Assessing Correlation between Peripheral Neuropathy Score and Angle of Dorsiflexion of Ankle Joint among Cases of Type-2 Diabetes Mellitus

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ARTICLE INFO
Article History
Submitted: 29 June 2025
Accepted: 25 July 2025
Published: 8 August, 2025
Source of support: None
Conflict of Interest: None

ABSTRACT

Introduction: Diabetic neuropathy, a major cause of diabetic foot, typically begins with sensory deficits and may progress to motor issues like ankle muscle weakness and reduced joint flexibility. If ankle dorsiflexion (ADF) angle correlates with neuropathy scores, it may serve as a simple, low-cost screening tool in community settings. This study aimed to assess the relationship between peripheral neuropathy scores and ADF angle in patients with Type 2 Diabetes Mellitus.

Methods: This cross-sectional analytical study was conducted in the community health program among 109 adults with Type 2 DM. Neuropathy was assessed using the Symptomatic method, 10g monofilament test, and 128-Hz tuning fork. Ankle dorsiflexion was measured using a manual goniometer in the knee-extended supine position. Correlation analysis was performed to determine the relationship between neuropathy scores and ADF angle.

Results: Among participants 38.5% were male, mean age was 57.7 years, and mean BMI was 28.52 kg/m². ADF angle showed significant negative correlation with symptomatic score ($r = -0.216$, $p = 0.024$), but weak, non-significant correlations with monofilament test and vibration perception time. This result supports the possibility of ADF angle as a potential screening tool to predict neuropathy in community setting among type 2 DM patients.

Conclusion: A significant inverse correlation found between ADF angle and symptomatic score supports the possibility of ADF angle as a potential screening tool to predict neuropathy in community setting among type 2 DM patients.

Keywords: Ankle joint; Diabetes Mellitus; Diabetic Neuropathy; Diabetic foot.

INTRODUCTION

The global burden of Type 2 Diabetes Mellitus (DM) is in rising trend. Recent studies and national surveys have shown a similar increasing trend, with prevalence reaching around 8.5% in Nepalese population.[1–3] Diabetic peripheral neuropathy (DPN), a common consequence of DM, affecting around 40 % of patients with long standing DM plays significant role in developing diabetic foot ulcers (DFUs).[4,5] The sensory and motor deficits of distal limb due to DPN lead to decreased the ability to maintain proper joint function and alignment, result in an abnormal and limited joint movement (LJM).[6] The LJM is also attributed to formation of advanced glycated end products (AGEs) in response to chronic hyperglycemia, their accumulation and cross-linking with collagen and elastin fibers.[7,8] Limited range of motion (ROM) of ankle joint may cause high plantar pressures and further contribute to foot ulceration in the susceptible neuropathic at-risk foot.[9, 10] Regular assessment of ankle joint mobility could be another feasible method to assess the risk of having DFU among diabetic patients.[11] However, it has not yet been clarified with enough evidence whether the determination of LJM is also useful in identifying diabetic patients with an at-risk foot. While assessment of plantar pressure has been suggested as a tool for identification of increased ulcer risk, the equipment is expensive and not readily available in clinical practice. [12] For this reason if a correlation could be found between ankle joint dorsiflexion (ADF) angle and neuropathy, measuring ADF could be a way to assess the risk of having foot ulcers among diabetic patients.

This study aimed to quantify the relationship between the peripheral neuropathy score assessed using objective and subjective methods and goniometric measurement of ankle joint dorsiflexion in patients with Type 2 DM.

METHODS

This cross-sectional analytical study was conducted from January 2025 to June 2025 within a community program that aim to prevent, detect, and manage chronic kidney disease, Hypertension, Diabetes, and Cardiovascular Disease (KHDC).[13] Permission was obtained from KHDC for conducting the study. Patients with type 2 DM visiting KHDC community program were selected using systematic random sampling method. Patients of age >20 years and diagnosis of Type 2 DM based on ADA criteria or physician-diagnosed Type2 DM under treatment for glycemic control were included and cases with neurological disorders, alcohol dependency, and significant foot deformities were excluded from study. Sample size was calculated based on a study that showed that coefficient of correlation between DPN and ROM of foot joints varied from 0.37 to 0.53.[14] Taking this, sample size was calculated using sample size estimation formula [15] where total of 109 participants were included in the study.

