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Original Research Article

ASSESSMENT OF VESTIBULAR FUNCTION AND ITS ASSOCIATION WITH GLYCAEMIC CONTROL IN PATIENTS WITH TYPE 2 DIABETES MELLITUS

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with multiple microvascular and neurological complications. Increasing evidence suggests that chronic hyperglycaemia may also affect the vestibular system, potentially contributing to impaired balance and increased risk of falls. However, vestibular dysfunction remains relatively under-recognised in routine diabetes care. The objective is to assess vestibular function in patients with T2DM and determine its association with glycaemic control.

Materials and Methods: A cross-sectional analytical study was conducted among 50 patients with T2DM. Demographic and clinical details, including duration of diabetes, were recorded. Fasting blood glucose, postprandial blood glucose and glycated haemoglobin (HbA1c) were assessed. Vestibular function was evaluated using the Romberg test, tandem walking test, Fukuda stepping test and head impulse test. Functional balance was assessed using the Timed Up and Go test. Associations between vestibular findings, glycaemic parameters and duration of diabetes were analysed statistically.

Results: The mean age of participants was 56.8 ± 8.2 years and the mean HbA1c was 7.8 ± 1.2%. Vestibular abnormality in at least one test was observed in 19 (38%) participants. Abnormal findings were more frequent among participants with HbA1c ≥7%. The TUG time was significantly higher in participants with poorer glycaemic control (11.2 ± 2.3 vs 9.1 ± 1.5 seconds; p=0.001). HbA1c showed positive correlations with impaired vestibular and balance performance.

Conclusion: Vestibular dysfunction was relatively common among patients with T2DM and was associated with poorer glycaemic control. Vestibular and balance assessment may help identify patients at increased risk of imbalance and falls.

Keywords: Type 2 diabetes mellitus; Vestibular function; Glycaemic control; HbA1c; Balance; Vestibular dysfunction; Hyperglycaemia.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterised by persistent hyperglycaemia and progressive involvement of multiple organ systems. The complications of diabetes are traditionally recognised in terms of neuropathy, retinopathy, nephropathy and cardiovascular disease; however, increasing evidence indicates that the auditory and vestibular systems may also be affected. The inner ear has a high metabolic requirement and depends on an adequate microvascular supply, making it potentially vulnerable to prolonged metabolic disturbances associated with diabetes mellitus. The vestibular system plays an essential role in maintaining spatial orientation, gaze stability and postural control by integrating information from the semicircular canals, otolith organs, visual system and somatosensory system. Impairment of any component of this system

can result in dizziness, imbalance, gait disturbances and increased susceptibility to falls. Diabetes-related vestibular dysfunction may develop through several mechanisms, including microangiopathy, oxidative stress, altered glucose metabolism, endothelial dysfunction and diabetic neuropathic changes affecting the vestibular end organs or their neural pathways. Although the precise anatomical and physiological mechanisms remain incompletely understood, experimental and clinical evidence supports a possible association between chronic hyperglycaemia and vestibular dysfunction.[1,2] Clinical studies have demonstrated that vestibular abnormalities are more frequent among individuals with diabetes than in non-diabetic populations. In a large population-based analysis, vestibular dysfunction was associated with longer duration of diabetes and higher serum glycated haemoglobin (HbA1c) concentrations. Importantly, vestibular dysfunction independently increased the odds of falling even after adjustment for peripheral neuropathy and retinopathy, suggesting that vestibular impairment may represent an independent contributor to diabetes-related functional disability.[3] More specific investigations have provided evidence of impairment involving different components of the peripheral vestibular system. Ward et al. reported abnormalities involving the semicircular canals as well as the otolith organs in patients with longstanding T2DM, with reduced performance on head-thrust dynamic visual acuity testing and abnormalities in cervical and ocular vestibular-evoked myogenic potentials (VEMPs).[4] Similarly, a study comparing patients with T2DM and healthy controls reported vestibular dysfunction in more than half of the diabetic participants and found that vestibular impairment was related to disease duration and HbA1c levels.[5] The association between glycaemic status and vestibular function is particularly important because HbA1c reflects average blood glucose exposure over the preceding several months and may therefore provide a useful indicator of the chronic metabolic burden on the vestibular system. Evidence from clinical studies suggests a possible dose-response relationship, wherein poorer glycaemic control and longer duration of diabetes are associated with greater vestibular impairment.[3,5] However, the available literature is not entirely consistent. A systematic review of auditory and vestibular function in individuals with T2DM found considerable variation in vestibular assessment methods and reported conflicting findings regarding peripheral vestibular end-organ involvement.[6] Recent evidence has further highlighted the clinical importance of vestibular dysfunction in T2DM. Individuals with diabetes who have vestibular dysfunction demonstrate poorer balance performance and reduced confidence in avoiding falls, with potential adverse effects on social participation and quality of life.[7] Meta-analytic evidence involving cVEMP has also indicated alterations in vestibular responses among individuals with diabetes, supporting the possibility of peripheral vestibular involvement.[8] Despite these observations, vestibular assessment is not routinely included in the evaluation of patients with T2DM, particularly in clinical settings where greater emphasis is placed on established diabetic complications. Evaluating vestibular function and examining its relationship with glycaemic control may therefore improve understanding of an under-recognised complication of diabetes. Hence, the present study was undertaken to assess vestibular function in patients with T2DM and determine its association with glycaemic control.

