REVIEW ARTICLE

Understanding Postural Control Deficits in Type 2 Diabetes Mellitus: A Narrative Review of Contributing Factors

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Abstract

Chronic diabetes mellitus (DM) represents a major global health challenge, significantly impacting morbidity and mortality through its direct effects and long-term complications. This narrative review explores the complex relationship between type 2 DM (T2DM) and balance impairments. The prevalence of diabetes has surged, with estimates suggesting 299 million cases by 2025. T2DM is known to affect balance, increasing the risk of falls and deteriorating quality of life. The review synthesizes evidence on the mechanisms underlying balance impairments in T2DM, including the roles of peripheral and autonomic neuropathy, as well as musculoskeletal changes. Key findings indicate that peripheral neuropathy, autonomic dysfunction, and musculoskeletal deterioration significantly impair balance. Interventions such as physical therapy and appropriate footwear have shown promise in improving balance and reducing fall risk. The review also highlights that balance issues are more pronounced in low-income countries and among younger populations in middle-income countries, where diabetes prevalence is rising. This review synthesizes findings from a range of relevant studies, revealing a strong correlation between diabetes and balance problems. This review underscores the importance of incorporating balance training into early diabetes management and recommends a multidisciplinary approach for effective intervention. Future research should focus on long-term intervention outcomes and innovative therapeutic strategies to manage balance impairments in T2DM.

Key words: Autonomic neuropathy, balance impairments, fall risk, musculoskeletal changes, peripheral neuropathy, type 2 diabetes mellitus

INTRODUCTION

Chronic diabetes mellitus (DM) is a significant global health issue, leading to high morbidity and mortality, including long-term complications.[1] According to the World Health Organization (WHO), diabetes cases rose from 110.4 million in the 1990s to 210 million in the 2000s, with an estimated 299 million cases by 2025.[2] Type 2 DM (T2DM) is associated with a range of complications, including balance impairments. These impairments contribute to increased fall risk and decreased quality of life.[3] This review aims to comprehensively analyze the mechanisms behind balance impairments in T2DM, evaluate the clinical evidence, and explore management strategies. Furthermore, the review first discusses the key mechanisms contributing to these impairments, followed by an overview of clinical evidence and a discussion of management strategies.

SEARCH STRATEGY

A comprehensive literature search was conducted in databases including PubMed, Scopus, and Google Scholar to identify relevant articles. Key terms such as "Type 2 Diabetes Mellitus," "balance impairments," and "neuropathy" were used to identify studies and reviews that provide insight into the mechanisms and management of postural control deficits.

Studies were selected based on their relevance to the topic, with a focus on key findings related to contributing factors,

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assessment methods, and effective interventions. The synthesis of this literature aims to provide a broad overview of the current understanding and management of these deficits.

Key findings and contributing factors

- A review of the literature reveals that postural control deficits in T2DM are multifaceted, stemming from a combination of neurological, musculoskeletal, and sensory impairments. Our synthesis of the included studies highlights the key mechanisms and effective interventions for these issues, as summarized in Table 1.
- Neurological factors: The role of neuropathy
  The most prominent factor contributing to balance impairment is neuropathy. Several studies confirm the link between diabetic peripheral neuropathy (DPN) and postural instability. For instance, Jaiswal *et al*. (2015) and Scherer *et al*. (2017) both found that peripheral neuropathy significantly impairs balance and stability, primarily by compromising sensory input and proprioception. Similarly, Menz *et al*. (2007) showed that impaired sensory feedback directly affects balance, leading to increased postural sway.
  Beyond the peripheral nervous system, autonomic neuropathy also plays a critical role. Research by Vincent *et al*. (2003; 2019) demonstrated that autonomic dysfunction can lead to orthostatic hypotension, which in turn exacerbates balance impairments and increases the risk of falls.
- Musculoskeletal changes and sensory deficits
  Diabetes can also negatively impact the musculoskeletal system, further compromising balance. Kumar *et al*. (2016) identified that decreased muscle strength and joint mobility are associated with impaired balance. This is compounded by reduced plantar tactile sensitivity, a factor that can be mitigated with appropriate footwear and orthotics, as shown by Kaufman *et al*. (2009). These findings underscore the importance of addressing both the neurological and mechanical aspects of the disease.
- Interventions and management strategies
  The literature also provides strong evidence for the effectiveness of specific interventions. Randomized controlled trials by Thomas *et al*. (2019) and Pollock *et al*. (2017) showed that structured physical therapy and balance training programs lead to significant improvements in stability and reduced fall risk. These findings suggest that targeted exercises can help compensate for some of the underlying deficits. Furthermore, as demonstrated by Kaufman *et al*. (2009), interventions as simple as using appropriate footwear and orthotics can also have a positive impact on balance.

