Type 2 Diabetes Mellitus; Unipedal Stance Test; Static Balance; Postural Balance; Cut-Off Point*

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder associated with progressive microvascular and macrovascular complications that can substantially affect

physical function, independence, and quality of life. Among the chronic complications of diabetes, diabetic peripheral neuropathy (DPN) is particularly important because it affects the peripheral nervous system and may impair sensory and motor function, especially in the lower extremities (Savelieff et al., 2025; Zhu et al., 2024). Peripheral nerve dysfunction can interfere with the ability to perceive and integrate sensory information required for postural control and may consequently contribute to impaired balance and increased risk of falls. The clinical burden of diabetes-related complications remains substantial in Indonesia, including among patients receiving care at tertiary referral hospitals (Hasan et al., 2024).

Evidence from Dr. Hasan Sadikin General Hospital (RSHS), Bandung, illustrates the substantial burden of complications among patients receiving diabetes care in a tertiary setting. In a study published in 2022, 809 adult patients with diabetes were recruited from 25 community health centers and the outpatient clinic of a referral hospital in Bandung, with 491 patients (61%) recruited from the hospital. Among the overall study population, 98% had T2DM and the median HbA1c was 8.3% (Permana et al., 2022). Glycemic control and management of diabetes complications were reported to require considerable improvement. The study therefore provides evidence that patients treated in the tertiary-care setting in Bandung represent a clinically complex population with a substantial burden of diabetes-related complications.

More recent evidence further demonstrates the clinical importance of diabetes-related complications in Bandung. A 2025 cross-sectional study involving 369 adults with T2DM recruited from primary, secondary, and tertiary healthcare facilities in Bandung found that multiple complications were particularly common among patients receiving secondary and tertiary care, occurring in 62.5% and 63.3% of patients, respectively. Importantly, the presence of diabetes-related complications was significantly associated with poorer quality of life, with patients having one complication showing an adjusted odds ratio of 4.118 (95% CI, 1.567–10.827) for poor quality of life (Ritonga et al., 2025). Although this study was conducted across different healthcare levels and therefore does not provide an RSHS-specific prevalence of DPN, it demonstrates the continuing functional and quality-of-life burden associated with diabetes complications in the Bandung population.

Among the complications of diabetes, DPN is particularly relevant to physical and functional performance because peripheral nerve dysfunction can affect sensory input, motor control, and postural regulation. Impairment of sensory information from the lower extremities may reduce the ability to detect changes in body position and maintain the center of mass within the base of support (Le Corre et al., 2023). Motor involvement may further compromise lower-extremity muscle activation and the motor responses required to correct postural disturbances. Thus, the consequences of DPN extend beyond sensory symptoms and may manifest as impaired balance, reduced mobility, and greater difficulty performing activities that require postural stability. The relationship between peripheral nerve dysfunction and balance performance has also been demonstrated objectively. In older adults with diabetes, lower-limb nerve conduction velocity showed moderate-to-strong correlations with several functional balance measures, including the unipedal stance

test (UST), and patients with DPN demonstrated poorer UST performance than those without DPN (Buckley et al., 2025).

Balance depends on the integration of information from the somatosensory, visual, and vestibular systems and the generation of appropriate motor responses (Guzmán-Muñoz et al., 2026). The somatosensory system provides information regarding body position and movement, while visual input provides an important external reference for maintaining postural orientation. When peripheral sensory information is impaired, as may occur in DPN, individuals may rely more heavily on visual information to maintain postural stability. Consequently, balance performance may appear relatively preserved when visual information is available but become more impaired when visual input is removed. Assessment under different visual conditions may therefore provide additional information regarding the functional consequences of peripheral sensory impairment.

The ability to maintain a single-leg stance is particularly relevant to functional balance because many everyday activities require temporary support on one lower extremity. Single-leg balance is involved in activities such as stepping, changing direction, stair negotiation, and dressing, and it becomes especially challenging when sensory information is reduced. The Unipedal Stance Test (UPST), also referred to as the unipedal or single-leg stance test, is a simple clinical measure of static balance that requires minimal equipment and can be completed in a short period (Čeklić et al., 2022). The test records the duration for which an individual can maintain a single-leg stance and can be performed with the eyes open or closed. Its simplicity makes it potentially useful in clinical settings where more sophisticated posturographic or laboratory-based assessments are not readily available.