The Neuropathy Symptomatic Score (NSS) was calculated using an older scoring system used by Young et al.[16], used and validated by Franklin et al.[17] On the basis of 5 symptoms related questions, its score ranged from 0 to 9. The Semmes Weinstein 10g (5.07) monofilament test (MTS) was performed bilaterally following the standard set by NHS foundation trust.[18] The test was done at 10 different sites (5 on each foot: the pulp of the 1st and 3rd toes and the planter aspect of 1st, 3rd, and 5th metatarsophalangeal joints.) in relaxed setting. One point was given for each correct response. Score ranged from 0 to 10. Sites with ulcers, calluses, or necrotic tissue were avoided while testing. Assessment of vibration sense was done by the 128-Hz tuning fork[19], a reliable and clinically practical tool for DPN screening.[20,21] Vibrating tuning fork was placed on the dorsal surface of the distal phalanx of the great toe, just proximal to the nail bed. Each participant was instructed to give a verbal response of “yes” upon first perceiving the vibration and “now” when sensation ceased. The time elapsed between these responses was measured in second with a digital stopwatch. This process was repeated twice and the mean time was recorded for analysis.The ADF angle was measured using a manual goniometer (66fit, UK) in extended knee in supine position passively with active assistance following the method described by Das et. al to ensure consistency in all subjects and to avoid the influence of balance and any compensatory movements.[22,23]The subject was instructed for dorsiflexion of the foot from its resting position, followed by measurement of the maximum range of ankle dorsiflexion using a goniometer. Two measurements were taken for each ankle, and the average was used. Final ADF values were calculated as the mean of both sides, following the method used by Soucie et al. and Perkins et al.[20, 24]

Ethical clearance to conduct the study was taken from Institutional Review Committee of BPKIHS (IRC 178/081/82, code no: 2922/024). Confidentiality of the data was maintained throughout the research process.
Data were entered in Excel and analyzed using IBM SPSS Statistics Version 20.0. Descriptive statistics were reported as mean ± SD or median with IQR, based on distribution. Normality was tested using the Shapiro Wilk test. Parametric tests were used for normally distributed variables (age, weight, height, and ADF angle), while non-parametric tests were applied to others (e.g., duration of diabetes, BMI, HbA1c, BP, neuropathy scores). Spearman correlation was used to examine the relationship between neuropathy scores and ADF angle. Statistical significance was set at $p < 0.05$.

RESULTS

In this study a total of 109 cases with type 2 DM were included. The mean age of participants was 57.7 years; 61.5% were female and mean BMI was 28.5 kg/m². When participants were further classified on the basis of BMI cut off value for Asian population, more than 92%

Table 1: Demographic Characteristics of the Study Participants

Characteristics	Value
Age (years)	Mean ± SD: 57.72 ± 10.13
	Range: 35-83
Weight (kg)	Mean ± SD: 66.55 ± 10.15
	Range: 44.00-99.00
Height (cm)	Mean ± SD: 153.08± 7.86
	Range: 126.00-177.00
BMI (kg/m²)	Mean ± SD: 28.52 ± 4.76
	Median (IQR): 27.69 (25.24- 31.80)
Sex	
Male	42 (38.5%)
Female	67 (61.5%)
Smoking status	
Yes (Male/Female)	44 (40.4%); (27/17)
No (Male/Female)	65 (59.6%); (15/50)
Diabetes Duration (years)	Mean ± SD: 7.94 ± 7.20
	Median (IQR):6 (2.00–12.00)

participants were in the overweight category. Only 6.4% of participants had normal BMI and only 1% had BMI less than normal and falls under underweight category. The median duration of DM was 6 years. Other demographic and clinical parameters are presented in Table 1.

Table 2 displays descriptive statistics of peripheral neuropathy related variables and ankle dorsiflexion (ADF) angle variables among 109 subjects. The neuropathy symptomatic score ranged from 0 to 9, with a median of 3.00. The monofilament test score that was used for the assessment of sensory perception ranged from 2 to 10 with median of 10.00. The vibration perception time ranged from 5.85 to 29.53 seconds with a median of 11.04 second. ADF angle showed wide range from 6.5° to 42.0°; with mean of 20.23° ± 7.30°. Four participants (3.7%) did not feel vibration upon placement of tuning fork at all, even on repetition, so those cases were not included in calculating the mean vibration time due to absence of measurable perception.

Table 3 presents the Spearman correlation matrix among ADF angle, neuropathy-related scores, and biochemical parameters. Significant negative correlation between ADF angle and neuropathy symptomatic score (NSS) was found (r=-0.216, p=0.024) indicating that if severity of neuropathy increases, there is decrease in ADF angle. Similarly, weak negative correlation was found between ADF angle and duration of diabetes (r=-0.071, p=0.462) and BMI (r=-0.144, p=0.136). Study also showed significant negative correlation between vibration time and NSS (r=-0.21, p=0.033) demonstrating that patients with higher NSS score felt vibration sensation for shorter time signifying poor nerve health. NSS score was negatively correlated with monofilament test score (r = -0.151, p = 0.118). Significant positive correlation was detected between HbA1c and fasting blood sugar level (r=0.605, p<0.001) that seems logical because both of these parameters are indicative of poor glycemic control. Positive correlation was also detected between BMI and HbA1c level (r=0.189, p=0.049).