Aim and objectives: The study aimed to assess vestibular function in patients with type 2 diabetes mellitus and determine its association with glycaemic control. It also evaluated the relationship of vestibular function with glycated haemoglobin (HbA1c), fasting blood glucose, postprandial blood glucose, and duration of diabetes mellitus among the study participants.

MATERIALS AND METHODS

Study design: A cross-sectional analytical study was conducted in the Department of Physiology in collaboration with the Department of Medicine/ENT at a tertiary care teaching hospital.

Study participants: A total of 50 patients with type 2 diabetes mellitus (T2DM) were recruited for the study. Participants were selected by convenient sampling after fulfilling the predetermined eligibility criteria. Previous studies had demonstrated vestibular abnormalities in patients with T2DM and had evaluated their relationship with metabolic parameters, providing the rationale for assessing vestibular function in the present study.[9,10]

Inclusion criteria:

Patients were included if they:

1. Were diagnosed with T2DM according to standard diagnostic criteria.
2. Were aged 40–70 years.
3. Had a documented history of T2DM.
4. Were willing to participate and provided written informed consent.
5. Were able to understand and perform the vestibular and balance assessments.

Exclusion criteria:

Patients were excluded if they had:

1. A previous history of diagnosed vestibular disorders or recurrent vertigo unrelated to diabetes.
2. Previous ear surgery or significant chronic ear disease.
3. Known neurological disorders affecting balance or gait.
4. Severe visual impairment.
5. Significant musculoskeletal disorders affecting standing or walking.
6. History of head injury affecting vestibular function.

7. Current use of medications known to substantially affect vestibular function.
8. Other major systemic illnesses that could independently influence balance or vestibular performance.

Assessment of glycaemic control: Glycaemic status was assessed using fasting blood glucose (FBG), postprandial blood glucose (PPBG), and glycated haemoglobin (HbA1c). Blood samples were collected following standard laboratory procedures. HbA1c was considered the principal indicator of long-term glycaemic control. Participants were categorised into groups based on their glycaemic control according to the HbA1c values. Assessment of glycaemic parameters along with vestibular testing has been used in previous investigations of vestibular function among individuals with T2DM.[9,10]

Assessment of vestibular function: Vestibular function was assessed using a standardised clinical vestibular assessment protocol. The participants underwent Romberg test, tandem walking test, Fukuda stepping test, and head impulse test. All assessments were performed in a quiet room by the same trained investigator to minimise inter-observer variation.

Romberg test: Participants were asked to stand upright with their feet together and arms by their sides, first with their eyes open and subsequently with their eyes closed. Excessive postural sway or loss of balance after eye closure was considered an abnormal response.

Tandem walking test: Participants were instructed to walk in a straight line by placing the heel of one foot directly in front of the toes of the opposite foot. Difficulty in maintaining the tandem position, excessive deviation or inability to complete the test was considered abnormal.

Fukuda stepping test: Participants stood with their arms extended forwards and eyes closed and were instructed to march in place for a predetermined number of steps. The degree of rotation and displacement from the initial position was assessed as an indicator of vestibular asymmetry.

Head impulse test: The participant was asked to maintain visual fixation on a stationary target while the examiner performed small, rapid and unpredictable horizontal head movements. Corrective saccades following head movement were considered suggestive of impaired vestibulo-ocular reflex function. Objective vestibular studies in T2DM have demonstrated abnormalities involving semicircular canal and otolith function.[9]

Assessment of balance: Balance performance was assessed using the Timed Up and Go (TUG) test. Participants were instructed to rise from a chair, walk a predetermined distance, turn around, return and sit down. The time required to complete the task was recorded. A longer completion time indicated poorer functional mobility and balance.

Outcome measures: The primary outcome was the presence of vestibular dysfunction based on the vestibular assessment findings. Secondary outcomes included the relationship between vestibular function and HbA1c, FBG, PPBG and duration of T2DM.

Data analysis: The collected data were entered into a Microsoft Excel spreadsheet and analysed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The association between vestibular function and glycaemic parameters was assessed using appropriate correlation and comparative statistical tests. Pearson's or Spearman's correlation analysis was used according to the distribution of the data. A p-value <0.05 was considered statistically significant.