The clinical relevance of the UPST in patients with diabetes has been supported by previous research. Studies evaluating balance in people with diabetes have demonstrated poorer unipedal stance performance among individuals with peripheral neuropathy compared with those without neuropathy (Richardson et al., 2025). In addition, a systematic review and meta-analysis of exercise interventions in patients with DPN used the unipedal stance test with both eyes-open and eyes-closed conditions as an outcome measure, supporting its continued use as a clinically relevant measure of balance in this population (Bijapuri et al., 2026). Nevertheless, the ability of UPST performance to distinguish patients with and without DPN may depend on how the test is performed, particularly with respect to visual condition and the limb used for testing.

Visual condition is an important consideration because the removal of visual input places greater demands on the somatosensory and vestibular systems for postural control. In patients with impaired peripheral sensation, eyes-closed testing may therefore expose balance deficits that are partially compensated for when the eyes are open (Talha et al., 2023). This distinction is clinically meaningful because patients do not always encounter optimal visual conditions during daily activities. Balance may need to be maintained in environments with reduced illumination or when visual information is temporarily unavailable. Assessing single-leg stance under both eyes-open and eyes-closed conditions

may consequently provide a more comprehensive evaluation of the relationship between peripheral sensory impairment and static balance.

Another consideration is lower-limb dominance. The dominant leg is commonly identified as the leg preferentially used for a task such as kicking a ball, and lower-limb dominance may influence the performance of single-leg stance. The contribution of the dominant and non-dominant legs to postural control may not necessarily be equivalent. Therefore, examining only one side may not fully characterize single-leg balance performance in patients with DPN. Evaluating both the dominant and non-dominant legs may provide additional information regarding whether the relationship between peripheral neuropathy and balance is consistent across the tested limbs (Vasilj et al., 2026).

Although previous research has established an association between peripheral neuropathy and impaired balance, an important clinical question remains regarding the threshold of UPST performance that may indicate an increased likelihood of DPN (Akbar et al., 2023; K Anastasi & Capili, 2022). A continuous measurement of standing time provides information about balance performance, but a clinically defined cut-off point may be more readily applicable for screening purposes. Determining such a threshold requires comparison of UPST performance between patients with and without DPN and identification of the value that best discriminates between the two groups. Receiver operating characteristic (ROC) analysis provides a method for determining a cut-off point based on the ability of a continuous clinical measurement to distinguish between predefined clinical groups.

The present study was therefore designed to investigate UPST performance in patients with T2DM with and without DPN and to determine whether performance differs according to visual condition and lower-limb dominance. DPN was clinically classified using the Diabetic Neuropathy Examination (DNE), while static balance was assessed using the UPST performed on both the dominant and non-dominant legs under eyes-open and eyes-closed conditions. The study specifically sought to determine the cut-off points of UPST performance for identifying DPN under each testing condition. By examining visual condition and limb dominance simultaneously, this study aimed to clarify whether the simple and clinically feasible UPST could provide useful information for the assessment of balance impairment associated with DPN in patients with T2DM.

METHOD

This cross-sectional analytical observational study was conducted at the Endocrinology Outpatient Clinic of the Department of Internal Medicine and the Gymnasium of the Department of Physical Medicine and Rehabilitation, Hasan Sadikin General Hospital, Bandung, Indonesia. The study included 62 patients with type 2 diabetes mellitus (T2DM) aged 41–60 years.

Participants were eligible if they had T2DM, were able to stand and walk independently without an assistive device, and were able to understand and follow the examination instructions. Patients were excluded if they had hypoglycemia, a history of stroke or severe head injury, were taking sedative medication, had visual impairment that

could not be corrected, had a vestibular disorder, or had musculoskeletal abnormalities of the lower extremities that could affect balance performance. All participants provided written informed consent before undergoing the study procedures. The study was conducted in accordance with the principles of research involving human participants and received approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Padjadjaran–Dr. Hasan Sadikin General Hospital, Bandung.

Diabetic peripheral neuropathy (DPN) was assessed using the Diabetic Neuropathy Examination (DNE). The DNE evaluates motor function, deep tendon reflexes, and sensory function. Motor assessment included examination of the quadriceps femoris and tibialis anterior muscles, while the Achilles tendon reflex was assessed as the deep tendon reflex. Sensory examination included pain sensation in the second toe and pain, touch, vibration, and joint-position sensation in the great toe. Each item was scored as 0 (normal), 1 (reduced), or 2 (absent or severely impaired), with a maximum total score of 16. Participants with a total DNE score >3 were classified as having DPN, whereas those with a score ≤3 were classified as having no DPN. Leg dominance was determined by asking participants which leg they naturally used to kick a ball. The leg used to kick the ball was classified as the dominant leg, while the opposite leg was classified as the non-dominant leg.

