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ASSOCIATION BETWEEN BALANCE DYSFUNCTION AND SLEEP APNOEA IN TYPE II DIABETIC POPULATION: A CROSS-SECTIONAL STUDY

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Abstract

Background: Type 2 Diabetes Mellitus T2DM) is associated with impaired postural control and an increased risk of falls, primarily due to diabetic neuropathy, proprioceptive deficits and musculoskeletal dysfunction. Obstructive sleep Apnoea (OSA), a common comorbidity in individuals with type 2 diabetes mellitus, may further compromise balance through intermittent hypoxia, sleep fragmentation and impaired sensorimotor integration. However, the influence of OSA risk on balance dysfunction among individuals with T2DM remains inadequately explored.

Objective: To compare balance performance and sensory function between individuals with T2DM with and without risk of Obstructive sleep apnoea and to examine the relationship between STOP-BANG scores and balance-related outcome measures.

Methods: This observational cross-sectional study included 64 adults with T2DM. Participants were categorized into two groups based on the STOP-BANG questionnaire; T2DM without risk of OSA and T2DM with risk of OSA. Functional balance was assessed using the Berg balance scale (BBS), while postural alignment was evaluated using computerized posturography. Peripheral sensory function was assessed using the 10-g Semmes-Weinstein monofilament test, 128Hz tuning form vibration perception test. Between group comparison were performed using Mann-Whitney test, Chi square test and the spearman's rank correlation coefficient was used to analyse the correlation between STOP-BANG scores and balance related outcomes.

Results: The T2DM at risk group demonstrated significantly lower Berg Balance Scale scores ($p=0.02$), greater knee malalignment ($p=0.001$), higher total body alignment scores (p-0.04), a greater proportion of participants with medium fall risk ($p=0.01$). Significant correlations were observed between STOP-BANG scores and Berg Balance Scale scores, as well as selected posturographt parameters ($p<0.05$).

Conclusion: Individuals with T2DM who were at risk of OSA demonstrated poorer balance performance, greater postural alignment abnormalities and increased sensory impairment compared with those without OSA risk. These findings suggest that screening for OSA risk may help identify individuals with T2DM who are at increased risk of balance dysfunction and falls. Highlighting the importance of incorporating balance assessment into routine clinical evaluation.

KEYWORDS: Type 2 Diabetes Mellitus; Obstructive Sleep Apnoea, STOP-BANG; Berg Balance Scale; Posturography; Falls

INTRODUCTION

Type 2 diabetes mellitus as a chronic metabolic disorder characterised by persistent hyperglycemia resulting from impaired insulin secretion, insulin resistance or a combination of both. It accounts for approximately 90 - 95% of all diabetes cases worldwide and continues to represent a major global public health challenge due to its increasing prevalence and associated morbidity (1). The burden of Type 2 DM has risen considerably over recent decades, particularly in Low- and middle-income countries owing to rapid urbanization, Sedentary lifestyles, Population ageing and increasing rate of obesity (2). In addition to its well established microvascular and macrovascular complications T2 DM Is increasingly recognised as a major contributor to functional impairment, reduced mobility, diminished quality of life and increased health care utilisation (3,4).

Maintenance of postural balance is a complex physiological process that depends on the coordinated integration of visual, vestibular and somatosensory inputs by the central nervous system (5). Chronic hyperglycaemia in individuals with type T2DM adversely affects this system through multiple mechanisms including diabetic peripheral neuropathy impaired proprioception muscle weakness, delayed neuro motor response, microvascular dysfunction which will impairment secondary to diabetic retinopathy (6,7). Consequently, these alterations impact postural control and increase the Importantly balance deficits have also been reported in individuals with T2DM without clinically evident peripheral neuropathy, suggesting that early subclinical sensory impairment and altered central sensory motor processing may contribute to postural instability even before overt neurological complications become apparent (8,9).