Table 2: Descriptive Statistics of Peripheral Neuropathy Related Variables and Ankle Dorsiflexion (ADF) Angle among Study Participants

Variables	N	Minimum	Maximum	Median	IQR	Mean	Std. Deviation
NSS	109	0.00	9.00	3.00	0-6.0	3.06	2.96
MTS	109	2.00	10.00	10.00	8.00-10.00	8.78	1.69
Vibration time	104	5.85	29.53	11.04	8.26-13.70	11.80	4.55
ADF angle	109	6.50	42.00	19.00	15.25-24.75	20.23	7.30

Table 3: Spearman's Rank-order Correlation between Neuropathy Related Scores and Other Parameters

Parameters	ADF angle	Vibration time	MTS	NSS	HbA1c	FBS	BMI	DM Duration
ADF angle	r	0.08	0.09	-0.22	-0.04	0.06	-0.14	-0.07
	P value	0.438	0.332	0.024	0.656	0.505	0.136	0.462
Vibration time	r		0.10	-0.21	0.07	0.03	0.06	-0.04
	P value		0.297	0.033	0.491	0.764	0.556	0.659
MTS	r			-0.15	-0.09	-0.06	-0.09	-0.003
	P value			0.118	0.355	0.521	0.350	0.972
NSS	r				-0.005	0.09	-0.08	0.14
	P value				0.955	0.375	0.411	0.150
HbA1c	r					0.60	0.19	-0.007
	P value					**<0.001**	0.049	0.946
FBS	r						0.01	-0.02
	P value						0.875	0.845
BMI	r							-0.182
	P value							0.059
DM Duration	r							
	P value							

DISCUSSION

This study found a statistically significant inverse correlation between ADF angle and NSS score, suggesting that individuals with higher grade neuropathy symptoms had lower dorsiflexion angles. Study also attempted to see how other variables are correlated with the ADF angle. Being older and having higher BMI was correlated with having lesser ADF angle. Variation in ADF angle has been reported across studies involving different populations.[14,25,26] It is likely due to multiple interacting factors. Age is one such variable. In the present study, a negative but statistically non-significant correlation was found between age and ADF angle, suggesting reduced ankle mobility in older participants. Similar findings were noted in studies by Yoshikawa et al. (mean age 74.1 years) and Francis et al. (median age 53 but older individuals showed more restricted dorsiflexion, increasing their risk for foot ulceration).[25,27] Variations in reported ADF angles also arise from the diverse methodologies used across research studies. These differences arises due to the choice of measurement tool, patient positioning, the definition of the initial reference point (also called initial zero) for measuring ADF angle.[28] Similar to the method applied by konor et al, in the present study, during measurement no attempt was made to control the foot position perpendicular to long axis of leg. This might be the reason for in general higher values of ADF angle as shown in the study comparing different methods of ankle ROM measurement.[29]

The present study showed a negative correlation between ADF angle and Neuropathy Symptomatic Score (NSS). This suggested that patients having higher degree of ADF angle tend to have less neuropathy related score in type 2 DM patients. These finding are in consistent with findings by McIllhatton et al., Francis et al, and Das et al. Such limited ankle ROM is believed to be the result of long-term hyperglycemia in connective tissue and stiffness of connective tissue.[14,27] Present study found that such limitation of movement increases as the duration of diabetes increases which is supported by
previous study result.[22]

Even though objective method of neuropathy assessment did not show significant correlation with ADF angle, these results are useful to know the feasibility of measuring ADF angle, being simple and cost-effective, as a potential marker for community based screening neuropathy in diabetic cohort. Integration of ADF assessment into routine diabetic checkups, particularly in resource-limited settings, could improve early risk detection for foot complications. This study could also contribute to the worldwide dataset and to compare the variability in ADF angle from other group of population.

The study also had several limitations. The study could not show a causal relationship between neuropathy and limited joint mobility due to cross sectional study design. There was possibility of occurrence of recall bias in self-reported neuropathy symptomatic score. Generalizability of the findings could not be made as this was done in a specific geographical area where the KHDC program was conducted during the study period.

CONCLUSION

The findings of this study are in agreement with the findings that altered foot biomechanics is related to the subjective neuropathy. This result supports the possibility of ADF angle as a potential screening tool to predict neuropathy in community setting among type 2 DM patients.

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