Static postural balance was assessed using the Unipedal Stance Test (UPST). The test was performed barefoot on a level surface with the participant's arms crossed over the chest. Each participant was assessed under four conditions: (1) dominant leg with eyes open, (2) non-dominant leg with eyes open, (3) dominant leg with eyes closed, and (4) non-dominant leg with eyes closed. The participant was instructed to lift one foot from the floor and maintain a stable one-leg stance. Timing began when the non-supporting foot was lifted from the floor. The test was terminated when the lifted foot touched the floor or the opposite leg, when the supporting foot moved to establish a new base of support, when the participant opened the eyes during the eyes-closed condition, when the arms were moved from the crossed position, or when the maximum testing time of 45 seconds was reached. A 3-minute rest interval was provided between successive trials to minimize fatigue. The UPST performance was recorded in seconds, with longer standing times indicating better static balance performance.

Participant characteristics and study variables were summarized using descriptive statistics, including means, standard deviations, medians, and minimum–maximum values, as appropriate. The Kolmogorov–Smirnov test was used to assess the normality of numerical data. Because UPST performance did not follow a normal distribution, comparisons of UPST performance between participants with and without DPN were performed using the Mann–Whitney U test. DPN status was defined according to the DNE threshold, with a score >3 indicating DPN and a score ≤3 indicating no DPN. Receiver operating characteristic (ROC) curve analysis was performed to determine the UPST cut-off points for identifying DPN for each leg and visual condition. After categorization according to the derived cut-off points, differences in the proportion of participants with and without DPN were evaluated using the chi-square test. Prevalence ratios (PRs) and their 95% confidence intervals (CIs) were calculated where appropriate. All statistical analyses were

performed using SPSS for Windows. Statistical significance was defined as a two-sided p-value ≤0.05, with a 95% confidence level.

FINDING AND DISCUSSION

RESEARCH RESULT

A total of 62 patients with type 2 diabetes mellitus (T2DM) were included in the analysis. The mean age of the participants was 52.58 ± 5.60 years, with an age range of 41–60 years. Women accounted for 46 participants (74.2%), while 16 (25.8%) were men. The mean duration of diabetes was 69.98 ± 56.38 months, with a mean body mass index (BMI) of 25.78 ± 4.00 kg/m². Most participants had a history of good glycemic control (42, 67.7%), whereas 20 (32.3%) had a history of poor glycemic control. A history of hypercholesterolemia was reported in 44 participants (71.0%), and 21 (33.9%) had a history of smoking. Most participants were physically inactive (42, 67.7%). The right leg was identified as the dominant leg in 61 participants (98.4%), while only one participant (1.6%) had the left leg as the dominant leg. Based on the DNE assessment, the mean DNE score was 3.27 ± 2.87, with a median score of 2.50 and a range from 0 to 12. Using the predefined DNE threshold, 22 participants (35.5%) had DPN (DNE >3), whereas 40 (64.5%) were classified as having no DPN (DNE ≤3).

The 22 participants with DPN and 40 participants without DPN were comparable with respect to the measured demographic and clinical characteristics. The mean age was 53.77 ± 5.70 years in the DPN group and 51.93 ± 5.51 years in the non-DPN group (p=0.154). Mean BMI was 25.85 ± 4.30 kg/m² and 25.74 ± 3.88 kg/m², respectively (p=0.982), while the mean duration of diabetes was 66.82 ± 40.86 months in the DPN group compared with 71.72 ± 63.75 months in the non-DPN group (p=0.791).