Obstructive Sleep Apnea (OSA) is one of the most prevalent comorbidities among individuals with T2DM with both conditions sharing common risk factors including obesity, advanced ageing and physical inactivity (10,11). OSA is

characterised by the recurrent episodes of partial or complete upper airway obstruction during sleep resulting in intermittent hypoxemia, sleep fragmentation, sympathetic nervous system activation, oxidative stress, systematic inflammation and endothelial dysfunction (12). These pathophysiological changes contribute not only to worsening insulin resistance and impaired glycaemic control but also to neurocognitive dysfunction, delayed reaction time, vestibular impairment and altered sensory motor integration, all of which are essential for maintaining posture stability (13).
The coexistence of T2DM and OSA may therefore exert additive or synergistic effect on the neural and vascular mechanism responsible for balance regulation. Diabetes related peripheral neuropathy and impaired proprioception may be further exacerbated by intermittent hypoxia, autonomic dysfunction, oxidative stress and neuroinflammation associated with OSA. Furthermore, recurrent nocturnal hypoxemia may impair vestibular function and reduce postural reflexes, thereby increasing the likelihood of functional instability and falls (14,15). Individuals with both T2DM and OSA may therefore experience greater impairment in postural control and mobility than those with T2DM alone. Despite these plausible mechanisms, routine assessment of balance is rarely incorporated into the clinical evaluation of patients with T2DM who are at risk of OSA.
Although previous studies have independently demonstrated the association between T2DM and balance dysfunction as well as between OSA and impaired postal control evidences evaluating the combined influence of OSA risk on balance performance in individuals with T2DM remains limited Furthermore, Studies integrating functional balance assessment objective postural analysis and peripheral sensory evaluation in this population are scars particularly in developing countries where disease characteristics body composition and healthcare accessibility differ from those reported in high income settings Early identification of balance impairment in this high risk population may facilitate timely multidisciplinary interventions including fall prevention strategies sleep disorder management and targeted physiotherapy programmes thereby improving functional independence and quality of life.
Therefore, the present cross section study was undertaken to investigate the association between the risk of obstructive sleep apnoea and balance dysfunction among individuals with type 2 diabetes mellitus.

MATERIALS AND METHODOLOGY

This observational cross-sectional study was conducted in the Department of Endocrinology, Sri Ramachandra Hospitals, Sri Ramachandra Institute of higher education and research (DU), Chennai, Tamil Nadu, India between 20th March 2026 and 25th May 2026. The study was designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross sectional studies (16). The study protocol was approved by the students' projects ethical committee, Sri Ramachandra Institute of higher education and research with reference number CSF-III/25/AUG/25/349. The study was prospectively registered with the clinical trial registry India (CTRI) – CTRI/2026/03/105620. All procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki (17). Written informed consent was obtained from all the participants prior to enrolment.

Participants:

Participants diagnosed with T2DM for a minimum of more than six months and willing to provide evil link inform the consent were considered Eligible for participation participants were excluded if they had type 1 diabetes monitors, gestational or secondary diabetes militants clinically significant cardiovascular disease are cardiac dysfunction neurological disorders affecting balance musculoskeletal disorders interfering with postural control or gait or other systemic conditions that could influence balance performance.

Sample Size Estimation:

The sample size was calculated using the formula for comparison between two independent Command with the 95% confidence level ($Z\alpha/2=1.96$), 80% statistical power ($Z\beta=0.84$) and then anticipated effective size of 0.72. The estimated sample size was 30 participants per group, resulting in a total sample size of 60 participants. To compensate for a potential 5% dropout rate, the sample size was adjusted to 64 participants with 32 participants recruited into each group.

Study Procedure:

In sample collection process, the participants were recruited from patients attending at Endocrine OPD, Sri Ramachandra Hospitals. Participants baseline characteristics such as demographic data including age, sex, body mass index (BMI), duration of diabetes, glycaed haemoglobin (HbA1c), neck circumference, resting oxygen saturation (SpO2) and relevant medical history were recorded. Laboratory parameters were retrieved from hospital medical records whenever available.

Stop – Bang Questionnaire:

The risk of obstructive sleep apnoea (OSA) was assessed using the Stop Bang Questionnaire, a validated and highly sensitive screening tool recommended for identifying individuals at increased risk of moderate severe OSA in clinical practise (18). The participants were considered to have low risk of having OSA if the score is of 0 – 2, intermediate risk with score of 3-4 and high risk with score of 5 – 8 points. Also, the participants with the score of 5 – 8 is considered to have moderate to severe OSA (19).
Based on the STOP_BANG score, participants were categorized into two groups:
Group 1- Individuals with T2DM without risk of OSA (Low STOP-BANG score).
Group 2 - - Individuals with T2DM with risk of OSA (High STOP-BANG score).