DISCUSSION

Balance impairments in T2DM are influenced by several factors, including peripheral and autonomic neuropathy and musculoskeletal changes. Effective management strategies involve physical therapy, proper footwear, and patient education. Multidisciplinary approaches are recommended for comprehensive care.

In this review, we established a connection between balance and diabetes.[1] Chronic DM is a major global health concern, contributing significantly to illness and mortality due to both the disease itself and its long-term effects.[19] India, a rapidly developing country with a large diabetic population, faces declining health standards among its young, economically active demographic, which escalates healthcare costs. With an estimated 65.1 million diabetes cases in 2013, India ranks second globally, following China. Projections indicate that by 2035, this number could reach 109.0 million.[20] Research shows that diabetes prevalence is lower in high-income countries (HICs) and higher in low-income countries. In HICs, diabetes predominantly affects individuals over 50, whereas in middle-income countries, younger, economically productive individuals are more affected. As life expectancy increases, the proportion of the elderly also rises.[19] The ICMR-INDIAB study is the largest national study on diabetes in India, covering data from 15 states and representing 51% of the adult population. According to WHO guidelines, diabetes affects an estimated 7.3% of the Indian population. Furthermore, prediabetes prevalence is estimated at 10.3%, though some predictive models suggest it could be as high as 24.7%. Prevalence is higher in urban areas (11%) compared to rural regions (5%), with mainland states showing 8% and the northeast at 5%. Untreated diabetes impacts approximately 193 million people globally, increasing the risk of complications.[21] Diabetes can lead to severe issues as it affects multiple organ systems. Complications are categorized into microvascular (retinopathy, nephropathy, and neuropathy) and macrovascular (peripheral vascular disease, heart disease, and stroke) issues. Key risk factors for vascular complications in diabetics, particularly those with type 2 diabetes, include hyperglycemia, insulin resistance, dyslipidemia, hypertension, tobacco use, and obesity. Peripheral vascular disease can lead to severe outcomes such as amputation, gangrene, and non-healing wounds. In this review, we analyzed 15 articles, which revealed an association between balance performance and diabetes.[22]

In T2DM, oxidative phosphorylation plays a key role in energy production. However, the disease's poor glucose regulation adversely affects both the mechanical and metabolic functions of skeletal muscles. Specifically, T2DM can lead to the abnormal accumulation of free fatty acids and triglycerides in muscle cells due to disrupted fatty-acid metabolism and impaired glucose transport and phosphorylation. Insulin resistance further worsens these issues by reducing the effectiveness of muscle mitochondria and impairing substrate utilization. This combination of factors leads to diminished muscle performance and strength. As a result, people with T2DM often experience significant declines in muscle function. Recent studies have also shown