Table 1. Comparison of Participant Characteristics According to DPN Status

Variable	DPN (n=22)	No DPN (n=40)	p-value
Age, years, mean ± SD	53.77 ± 5.70	51.93 ± 5.51	0.154
BMI, kg/m², mean ± SD	25.85 ± 4.30	25.74 ± 3.88	0.982
Duration of diabetes, months, mean ± SD	66.82 ± 40.86	71.72 ± 63.75	0.791
Male, n (%)	7 (31.8)	9 (22.5)	0.422
Female, n (%)	15 (68.2)	31 (77.5)	
Good glycemic control, n (%)	13 (59.1)	29 (72.5)	0.280
Poor glycemic control, n (%)	9 (40.9)	11 (27.5)	
Hypercholesterolemia, n (%)	18 (81.8)	26 (65.0)	0.163
No hypercholesterolemia, n (%)	4 (18.2)	14 (35.0)	
Smoking history, n (%)	10 (45.5)	11 (27.5)	0.153
No smoking history, n (%)	12 (54.5)	29 (72.5)	
Active physical activity, n (%)	6 (27.3)	14 (35.0)	0.533
Inactive physical activity, n (%)	16 (72.7)	26 (65.0)	

Continuous variables were analyzed using the Mann–Whitney U test and categorical variables using the chi-square test.

The distribution of categorical characteristics was also not significantly different between the groups. Men accounted for 31.8% of the DPN group and 22.5% of the non-DPN group (p=0.422). Good glycemic control was reported in 59.1% of participants with DPN and 72.5% of those without DPN (p=0.280). Hypercholesterolemia was present in 81.8% and 65.0% of the respective groups (p=0.163). A history of smoking was reported by 45.5% of participants with DPN and 27.5% of those without DPN (p=0.153), while physical inactivity was observed in 72.7% and 65.0%, respectively (p=0.533). Thus, none of the measured baseline characteristics differed significantly between participants with and without DPN.

UPST performance varied substantially according to visual condition. With eyes open, the mean UPST duration was 37.69 ± 13.37 seconds on the dominant leg and 37.37 ± 13.37 seconds on the non-dominant leg. The median performance for both legs was 45 seconds, corresponding to the maximum testing duration. When the test was performed with eyes closed, UPST performance was considerably shorter. The mean duration was 8.67 ± 7.77 seconds on the dominant leg and 6.88 ± 5.22 seconds on the non-dominant leg. The median values were 5.69 seconds and 5.43 seconds, respectively. The observed ranges were 1.54–40.59 seconds for the dominant leg and 0.99–29.81 seconds for the non-dominant leg.

Table 2. UPST Performance in the Overall Study Population

UPST condition	Mean ± SD (seconds)	Median (range), seconds
Dominant leg, eyes open	37.69 ± 13.37	45.00 (3.19–45.00)
Non-dominant leg, eyes open	37.37 ± 13.37	45.00 (2.90–45.00)
Dominant leg, eyes closed	8.67 ± 7.77	5.69 (1.54–40.59)
Non-dominant leg, eyes closed	6.88 ± 5.22	5.43 (0.99–29.81)

UPST performance was compared between participants with and without DPN for each combination of leg dominance and visual condition. With eyes open, the mean UPST duration on the dominant leg was 35.03 ± 15.71 seconds in participants with DPN and 39.16 ± 11.86 seconds in those without DPN. The corresponding median values were both 45 seconds, with ranges of 3.19–45.00 seconds and 5.68–45.00 seconds, respectively. The difference was not statistically significant (p=0.639). Similarly, for the non-dominant leg with eyes open, mean UPST duration was 36.81 ± 14.00 seconds in the DPN group and 37.68 ± 13.18 seconds in the non-DPN group. Median values were again 45 seconds in both groups, and the difference was not statistically significant (p=0.390).

A different pattern emerged when visual input was removed. With eyes closed, participants with DPN demonstrated substantially shorter UPST durations than those without DPN, suggesting greater difficulty maintaining postural stability in the absence of visual compensation. On the dominant leg, the mean UPST duration was 5.67 ± 3.58 seconds in the DPN group compared with 10.33 ± 8.93 seconds in the non-DPN group, with median values of 4.54 and 7.43 seconds, respectively (p=0.019). Similarly, on the non-dominant leg, the mean duration was 5.17 ± 3.92 seconds in the DPN group versus 7.81 ± 5.64 seconds in the non-DPN group, with median values of 4.22 and 6.32 seconds, respectively (p=0.029).

These findings indicate that the presence of DPN was associated with reduced single-leg postural endurance, particularly when visual feedback was unavailable.