Outcome Measures:

Balance Assessment:
Functional balance was assessed using the Berg Balance Scale (BBS), a reliable and a valid clinical outcome measure consisting of 14 functional task that evaluate static and dynamic balance. The BBS has been widely used to assess balance impairment and predict fall risk in individuals with diabetes and other neurological conditions (20).
Objective postural stability was further evaluated using computerized posturography, which provides quantitative assessment of postural alignment and balance by analysing body sway and weight distribution. Computerized posturography is considered a sensitive method for detecting subtle balance impairments that may not be identified through clinical assessment alone (21).

Sensory Assessment:
Peripheral sensory function was assessed using standardized clinical tests to identity sensory deficits associated with diabetic peripheral neuropathy. Protective planar sensation was evaluated using the 10-g Semmes-Weinstein monofilament test, which is widely recommended for screening diabetic peripheral neuropathy (21). Vibration perception was assessed using a 12-Hz tuning fork, a reliable clinical method for evaluating large-fibre sensory function and early neuropathic changes (22). Light-touch sensation was also examined to assess superficial sensory integrity.
Each participant completed a single assessment session lasting approximately 15-20 minutes.

Statistical Analysis:
Statistical analysis was performed using the SPSS 19.0 version. Normally distributed data are presented as mean ± standard deviation (SD), whereas non-normally distributed data are expressed as median and interquartile range (IQR). Categorical variables are presented as frequencies and percentages. Comparison between the two study groups were analysed using the independent sample t-test for normally distributed continuous variables and the Mann-Whitney U test for non-normally distributed continuous variables. Chi-square test was used to analyse the categorical variables. Correlations between STOP-BANG scores and balance related outcome measures were assessed using spearman's rank correlation coefficient. A two-sided p-value of <0.05 was considered statistically significant.

RESULTS:
The total Sixty-four participants were included in the study with 32 in the T2DM without OSA group and 32 participants in the T2DM with OSA group. The demographic and clinical characteristics of the participants are presented in table 1.
Table 1. Demographic & Clinical Characteristics of the Participants

VARIABLES	T2DM Without OSA N=32 Mean ± SD	T2DM with OSA N=32 Mean ± SD
Age (years), mean ± SD	47.28 ± 8.03	53.09 ± 6.77
Gender (Male/Female), n (%)	17/15 (53.1%/46.9%)	16/16 (50.0%/50.0%)
BMI (kg/m²) [median (IQR)]	26.6 (22.7–31.4)	28.2 (24.6–31.5)
HbA1c (%)	7.04 ± 1.12	7.23 ± 1.33
Duration of DM (yrs) [median (IQR)]	6.0 (5.0–8.2)	10.0 (6.8–12.2)
Neck Circumference (cm)	38.09 ± 3.84	42.11 ± 3.46
SpO_2 [median (IQR)]	98.0 (97.0–98.0)	97.0 (97.0–97.2)
Comorbidities [n (%)]	8 (25.0%)	26 (81.2%)

SD- Standard Deviation; BMI – Body Mass Index; IQR- Inter Quartile Range; DM – Diabetes Mellitus; * $p < 0.05$

Table 1 represents that participants in T2DM with OSA group where significantly older than those without OSA. The median duration of diabetes is also significantly longer in T2DM with OSA group. Neck circumference was significantly greater among participants with OSA while median oxygen saturation was significantly lower. The prevalence of comorbidities was significantly higher in the T2DM with OSA group.