RESULTS

Results are presented in table 1 to 5. A total of 50 patients with type 2 diabetes mellitus were included in the study [Table 1]. The mean age of the participants was approximately 57 years. Vestibular abnormalities were identified in a considerable proportion of the participants, with poorer vestibular performance being more frequently observed among those with inadequate glycaemic control. The majority of participants had suboptimal glycaemic control, with 32 (64%) having HbA1c values ≥7% [Table 2]. Overall, 19 participants (38%) demonstrated abnormal findings in at least one vestibular assessment. Tandem walking showed abnormalities in 32% of participants, followed by the Romberg test (28%), Fukuda stepping test (26%) and head impulse test (22%). Participants with HbA1c ≥7% demonstrated a greater frequency of abnormal vestibular findings than those with HbA1c <7%. The difference was statistically significant for the Romberg and head impulse tests. Participants with poorer glycaemic control also required significantly more time to complete the TUG test [Table 3]. A positive correlation was observed between HbA1c and impaired vestibular and balance performance. Higher HbA1c values were associated with poorer Romberg and tandem walking performance and greater TUG completion time. Duration of diabetes also showed a positive association with most vestibular and balance parameters. These findings were in agreement with previous observations that vestibular dysfunction in T2DM may be related to disease duration and HbA1c levels [Table 4].

Table 1: Demographic and clinical characteristics of the study participants (n=50)

Parameter	Findings
Age (years), mean ± SD	56.8 ± 8.2
Male, n (%)	29 (58.0)
Female, n (%)	21 (42.0)

Duration of diabetes (years), mean ± SD	8.1 ± 4.7
Fasting blood glucose (mg/dL), mean ± SD	139.6 ± 28.4
Postprandial blood glucose (mg/dL), mean ± SD	196.8 ± 42.6
HbA1c (%), mean ± SD	7.8 ± 1.2
HbA1c <7%, n (%)	18 (36.0)
HbA1c ≥7%, n (%)	32 (64.0)
History of dizziness/imbalance, n (%)	17 (34.0)
Previous history of fall, n (%)	8 (16.0)

Table 2: Findings of clinical vestibular assessment among the participants (n=50)

Vestibular assessment	Normal, n (%)	Abnormal, n (%)
Romberg test	36 (72.0)	14 (28.0)
Tandem walking test	34 (68.0)	16 (32.0)
Fukuda stepping test	37 (74.0)	13 (26.0)
Head impulse test	39 (78.0)	11 (22.0)
At least one abnormal vestibular test	31 (62.0)	19 (38.0)

Table 3: Comparison of vestibular findings according to glycaemic control

Parameter	HbA1c <7% (n=18)	HbA1c ≥7% (n=32)	p-value
Romberg abnormality, n (%)	2 (11.1)	12 (37.5)	0.047
Tandem walking abnormality, n (%)	3 (16.7)	13 (40.6)	0.081
Fukuda abnormality, n (%)	2 (11.1)	11 (34.4)	0.064
Head impulse abnormality, n (%)	1 (5.6)	10 (31.3)	0.038
≥1 abnormal vestibular test, n (%)	4 (22.2)	15 (46.9)	0.082
TUG test (seconds), mean ± SD	9.1 ± 1.5	11.2 ± 2.3	0.001

Table 4: Correlation of vestibular and balance parameters with glycaemic variables

Variable	HbA1c	Fasting blood glucose	Duration of diabetes
Romberg score	r = 0.38, p = 0.006	r = 0.29, p = 0.041	r = 0.32, p = 0.023
Tandem walking score	r = 0.41, p = 0.003	r = 0.31, p = 0.028	r = 0.35, p = 0.013
Fukuda deviation	r = 0.34, p = 0.016	r = 0.27, p = 0.056	r = 0.30, p = 0.034
TUG time	r = 0.46, p = 0.001	r = 0.33, p = 0.019	r = 0.39, p = 0.005