Table 3. UPST Performance According to DPN Status

UPST condition	DPN (n=22)	No DPN (n=40)	p-value
Dominant leg, eyes open			
Mean ± SD, s	35.03 ± 15.71	39.16 ± 11.86	0.639
Median (range), s	45.00 (3.19–45.00)	45.00 (5.68–45.00)	
Non-dominant leg, eyes open			
Mean ± SD, s	36.81 ± 14.00	37.68 ± 13.18	0.390
Median (range), s	45.00 (2.90–45.00)	45.00 (3.61–45.00)	
Dominant leg, eyes closed			
Mean ± SD, s	5.67 ± 3.58	10.33 ± 8.93	0.019
Median (range), s	4.54 (2.15–15.71)	7.43 (1.54–40.59)	
Non-dominant leg, eyes closed			
Mean ± SD, s	5.17 ± 3.92	7.81 ± 5.64	0.029
Median (range), s	4.22 (0.99–19.16)	6.32 (1.75–29.81)	

Mann–Whitney U test. Statistically significant at p≤0.05.

ROC curve analysis yielded distinct UPST cut-off values for each leg and visual condition. For the dominant leg, the cut-off was 42.64 seconds with eyes open and 6.32 seconds with eyes closed. For the non-dominant leg, the corresponding cut-offs were 30.52 seconds with eyes open and 5.35 seconds with eyes closed.

These thresholds were subsequently used to categorize UPST performance and examine its association with DPN status. For the dominant leg with eyes open, 10 participants with DPN (45.5%) had UPST values ≤42.64 seconds, compared with 12 (30.0%) without DPN. Among those with UPST >42.64 seconds, 12 participants with DPN (54.5%) and 28 without DPN (70.0%) were identified. The association was not statistically significant (p=0.347; PR 1.52, 95% CI 0.78–2.93).

For the non-dominant leg with eyes open, 7 participants with DPN (53.8% of those with UPST ≤30.52 seconds) and 6 participants without DPN (46.2%) were classified below the cut-off. Among those with UPST >30.52 seconds, 15 participants with DPN (30.6%) and 34 without DPN (69.4%) were observed. The difference was also not statistically significant (p=0.219; PR 1.76, 95% CI 0.91–3.39).

The eyes-closed condition demonstrated stronger associations with DPN. For the dominant leg, 18 of 38 participants (47.4%) with UPST ≤6.32 seconds had DPN, compared with 4 of 24 participants (16.7%) with UPST >6.32 seconds. The prevalence ratio was 2.84 (95% CI 1.09–7.38), with a statistically significant association (p=0.029).

For the non-dominant leg, 14 of 26 participants (53.8%) with UPST ≤5.35 seconds had DPN, compared with 8 of 36 participants (22.2%) whose UPST exceeded 5.35 seconds. The prevalence ratio was 2.42 (95% CI 1.19–4.92), and the association was statistically significant (p=0.021).

Table 4. ROC-Derived UPST Cut-offs and Association with DPN

UPST condition	Cut-off (seconds)	DPN, n (%)	No DPN, n (%)	p-value	PR (95% CI)
Dominant leg, eyes open	≤42.64	10 (45.5)	12 (54.5)	0.347	1.52 (0.78–2.93)
Dominant leg, eyes open	>42.64	12 (30.0)	28 (70.0)		
Non-dominant leg, eyes open	≤30.52	7 (53.8)	6 (46.2)	0.219	1.76 (0.91–3.39)
Non-dominant leg, eyes open	>30.52	15 (30.6)	34 (69.4)		
Dominant leg, eyes closed	≤6.32	18 (47.4)	20 (52.6)	**0.029**	**2.84 (1.09–7.38)**
Dominant leg, eyes closed	>6.32	4 (16.7)	20 (83.3)		
Non-dominant leg, eyes closed	≤5.35	14 (53.8)	12 (46.2)	**0.021**	**2.42 (1.19–4.92)**
Non-dominant leg, eyes closed	>5.35	8 (22.2)	28 (77.8)		

PR, prevalence ratio; CI, confidence interval. Chi-square test.

Across the four UPST conditions, the findings showed a consistent difference according to visual condition. Eyes-open testing did not significantly distinguish participants with DPN from those without DPN, regardless of whether the dominant or non-dominant leg was tested. In contrast, eyes-closed testing demonstrated significantly shorter standing times among participants with DPN on both the dominant and non-dominant legs. The ROC-derived thresholds were 6.32 seconds for the dominant leg and 5.35 seconds for the non-dominant leg under the eyes-closed condition, and both thresholds were significantly associated with DPN. The corresponding prevalence ratios were 2.84 and 2.42, respectively.