Table 2: Comparison of Balance performance, Postural Alignment and sensory outcomes between T2DM with and Without risk of OSA

Outcome Variable	**T2DM without OSA Median (IQR)**	**T2DM + OSA Median (IQR)**	**p-value**	**Effect Size (r)**
Berg Balance Score	54.0 (6.75)	53.04 (17.0)	0.02* μ	0.34
Posturography - Head Tilt	3.0 (3.0)	2.5 (3.0)	0.89 μ	0.02
Posturography - Shoulder Aligment	1.5 (3.0)	1.0 (3.0)	< 0.65 μ	0.1

Posturography - Pelvic Tilt	1.0 (2.0)	1.0 (3.0)	0.89 μ	0.02
Posturography – Knee	1.0 (2.0)	2.5 (2.0)	0.001** μ	0.46
Posturography – Ankle	3.0 (1.5)	2.0 (3.0)	0.24 μ	0.19
Body Alignment Total	1.00 (1.00)	2.0 (2.0)	0.04* μ	0.26
BBS Category (Low:Medium Risk), n (%)	30:2 (93.8: 6.2)	25/7 (78.1:10.9)	0.01* β	
Sensation (Normal/Altered), n (%)	30:2 (93.8:6.2)	22:10 (68.75:31.25)	0.01* β	

*BBS: Berg Balance Score; IQR – Inter Quartile Range; * p <0.05; μ Mann Whitney test; β- Chi Square Test

Table 2 represents that participants with T2DM with OSA demonstrated significantly lower Berg balance scale score than without OSA. Among posturography variables, a significant difference was observed only for knee alignment with greater deviation in the T2DM with OSA group. Similarly, the total body alignment score was significantly higher in T2DM with OSA group. No statistically significant differences were found for head tile, shoulder alignment, pelvic tilt or ankle alignment.

A significantly greater proportion of participants in the T2DM with

OSA group demonstrated medium fall risk based on the berg balance scale categories compared with T2DM without OSA group. Likewise, altered sensory function was significantly more prevalent among participants with OSA than those without OSA group.

Table 3: Correlation between STOP-BANG score, berg balance score and Posturography alignment.

Variables	**T2DM without OSA (n=32)**		**T2DM without OSA(n=32)**	
	rho (ρ) value	**p-value**	**rho (ρ) value**	**p-value**
STOP-BANG score vs BBS total score	0.45	0.01*	-0.37	0.040*
STOP-BANG score vs Posturography - Head tilt Front	0.4	0.02*	-0.42	0.02*
STOP-BANG score vs Posturography Shoulder alignment	0.45	0.01*	0.41	0.02*
STOP-BANG score vs Posturography Pelvic Tilt	0.39	0.03*	0.39	0.03*
STOP-BANG score vs Posturography Knee	0.42	0.02*	0.07	0.72
STOP-BANG score vs Posturography Ankle	0.36	0.4*	-0.07	0.69
STOP-BANG score vs Posturography Body Alignment Total	0.24	0.19	0.38	0.03*

T2DM- Type II Diabetes Mellitus; BBS- Berg Balance Scale; *p<0.05.

Table 3 represents that significant correlation was observed between STOP_BANG score and berg balance scores in both the groups. STOP-BANG scores also demonstrated statistically significant correlations with head tilt, shoulder alignment and pelvic tilt measurements in both groups. A significant correlation with knee alignment was observed only in T2DM without OSA group, whereas no significant correlation was identified in T2DM with OSA group. Similarly, no significant correlation was observed between STOP-BANG scores and ankle alignment in either group. The total body alignment score showed no significant correlation with STOP-BANG scores in the T2DM without OSA group, whereas a significant positive correlation was observed in T2DM with OSA group.

Discussion:

The present study investigated the association between obstructive sleep apnoea (OSA) risk and balance dysfunction among individuals with type two diabetes mellitus. The findings demonstrated that Participants with T2DM who wear at high risk for OSA exhibited significantly poorer balance performance, greater postural alignment abnormalities and increased sensory impairment compared to individuals with T2DM without OSA risk. These observations suggest that OSA may contribute additionally to functional instability in individuals already affected with diabetes related neuromuscular changes.

In the present study The T2DM with OSA group was significantly older and had a long duration of diabetes compared to T2DM only group. Increasing age and prolonged disease duration are well established contributors to postural instability

and functional decline in diabetes (8,24). Chronic hyperglycaemia over time may accelerate peripheral nerve dysfunction, musculoskeletal weakness and impact proprioceptive feedback thereby negatively affecting balance control. The findings are consistent with functional limitations reporting that older adults with long standing diabetes demonstrate greater impairment in gate and postural stability.

