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Association Between Knee Joint Position Sense and Fall-Risk in Adults with Type 2 Diabetes Mellitus Without Clinically Detectable Peripheral Neuropathy: A Cross-Sectional Study

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Abstract

Background: Type 2 diabetes mellitus (T2DM) may be associated with sensorimotor and balance abnormalities even when clinically detectable peripheral sensory neuropathy is absent. The relationship between knee joint position sense (JPS) error and fall-related functional outcomes in this population remains insufficiently described.

Objective: To examine the correlations between knee JPS error and functional mobility, balance performance, and concern about falling in adults with T2DM without clinically detectable peripheral sensory neuropathy.

Methods: This cross-sectional correlational study included 66 adults aged 40–65 years with diagnosed T2DM who met the eligibility criteria. Peripheral sensory neuropathy was screened using a 10-g Semmes–Weinstein monofilament and a 128-Hz tuning fork. Knee JPS was assessed in the non-dominant limb at target positions of 15° and 45°, with three repetitions at each position. Absolute angular error was measured using a universal goniometer. Functional mobility, balance, and concern about falling were assessed using the Timed Up and Go (TUG) test, Berg Balance Scale (BBS), and Falls Efficacy Scale–International (FES-I), respectively. Pearson correlation coefficients were calculated.

Results: The mean age was 52.74 ± 5.24 years and mean body mass index was 27.88 ± 3.79 kg/m². Overall mean knee JPS error was 3.28 ± 1.18°. JPS error was positively correlated with TUG time ($r = 0.742$, 95% CI 0.610 to 0.834; $p < 0.001$), negatively correlated with BBS score ($r = −0.493$, 95% CI −0.657 to −0.285; $p < 0.001$), and positively correlated with FES-I score ($r = 0.455$, 95% CI 0.240 to 0.628; $p < 0.001$).

Conclusion: Greater knee JPS error was associated with slower functional mobility, lower balance scores, and greater concern about falling making fall risk higher. These cross-sectional associations do not establish causation. Further studies should examine confounding factors and the clinical utility of knee JPS assessment.

Keywords: Type 2 diabetes mellitus; proprioception; joint position sense; knee; balance; functional mobility; falls efficacy.

1. Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic condition associated with complications that may affect neurological, vascular, and musculoskeletal function. Changes in lower-limb sensation, muscle performance, gait, and postural control can affect functional mobility and balance. Falls and fall-related concerns are therefore clinically relevant when assessing people living with T2DM. Previous work has reported balance and postural-control differences in people with T2DM, including in some individuals without clinically detectable peripheral neuropathy [3,4,7,8].

Diabetic peripheral neuropathy is an important contributor to altered sensory feedback and balance dysfunction. However, the absence of clinically detectable peripheral sensory neuropathy does not necessarily exclude other sensorimotor changes. Research has reported knee proprioceptive deficits in people with T2DM, including individuals without clinically evident neuropathy [11–13]. Joint position sense (JPS), a component of proprioception, describes the ability to perceive and reproduce a joint position. Reduced accuracy can be quantified as the absolute difference between a target joint angle and the angle reproduced by the participant [9,10].

The knee contributes to lower-limb control during standing, walking, turning, and transfers. Although prior studies have investigated knee proprioception in T2DM, the association between the magnitude of knee JPS error and clinically relevant functional outcomes among adults without clinically detectable peripheral neuropathy warrants further examination. Functional mobility, balance performance, and concern about falling represent related but distinct domains and can be assessed using the Timed Up and Go (TUG) test, Berg Balance Scale (BBS), and Falls Efficacy Scale–International (FES-I), respectively [17–19].

Therefore, this study aimed to determine the relationship between knee JPS error and TUG performance, BBS score, and FES-I score in adults aged 40–65 years with T2DM without clinically detectable peripheral sensory neuropathy.

Materials and Methods

Study design and participants

A cross-sectional correlational study was conducted over six months in a physiotherapy clinic/hospital outpatient setting. Adults aged 40–65 years with a clinical diagnosis of T2DM were recruited using non-probability consecutive sampling. The planned sample size was 66, based on a Fisher z-transformation calculation for a two-tailed correlation test (anticipated $r = 0.36$, $\alpha = 0.05$, power = 80%), with an allowance for approximately 10% incomplete data. All 66 participants had complete outcome data and were included in the analysis.