DISCUSSION

The present study evaluated the performance of the Unipedal Stance Test (UPST) on the dominant and non-dominant legs under eyes-open and eyes-closed conditions in patients with type 2 diabetes mellitus (T2DM), with particular emphasis on its ability to distinguish patients with and without diabetic peripheral neuropathy (DPN). The principal finding was that UPST performance with the eyes closed significantly differed between participants with and without DPN, whereas no significant difference was observed under the eyes-open condition. The ROC-derived cut-off points were 6.32 seconds for the dominant leg and 5.35 seconds for the non-dominant leg. These findings are consistent with contemporary evidence indicating that DPN is associated with impaired postural control. A systematic review by Khan & Andersen (2022), which evaluated 34 studies after quality assessment, concluded that diabetic neuropathy negatively affects postural balance and gait and is associated with increased fall risk. Research also emphasized that postural

instability represents an important functional consequence of diabetic neuropathy and that assessment of postural stability should be considered in clinical management and fall-prevention strategies (Kardm et al., 2025; Khurshid et al., 2025).

The significantly shorter UPST duration among participants with DPN under the eyes-closed condition provides an important functional interpretation of the present findings. For the dominant leg, the mean UPST duration was 5.67 ± 3.58 seconds in participants with DPN compared with 10.33 ± 8.93 seconds in those without DPN (p=0.019). For the non-dominant leg, the corresponding values were 5.17 ± 3.92 seconds and 7.81 ± 5.64 seconds (p=0.029). These results indicate that participants with clinically defined DPN had greater difficulty maintaining single-leg postural stability when visual information was removed. DPN can affect sensory information from the lower extremities, including information required for postural orientation and balance. Bhatt et al. described postural instability as a consistent functional problem in people with DPN and emphasized the contribution of sensory deficits to impaired postural control. Research also reported impairment across multiple balance measures, including single-leg stance, supporting the use of functional balance assessment (Jørgensen et al., 2023).

The importance of visual input in the present findings is particularly supported by the study of Irikeva et al. (2022), which directly examined postural stability in adults with T2DM with and without DPN under eyes-open and eyes-closed conditions. In their study, participants with DPN demonstrated significantly greater postural instability than participants without DPN while standing on a firm surface under the eyes-closed condition, whereas this difference was not observed under the eyes-open condition. The authors also reported greater visual dependence among individuals with diabetes. This pattern closely parallels the present results, in which the UPST significantly differentiated the DPN and non-DPN groups when the eyes were closed but not when the eyes were open.

The greater discriminatory value of the eyes-closed condition can be understood from the role of sensory integration in maintaining postural stability. When the eyes are open, visual information provides an important external reference for orientation and can help compensate for impaired sensory information from the feet and lower limbs. When the eyes are closed, this visual reference is removed, increasing dependence on other sensory systems involved in postural control. In individuals with DPN, impairment of peripheral sensory information may therefore become more apparent when visual compensation is unavailable. Bhatt et al. (2022) described DPN-related postural instability as a consequence of disturbances in the sensory and motor systems required for maintaining equilibrium, while Irikeva et al. (2022) demonstrated experimentally that visual conditions influence the degree to which postural instability becomes apparent in patients with DPN.

In contrast, neither the dominant nor non-dominant eyes-open UPST demonstrated a statistically significant difference between participants with and without DPN. The mean duration was 35.03 ± 15.71 seconds in participants with DPN and 39.16 ± 11.86 seconds in those without DPN for the dominant leg (p=0.639), while the corresponding values for the non-dominant leg were 36.81 ± 14.00 seconds and 37.68 ±

13.18 seconds (p=0.390). The availability of visual information may have allowed participants with DPN to compensate for impaired peripheral sensory input sufficiently to maintain single-leg stance. This interpretation is supported by (Irikeva et al., 2022; Lund et al., 2026; Ullah et al., 2025), who found that the difference in postural instability between T2DM participants with and without DPN was evident under the eyes-closed condition on a firm surface but not under the eyes-open condition. Their findings suggest that visual input may partially mask differences in postural control associated with DPN.