The significantly larger neck circumference observed in T2DM with OSA group reflects one of the characteristic anthropometric markers associated with obstructive sleep apnoea. Reduced resting oxygen saturation in this group further supports the presence of intermittent hypoxic changes commonly associated with sleep disordered breathing. Repeated nocturnal fragmentation, reaction time, cognitive attention and semiconductor integration all of which are essential for maintaining Posture control (12,25). This may partly explain the poorer balance outcomes identified among participants at high risk of OSA.

The berg balance scale score where significantly lower in type 2 DM with OSA group, indicating reduced functional balance performance. Although the absolute difference between group was modest, the findings remain clinically important because even mild balance impairment can substantially increase fall risk in individuals with diabetes. Furthermore, a high proportion of participation in T2DM with OSA group demonstrated medium fall risk categories compared to those without OSA. These results are in agreement with earlier studies reporting that both diabetes and OSA independently contribute to impaired postural stability and increased fall susceptibility (16,26).

The Posturography findings demonstrator significantly greater Impairment at the knee and overall body alignment in T2DM with OSA group. Altered lower limb alignment may reflect compensatory postural adaptation due to impaired proprioception, reduced muscular control and sensory deficits. Chronic intermittent hypoxia associated with OSA may additionally influence muscle endurance and neuromuscular condition, thereby worsening postural regulation. Interestingly, no statistically significant difference was identified in head and shoulder alignment, pelvic tilt or ankle alignment individually, suggesting that balance impairment may be multifactorial rather than localised to a single postural segment.

Sensory testing also revealed a significantly greater proposition of altered sensation among individuals with T2DM with OSA risk. Peripheral sensory impairment is one of the major contributors to balance dysfunction in diabetes because accurate somatosensory feedback is essential for maintaining stability (7,9). The coexistence of OSA may intensify neural dysfunction through oxidative stress, vascular compromise and inflammatory pathways. These combined effects may Twitter detonation in sensory integration and balance performance.

The correlation analysis demonstrates significant association between STOP-BANG score and balance related outcomes. Higher STOP-BANG scores were associated with poor BBS performance and greater postural abnormalities. Although most correlations were weak to moderate in strength, they support the possibility of an interactions between OSA severity and balance dysfunction in T2DM individuals. The absence of a significant correlation between HBA1C and BBS score suggests that glycaemic control alone may not fully explain balance impairment and other factors such as sleep quality, hypoxia, sensory dysfunction and diabetes duration may also play substantial roles.

Few limitations include, cross-sectional design prevents establishment of causal relationship between OSA and balance dysfunction. The sample size was relatively small and derived from a single tertiary care centre which may limit generalizability. OSA was identified using the STOP-BANG questionnaire rather than polysomnography, which remains the diagnostic gold standard. Additionally, potential confounding factors such as physical activity levels, medications use, muscle strength and severity of diabetic neuropathy were not extensively analysed. Further longitudinal studies using objective sleep assessment methods and larger multicentre populations are recommended to further clarify the relationship between OSA and balance dysfunction in T2DM.

CONCLUSION

The present study demonstrated that individuals with T2DM who were at high risk for OSA exhibited significantly poorer balance performance, greater postural alignment abnormalities and increased sensory impairment compared to individuals without OSA risk. Higher STOP-BANG scores were associated with reduced berg balance scale scores and altered postural parameters, suggesting a meaningful relationship between sleep disordered breathing and functional instability in T2DM patients. Although the observed correlations were weak to moderate, the findings indicate that OSA may act as additional contributing factor to balance dysfunction beyond the effects of diabetes alone.

These results highlight the importance of early screening for obstructive sleep apnoea and routine balance assessment in individuals with T2DM, particularly among these with longer disease duration and associated comorbidities. Integrating sleep evaluation, sensory assessment and balance rehabilitation into diabetes management may help reduce fall risk improve functional independence and enhance quality of life. Further longitudinal and multi centric studies using objective diagnostic methods such as polysomnography are recommended to better establish the causal relationship between OSA and balance dysfunction in individuals with Type 2 Diabetes mellitus.

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