Participants were eligible if they were able to stand and walk independently without an assistive device, understand the assessment instructions, were medically stable, and provided written informed consent. Participants with clinically detectable peripheral sensory neuropathy, other neurological disorders affecting balance or gait, significant lower-limb/hip/spinal musculoskeletal conditions, recent lower-

limb fracture or surgery (within six months), active foot ulcer or significant foot deformity, major uncorrected visual impairment or vestibular disorder, significant cognitive impairment, or an acute/unstable medical condition were excluded.

Peripheral sensory neuropathy screening

Screening was performed before functional assessment using a 10-g Semmes–Weinstein monofilament to assess protective sensation and a 128-Hz tuning fork to assess vibration sensation. Participants with clinically detectable peripheral sensory neuropathy on the study screening protocol were excluded.

Knee joint position sense

Lower-limb dominance was determined by the participant's self-reported preferred kicking leg, and the non-dominant limb was assessed. Participants were seated with the test limb unsupported and the knee initially positioned at approximately 90° of flexion. Vision was occluded. The examiner passively positioned the knee at target angles of 15° and 45° and held each position for approximately five seconds. The limb was returned to the starting position, after which the participant actively reproduced the target angle without visual feedback. Three repetitions were performed at each target angle. Reproduced angles were measured using a universal goniometer. Absolute error was calculated as |target angle − reproduced angle|. The mean absolute error was calculated for each target, and overall mean JPS error was calculated as the average of the mean errors at 15° and 45°.

Functional outcome measures

The TUG test assessed functional mobility. Participants rose from a standard chair, walked three metres, turned, returned, and sat down; completion time was recorded in seconds. The BBS assessed functional balance across 14 tasks scored from 0 to 4, for a total of 0–56; higher scores indicate better balance. The 16-item FES-I assessed concern about falling during daily activities, with total scores ranging from 16 to 64; higher scores indicate greater concern about falling.

Statistical analysis

Descriptive statistics were reported as mean ± standard deviation (SD) and range. Pearson's correlation coefficient was used to assess associations between overall mean knee JPS error and each outcome (TUG, BBS, and FES-I). Statistical significance was set at $p < 0.05$. Correlation coefficients, 95% confidence intervals (CIs), test statistics, degrees of freedom, and coefficients of determination (R^2) are reported as provided in the project analysis. The statistical software used should be specified before submission.

Ethics

The study topic was discussed with the ethical committee and ethical approval was obtained before commencement of the study. Written permission was obtained from the clinical facility, and written informed consent was obtained from all participants. The exact name of the approving ethics committee and approval/reference number should be inserted before submission.

Results

Sixty-six participants were included in the analysis. The mean age was 52.74 ± 5.24 years; 36 participants (54.5%) were male and 30 (45.5%) were female. Mean BMI was 27.88 ± 3.79 kg/m². Descriptive statistics for the study variables are presented in Table 1.

Table 1. Participant characteristics and study-variable descriptive statistics

Variable	n	Mean ± SD	Minimum	Maximum
Age (years)	66	52.74 ± 5.24	43.00	64.00
Height (cm)	66	161.21 ± 8.26	143.00	178.00
Weight (kg)	66	72.59 ± 11.87	49.00	95.00
BMI (kg/m²)	66	27.88 ± 3.79	20.66	35.49
Mean JPS error at 15° (°)	66	2.71 ± 1.47	0.33	8.67
Mean JPS error at 45° (°)	66	3.85 ± 1.06	1.67	7.67
Overall mean knee JPS error (°)	66	3.28 ± 1.18	1.00	7.33
TUG (s)	66	8.90 ± 1.52	6.32	13.34
BBS (/56)	66	51.23 ± 2.96	46.00	56.00
FES-I (/64)	66	20.65 ± 4.66	16.00	35.00

A strong positive correlation was found between overall mean knee JPS error and TUG time ($r = 0.742$, $t(64) = 8.86$, $p < 0.001$; 95% CI 0.610 to 0.834; $R^2 = 0.551$). A moderate negative correlation was observed between JPS error and BBS score ($r = −0.493$, $t(64) = −4.53$, $p < 0.001$; 95% CI −0.657 to −0.285; $R^2 = 0.243$). JPS error was moderately positively correlated with FES-I score ($r = 0.455$, $t(64) = 4.09$, $p < 0.001$; 95% CI 0.240 to 0.628; $R^2 = 0.207$). The correlation results are summarized in Table 2.