The absence of a significant difference under the eyes-open condition may also be related to the ceiling effect produced by the 45-second maximum duration of the UPST protocol. In the present study, the median UPST duration under the eyes-open condition was 45 seconds for both the dominant and non-dominant legs. Thus, participants who were capable of maintaining single-leg stance for longer than the maximum testing period were assigned the same recorded value. This limits the ability of the test to distinguish individuals with relatively good versus very good balance performance. Consequently, the lack of a statistically significant difference under the eyes-open condition should not be interpreted as evidence that DPN has no effect on postural control when vision is available. Rather, the finding may indicate that the eyes-open condition, combined with the 45-second ceiling, was insufficiently challenging to expose differences in balance associated with DPN.

The present results also fit within the broader evidence concerning the functional consequences of DPN. Khan & Andersen (2022) found that most studies included in their systematic review reported impaired postural stability in individuals with diabetic neuropathy, with additional evidence of altered gait and increased fall risk. They also noted that postural instability in DPN may be influenced by multiple factors, including sensory impairment, muscle weakness, impaired mobility, and structural or functional changes in the foot. This multifactorial perspective is important when interpreting the present UPST findings because a reduced single-leg stance time should not be considered a direct measurement of peripheral nerve function. Rather, it represents a functional manifestation of impaired postural control that may be influenced by the combined effects of neurological and musculoskeletal factors.

The ROC analysis identified cut-off points of 6.32 seconds for the dominant leg and 5.35 seconds for the non-dominant leg under the eyes-closed condition. These thresholds were clinically relevant because UPST performance at or below the respective cut-offs was significantly associated with a higher prevalence of DPN. For the dominant leg, an eyes-closed UPST of ≤6.32 seconds was associated with a prevalence ratio of 2.84 (95% CI, 1.09–7.38; p=0.029). For the non-dominant leg, an UPST of ≤5.35 seconds was associated with a prevalence ratio of 2.42 (95% CI, 1.19–4.92; p=0.021). Thus, participants who were unable to maintain single-leg stance beyond these thresholds had approximately two-to three-fold higher prevalence of clinically defined DPN. The findings provide a clinically interpretable relationship between reduced single-leg balance performance and DPN status and strengthen the potential usefulness of the eyes-closed UPST as a complementary functional assessment.

The cut-off values identified in the present study should, however, be interpreted as study-specific thresholds rather than universal diagnostic criteria. The existing 2022 literature supports the relationship between DPN and impaired postural control but does not establish a universally accepted UPST threshold for diagnosing DPN. Irikeva et al. (2022) used static posturography rather than UPST, while the reviews by Bhatt et al. (2022) and Khan & Andersen (2022) emphasized the heterogeneity of balance assessment methods used across studies. Consequently, the specific thresholds of 6.32 seconds and 5.35 seconds identified in the present study should be externally validated before they are applied to broader T2DM populations.

The difference between the dominant- and non-dominant-leg cut-off points also requires cautious interpretation. The dominant-leg threshold was 6.32 seconds, whereas the non-dominant-leg threshold was 5.35 seconds. Although this difference may suggest that the tested limb could influence the absolute UPST threshold, almost all participants in the present study were right-leg dominant, with only one participant classified as left-leg dominant. Therefore, the study does not provide sufficient evidence to establish an independent effect of leg dominance on UPST performance. The different thresholds should instead be considered findings specific to the two testing conditions in this sample. Future research involving a more balanced distribution of limb dominance would be necessary to determine whether dominant and non-dominant legs require different reference values in patients with DPN.

The clinical implications of the findings are relevant to rehabilitation practice because impaired balance is an important functional consequence of DPN. Khan & Andersen (2022) emphasized that postural instability and impaired gait in diabetic neuropathy are associated with increased fall risk and suggested that assessment of postural stability should form part of fall-prevention strategies. Similarly, Bhatt et al. (2022) highlighted the relevance of balance assessment and rehabilitation interventions in individuals with DPN, reporting that several balance measures, including single-leg stance, can be used to evaluate postural control and that physiotherapy interventions may improve balance performance. Within this context, the eyes-closed UPST may provide a practical functional assessment that can complement neurological examination by identifying patients whose peripheral sensory impairment is accompanied by measurable difficulty maintaining postural stability.

The potential clinical value of the eyes-closed UPST lies in its simplicity and low equipment requirements. A patient who demonstrates a markedly reduced stance time under the eyes-closed condition may warrant additional assessment of peripheral sensory function, gait, balance, and fall risk. This is particularly relevant because DPN may affect postural stability even when the patient does not report substantial functional limitations. However, the UPST should be performed under appropriate safety conditions, particularly when visual input is removed, because individuals with impaired sensory integration may be unable to maintain stability. The test should therefore be regarded as a complementary assessment rather than a substitute for a comprehensive neurological and functional examination.