Table 1: Summary of included studies

Study	Year	Study design	Sample size	Participants	Balance assessment method	Key findings	Interventions (if applicable)
Menz *et al*.[4]	2004	Cross-sectional	150	T2DM patients	Tinetti balance and gait scale	Higher fall risk and gait disturbances in T2DM patients	Not applicable
Jaiswal *et al*.[5]	2015	Cohort study	200	T2DM patients	Berg balance scale	Peripheral neuropathy significantly affects balance	The exercise program improved balance
Vincent *et al*.[6]	2003	Cross-sectional	120	T2DM patients	Dynamic gait index	Autonomic neuropathy is linked to impaired balance and orthostatic hypotension	Not applicable
Thomas *et al*.[7]	2019	RCT	100	T2DM patients	Timed up and go test	Structured physical therapy improved balance and reduced fall risk	Physical therapy intervention
Kumar *et al*.[8]	2016	Cross-sectional	80	T2DM patients	Functional reach test	Decreased muscle strength and joint mobility affect balance	Not applicable
Pollock *et al*.[9]	2015	Cohort study	250	T2DM patients	Balance error scoring system	Significant balance and gait disturbances observed	Balance training exercises
Sung *et al*.[10]	2014	Review	30 studies	Mixed	Various	Diabetes impacts vestibular function, but evidence is limited	Not applicable
Kaufman *et al*.[11]	2009	Cross-sectional	60	T2DM patients	Foot function index	Proper footwear and orthotics improve balance	Customized footwear
Boulton *et al*.[12]	2008	Review	40 studies	Mixed	Various	Foot ulcers and deformities exacerbate balance issues	Foot care and patient education
Elder *et al*.[13]	2015	RCT	90	T2DM patients	Balance and mobility scale	Exercise interventions improve balance and reduce fall risk	Exercise intervention
Tandon *et al*.[14]	2016	Cohort study	70	T2DM patients	Postural stability test	Neuropathy significantly impairs balance and stability	Not applicable
Scherer *et al*.[15]	2017	Cross-sectional	130	T2DM patients	Balance evaluation systems test	Peripheral neuropathy correlates with balance impairments	Not applicable
Menz *et al*.[16]	2007	Cross-sectional	110	T2DM patients	Clinical test of sensory interaction and balance	Impaired sensory feedback affects balance	Not applicable
Pollock *et al*.[17]	2017	RCT	85	T2DM patients	Balance and gait test	Balance training programs improve stability and gait	Balance training
Vincent *et al*.[18]	2019	Cohort study	95	T2DM patients	Static and dynamic balance tests	Autonomic dysfunction exacerbates balance impairments	Not applicable

T2DM: Type 2 diabetes mellitus

that diabetes accelerates damage to skeletal muscles, leading to a rapid decrease in muscle quality, which is linked to the disease's prolonged progression.[23]

Maintaining equilibrium relies on information from three sensory systems: Somatosensory, visual, and vestibular. These systems help determine the body's orientation in various contexts. According to Black and Mirka, "somatosensory and visual inputs provide references to the support surface and the surrounding visual environment, while vestibular input provides a reference to gravity." Therefore, the vestibular system is crucial for determining vertical orientation relative

to the Earth, whereas the other senses offer information about relative direction. When somatosensory or visual inputs are compromised, the vestibular system becomes critical for maintaining balance.[24]

Evidence suggests that DPN worsens postural instability. Individuals with DPN exhibit greater sway in both the anterior-posterior and medial-lateral directions and increased sway speed, compared to age-matched controls. While it is well-established that both neuropathy and retinopathy associated with diabetes heighten the risk of falls, other factors may also influence gait and balance. Research has shown a link between reduced pressure and vibration sensitivity and an increased incidence of falls. In addition, due to diminished proprioceptive feedback and greater stride variability, older adults with diabetes tend to walk more slowly, which further elevates their fall risk.[24]

CONCLUSION

Balance impairments in T2DM are complex and require targeted interventions. This narrative review identified a correlation between diabetes and balance issues. In addition, a significant link between balance performance and diabetes was uncovered. These findings help medical professionals consider these factors in fall prevention strategies and incorporate balance training into early-stage diabetes rehabilitation programs. Future research should focus on refining intervention strategies and further elucidating the underlying mechanisms.

Limitations

The review is limited by the heterogeneity of included studies and potential publication bias. In addition, most studies focused on short-term outcomes.

Future research directions

Future studies should investigate the long-term effects of interventions and explore novel therapeutic approaches to manage balance impairments in T2DM.

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