Table 2. Correlations between overall mean knee JPS error and functional outcomes

Outcome	Pearson r	95% CI	t	df	p-value	R^2
TUG time	0.742	0.610 to 0.834	8.86	64	<0.001	0.551
BBS score	−0.493	−0.657 to −0.285	−4.53	64	<0.001	0.243
FES-I score	0.455	0.240 to 0.628	4.09	64	<0.001	0.207

Discussion

In this cross-sectional study of adults with T2DM without clinically detectable peripheral sensory neuropathy, greater knee JPS error was associated with slower TUG performance, lower BBS scores, and greater concern about falling on the FES-I. The strongest association was observed for TUG time (r = 0.742), suggesting that participants with less accurate knee position reproduction tended to take longer to complete a task involving standing, walking, turning, and sitting.

The negative association between JPS error and BBS score indicates that greater proprioceptive error co-occurred with poorer performance on functional balance tasks. The positive association between JPS error and FES-I score indicates that greater error also co-occurred with higher self-reported concern about falling. These outcomes reflect different aspects of function: TUG captures functional mobility, BBS quantifies observed balance performance, and FES-I measures concern about falling. The consistency of the directions across these measures supports the clinical relevance of exploring proprioceptive function alongside conventional balance and mobility assessments.

Previous studies have reported altered knee proprioception in people with T2DM, including participants without clinically evident peripheral neuropathy [11–13]. Other work has identified postural-control or balance differences in T2DM populations without neuropathy [4,7,8]. The present findings extend this line of inquiry by examining associations between knee JPS error and three fall-related functional measures within a sample selected to exclude clinically detectable peripheral sensory neuropathy. However, because this study did not include a non-diabetic control group, it cannot establish whether JPS error or functional outcomes differed from those of people without diabetes.

The findings should not be interpreted as evidence that knee JPS error causes falls or independently predicts future falls. The design was cross-sectional and actual prospective fall incidence was not measured. TUG, BBS, and FES-I provide information relevant to mobility, balance, and concern about falling, but they are not interchangeable with observed future falls. In addition, the analyses were bivariate and did not adjust for potential confounders such as duration of diabetes, glycaemic control, lower-limb strength, physical activity, visual function, vestibular function, or comorbidities.

Several methodological considerations should also be acknowledged. Consecutive non-probability sampling may limit generalisability. JPS was measured with a universal goniometer, and the result may be affected by examiner technique, attention, comprehension, and measurement resolution. The screening approach identified clinically detectable sensory neuropathy using the specified bedside tests; it should not be interpreted as excluding all subclinical nerve dysfunction. Future research could use blinded assessors, report inter- and intra-rater reliability for the JPS protocol, include objective glycaemic and diabetes-duration variables, and use prospective follow-up to examine actual falls.

Clinical implications

The observed associations suggest that knee JPS assessment may provide supplementary information when evaluating sensorimotor function in adults with T2DM, including those without clinically detectable peripheral sensory neuropathy. JPS should be interpreted alongside established mobility, balance, sensory, strength, and fall-history assessments rather than used alone to classify fall risk. Intervention studies are required to determine whether improving knee JPS leads to meaningful changes in mobility, balance, concern about falling, or actual fall incidence.

Limitations

- Cross-sectional design precludes causal inference and prospective prediction of falls.
- Consecutive non-probability sampling limits generalisability.
- Knee JPS was measured using a universal goniometer and may be influenced by examiner and participant factors.
- Clinically detectable neuropathy was screened using bedside sensory tests; subclinical neuropathy cannot be ruled out.
- Potential confounders were not included in adjusted analyses, and there was no non-diabetic comparison group.

Conclusion

Among 66 adults aged 40–65 years with T2DM without clinically detectable peripheral sensory neuropathy, greater knee JPS error was significantly associated with slower TUG performance, lower BBS scores, and greater concern about falling on the FES-I. These findings support further investigation of knee proprioception as one component of a broader sensorimotor and functional assessment. Longitudinal and intervention studies are needed before causal or predictive conclusions can be drawn.

Declarations

Ethics approval: The study topic was discussed with the ethical committee and ethical approval was obtained before commencement of the study.

Consent to participate: Written informed consent was reported in the project materials; confirm that consent was obtained from all participants before data collection.

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Data availability: The underlying study data are not included in this manuscript. Data availability should be stated in accordance with the institutional and journal requirements before submission.

Author contributions: Swapnil Indrajeet Yadav: study conception and design, participant/data collection, analysis and interpretation, manuscript preparation and final approval of the manuscript..

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