The present study also has several limitations that should be considered when interpreting the results. First, the sample consisted of only 62 participants, which limits the precision and generalizability of the estimated cut-off points. Second, participants were restricted to the 41–60-year age range, limiting application of the findings to younger or older patients with T2DM. Third, DPN was clinically defined using the Diabetic Neuropathy Examination rather than an electrophysiological reference standard. The 2022 systematic review by Khan & Andersen (2022) highlighted considerable heterogeneity in the methods used to define and assess diabetic neuropathy across the literature, reinforcing the importance of considering the diagnostic method when comparing findings between studies. Fourth, the marked predominance of right-leg dominance limits conclusions regarding differences between dominant and non-dominant limbs. Finally, the 45-second maximum UPST duration likely contributed to a ceiling effect in the eyes-open condition and may have reduced its discriminatory capacity.

Another limitation concerns the interpretation of the ROC-derived cut-off points. Although the cut-offs were associated with statistically significant differences in DPN prevalence, sensitivity, specificity, positive predictive value, negative predictive value, and area under the ROC curve were not reported in the available analysis. Therefore, the current findings do not establish the UPST as a definitive diagnostic test for DPN. Instead, they indicate that specific levels of impaired eyes-closed single-leg stance performance are associated with a higher prevalence of clinically defined DPN. Future studies should validate the 6.32-second and 5.35-second thresholds in larger and independent samples and should report comprehensive diagnostic performance measures. Studies comparing UPST performance with standardized neurological and, where appropriate, electrophysiological assessments would also help clarify its diagnostic and screening value.

Overall, the present study demonstrates that the eyes-closed UPST provides greater discriminatory value than the eyes-open condition for distinguishing patients with T2DM with and without clinically defined DPN. Significant differences were observed for both the dominant and non-dominant legs, and the identified cut-off points of 6.32 seconds and 5.35 seconds, respectively, were associated with approximately two- to three-fold higher prevalence of DPN. The findings closely correspond with the 2022 evidence showing that DPN is associated with impaired postural stability and that differences in postural control may become particularly evident when visual information is removed. The main clinical implication is that the eyes-closed UPST may serve as a simple, low-resource complementary functional assessment for identifying patients with T2DM who demonstrate impaired postural control and who may benefit from further neurological, balance, and fall-risk evaluation. Nevertheless, the identified cut-off points should be considered preliminary, study-specific thresholds and require validation in larger independent populations before being adopted as general diagnostic criteria for DPN.

CONCLUSION

The Unipedal Stance Test (UPST) performed with the eyes closed significantly differentiated patients with type 2 diabetes mellitus (T2DM) with and without diabetic

peripheral neuropathy (DPN). Patients with DPN demonstrated substantially shorter stance times on both the dominant and non-dominant legs, with mean durations of 5.67 ± 3.58 seconds and 5.17 ± 3.92 seconds, respectively, compared with 10.33 ± 8.93 seconds and 7.81 ± 5.64 seconds in patients without DPN (p=0.019 and p=0.029, respectively). The identified cut-off points were 6.32 seconds for the dominant leg and 5.35 seconds for the non-dominant leg. Performance at or below these thresholds was associated with a higher prevalence of DPN, with prevalence ratios of 2.84 (95% CI, 1.09–7.38) for the dominant leg and 2.42 (95% CI, 1.19–4.92) for the non-dominant leg. In contrast, the eyes-open UPST did not significantly distinguish patients with and without DPN.

These findings indicate that the eyes-closed UPST may have practical clinical value as a simple, low-resource functional screening assessment for identifying T2DM patients with impaired postural control who may warrant further evaluation for DPN and fall-related functional risk. The identified cut-off points may assist clinicians in interpreting single-leg balance performance, although they should be considered complementary clinical thresholds rather than definitive diagnostic criteria for DPN.

Future research should further validate these cut-off values in larger and more diverse T2DM populations and examine their performance against established clinical and neurophysiological measures of DPN. Longitudinal studies could also determine whether reduced eyes-closed UPST performance predicts subsequent falls, functional decline, or progression of neuropathy, while intervention studies may assess whether balance training or neuropathy-focused rehabilitation can improve UPST performance and reduce fall risk.

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