DISCUSSION

The present study evaluated vestibular function in 50 patients with type 2 diabetes mellitus (T2DM) and examined its relationship with glycaemic control. The major finding was that vestibular abnormalities were relatively common, with 38% of participants demonstrating an abnormality in at least one clinical vestibular test. Furthermore, participants with HbA1c ≥7% showed poorer vestibular and functional balance performance than those with HbA1c <7%. Positive correlations were also observed between HbA1c, duration of diabetes and several vestibular or balance parameters. The observed frequency of vestibular abnormality supports the concept that the vestibular system may represent an under-recognised target of chronic diabetes-related complications. Diabetes can affect several sensory systems simultaneously, including peripheral somatosensation, vision and vestibular function. Earlier experimental and clinical evidence has suggested that metabolic and microvascular alterations associated with diabetes may affect the labyrinth and vestibular neural pathways.[11,12] The proposed mechanisms include microangiopathy, oxidative stress, altered glucose metabolism, neuronal degeneration and impaired vascular supply to the inner ear. However, the precise site and mechanism of vestibular injury remain incompletely established. The finding of abnormal vestibular function in 38% of the present participants was clinically important. Previous studies using objective vestibular methods have reported abnormalities in diabetic populations, although the reported prevalence has varied according to the test employed. VEMP studies have demonstrated abnormalities involving the otolith organs and vestibular reflex pathways in individuals with diabetes.[13,14] A systematic review and meta-analysis also reported significant differences in cVEMP amplitude between individuals with diabetes and healthy controls, supporting the presence of peripheral vestibular involvement.[15] These findings suggest that vestibular dysfunction may occur even in the absence of prominent vestibular symptoms. In the present study, abnormalities were observed most frequently during tandem walking and the Romberg test. These findings may reflect the combined contribution of vestibular, visual and somatosensory inputs to postural control. Maintenance of upright posture depends on appropriate integration of these sensory systems, and impairment of one system may be compensated for by the others during uncomplicated conditions. When visual information is removed or the support surface is altered, however, greater dependence is placed on vestibular information. Studies in diabetic neuropathy have demonstrated increased postural sway, particularly under challenging sensory conditions, indicating impaired sensory integration and compensatory postural control.[16,17] Poorer glycaemic control was associated with greater vestibular impairment in the present study. Participants with HbA1c ≥7% had more frequent abnormalities in the Romberg and

head impulse tests and demonstrated significantly longer TUG completion times. This observation is biologically plausible because prolonged exposure to hyperglycaemia can promote endothelial dysfunction, oxidative injury and microvascular changes. Evidence from electrophysiological vestibular investigations has demonstrated positive associations between HbA1c or fasting glucose and VEMP latency, suggesting that chronic metabolic dysregulation may adversely affect vestibular pathways.[18] Similar associations between diabetic status and vestibular abnormalities have also been described using objective vestibular testing.[19] The positive relationship between duration of diabetes and impaired balance observed in the present study further supported the possibility of cumulative metabolic injury. Longer duration of diabetes is commonly associated with increasing prevalence and severity of peripheral neuropathy, which itself can compromise postural control.[20] Nevertheless, vestibular impairment should not be considered merely a consequence of peripheral neuropathy. Studies have demonstrated vestibular abnormalities in patients with diabetes both with and without clinically evident diabetic polyneuropathy, suggesting that vestibular involvement may occur independently.[21] Recent evidence has similarly shown that vestibular dysfunction and peripheral neuropathy can coexist in diabetes and may contribute separately to impaired balance.[22] The findings also have implications for fall prevention. The TUG performance was significantly poorer among participants with inadequate glycaemic control. Diabetes itself has been associated with increased fall risk, while vestibular dysfunction may further increase this risk by reducing the ability to maintain orientation during movement.[23] In patients with T2DM, vestibular dysfunction has been associated with postural instability and a greater frequency of falls, irrespective of the presence of diabetic polyneuropathy.[24] Similarly, recent research has shown that vestibular dysfunction can contribute to impaired standing balance in individuals with T2DM, alongside peripheral neuropathy.[25] The clinical relevance of identifying vestibular dysfunction extends beyond fall prevention. Vestibular impairment may influence gait, physical activity, confidence during mobility and participation in daily activities. Individuals with T2DM and vestibular dysfunction have been reported to demonstrate poorer balance performance, reduced falls-efficacy and lower social participation and quality of life.[26] Therefore, vestibular screening may have value in patients with longstanding or poorly controlled diabetes, particularly those reporting dizziness, imbalance or previous falls. The present study had certain limitations. The sample size was relatively small, and the cross-sectional design prevented establishment of a causal relationship between hyperglycaemia and vestibular dysfunction. The study also relied predominantly on clinical vestibular tests rather than comprehensive objective investigations such as VEMP, video head impulse testing or computerised dynamic posturography. Peripheral neuropathy and other diabetic complications may also have influenced balance performance. Future studies involving larger samples, healthy controls and objective vestibular investigations may provide more definitive evidence regarding the relationship between glycaemic control and vestibular function. Overall, the findings indicated that vestibular dysfunction and impaired balance were relatively frequent among patients with T2DM and were more evident in those with poorer glycaemic control. Incorporating simple vestibular and balance screening into diabetes-related clinical assessment may help identify individuals at increased risk of imbalance and falls.

CONCLUSION

Vestibular dysfunction was observed in a considerable proportion of patients with type 2 diabetes mellitus and was associated with poorer glycaemic control and longer disease duration. The findings suggested that vestibular assessment may be useful in identifying patients at increased risk of impaired balance and falls, particularly those with suboptimal glycaemic control.

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