Literature review

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Oscillations in static balance related to type 2 diabetes mellitus – a systematic review

Oscilações no equilíbrio estático relacionadas a diabetes mellitus tipo 2 – uma revisão sistemática

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ABSTRACT | INTRODUCTION: Type 2 diabetes mellitus (DM2) is a chronic systemic disease linked to changes in lifestyle, genetic and environmental factors, causing complications such as peripheral diabetic neuropathy (PDN). In addition, people with DM2 have a delay in nerve conduction in motor and sensory pathways, which can lead to changes in balance. **OBJECTIVE:** To describe static balance changes in patients with DM2. **MATERIALS AND METHODS:** The systematic review started in October 2021 with the last search occurring in March 2023, the articles were selected by two authors independently from the Pubmed, Scopus and Web of Science databases. Following the protocol registered in PROSPERO and described based on the PRISMA recommendations, observational studies were selected without restriction on year of publication and language, involving DM balance at any age. **RESULTS:** 20 articles were chosen with DM and NPD individuals in a total of 1564 volunteers, demonstrating that DM causes changes in the speed and displacement of the COP, altering the static balance and the presence of NPD worsens body stability due to sensory-motor changes. **CONCLUSION:** Individuals with DM and NPD demonstrate changes in postural stability such as velocity and displacement of the center of pressure (COP) for the AP and ML directions, with or without visual information and in the presence of DPN.

KEYWORDS: Diabetes Mellitus. Postural Balance. Diabetic Neuropathies. Systematic Review.

RESUMO | INTRODUÇÃO: A diabetes mellitus tipo 2 (DM2) é uma doença crônica sistêmica ligada às mudanças no estilo de vida, fatores genéticos e ambientais, ocasionando complicações como a neuropatia diabética periférica (NDP). Além disso, pessoas com DM2 apresentam um retardo na condução nervosa das vias motoras e sensoriais, podendo levar a alterações no equilíbrio. **OBJETIVO:** Descrever as alterações de equilíbrio estático em pacientes com DM2. **MATERIAIS E MÉTODOS:** A revisão sistemática iniciou em outubro de 2021 ocorrendo a última busca em março de 2023, os artigos foram selecionados por dois autores de forma independente nas bases de dados Pubmed, Scopus e Web of Science. Seguindo o protocolo registrado no PROSPERO e descrito com base nas recomendações do PRISMA, foram selecionados estudos observacionais sem restrição a ano de publicação e idioma, envolvendo equilíbrio de DM em qualquer idade. **RESULTADOS:** Foram eleitos 20 artigos com indivíduos DM e NPD em um total de 1564 voluntários, demonstrando: DM causa mudança na velocidade e deslocamento do COP alterando o equilíbrio estático, a presença da NPD piora a estabilidade corporal devido as alterações sensitivo motoras. **CONCLUSÃO:** Indivíduos com DM e NPD demonstram alterações na estabilidade postural como velocidade e deslocamento do centro de pressão (COP) para as direções AP e ML, com ou sem informação visual e na presença da NPD.

PALAVRAS-CHAVE: Diabetes Mellitus. Equilíbrio Postural. Neuropatias Diabéticas. Revisão Sistemática.

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Introduction

Diabetes mellitus (DM) stands out as a worldwide epidemic due to the high prevalence and increasing incidence of the disease in the world.[1] The cause associated with type 2 DM (DM2), the most frequent type, is mainly linked to changes in lifestyle, genetic and environmental factors.[1] The International Diabetes Federation (IDF) in 2010 estimated that there would be around 438 million people in the world with DM in 2025, however, this number was exceeded ahead of schedule. In 2021, in adults between 20 and 79 years old, the worldwide prevalence was 536.6 million people with DM, estimating 643 million in 2030 and 783 million adults with DM by 2045, while in Brazil, the prevalence of adults with DM was 15.7 million in 2021 and an estimated 23.2 million in 2045.[2]

Because it is a chronic systemic disease, it causes several complications such as retinopathy, deficit in the locomotor system, Diabetic Peripheral Neuropathy (DPN), changes in postural balance and consequently risk of falls.[3] Postural balance is the ability to sustain the body's center of gravity in relation to the base of support[4], being dependent on the interaction between sensory, vestibular and visual information, as well as the use of postural strategies arising from oscillatory movements around the hip and ankle joints.[5,6] Balance can be classified as static or dynamic, which consist of low body sway by maintaining a posture or performing motor tasks, respectively.[7]

Previous studies have shown changes in the static balance of people with DM[3,8], as individuals with DM may have changes in postural stability due to delayed nerve conduction of motor and sensory pathways, reduced muscle strength and joint mobility leading to gait abnormalities.[9-11] This postural instability becomes more significant with DPN, which is characterized by sensory and motor changes resulting from hyperglycemia. This condition alters the microvascularization leading to axonal thickening and decreased blood flow, generating hypoxia in the nerves. Symptoms such as numbness, paresthesia, lack of sensitivity to temperature and pain are characteristic of DPN.[12] These sensory-motor changes contribute to the development of ulcers, deformities, lower limb amputations, and other microvascular complications, causing an increase in hospitalized people and cardiovascular deaths due to autonomic advancement.[13]

However, the literature does not present homogeneous data regarding the emergence of changes in balance in people with DM, regarding their association or not with DPN, as a result, the set of these data can offer important information on which measures of postural stability are affected by DM and under what conditions they occur. Therefore, this systematic review aims to describe static balance changes in patients with type 2 DM.

Materials and methods

This article is a Systematic Review of the literature described based on the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020[14] registered on the PROSPERO platform (CRD42020157495).

Eligibility criteria

For inclusion, studies needed to meet the following criteria: (1) articles published and fully available in scientific databases; (2) unrestricted by year of publication, language, and age; (3) observational studies involving the balance of people with type 2 DM. As exclusion criteria were used: articles that presented results of individuals with type 1 DM, gestational diabetes or who have other diseases that may interfere with the condition of the subjects and analysis of the results such as cerebrovascular accident, Parkinson's and leprosy.

Sources of information and search

The last search was carried out in March 2023 in the databases Pubmed, Scopus e Web of Science. The following descriptors were used: "Diabetes mellitus", "diabetic neuropathy", "diabetic peripheral neuropathy" "postural balance", "balance", "static balance", "static balance control", "postural stability", "observational study". These were combined with Boolean operators to build the search strategy and used separately in the manual search to include studies not selected by the chosen strategy. The reference list of selected articles was analyzed for selection of eligible studies. The strategy used for each database is outlined in Table 1.

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Table 1. Article Search strategy in databases

PubMed
#1 "Diabetes Mellitus" (Title/Abstract) OR "Diabetic Neuropathy" (Title/Abstract) OR "Diabetic Peripheral Neuropathy" (Title/Abstract)
#2 "Postural Balance" (Title/Abstract) OR "Balance" (Title/Abstract) OR "Static balance" (Title/Abstract) OR "Static balance control" (Title/Abstract) OR "Postural stability" (Title/Abstract)
#3 "Observational Study" (Title/Abstract)
#4 #1 AND #2 AND #3

Scopus
"Diabetes Mellitus" (Article title, Abstract, Keywords) OR "Diabetic Neuropathy" (Article title, Abstract, Keywords) OR "Diabetic Peripheral Neuropathy" (Article title, Abstract, Keywords) AND "Postural Balance" (Article title, Abstract, Keywords) OR "Balance" (Article title, Abstract, Keywords) OR "Static balance" (Article title, Abstract, Keywords) OR "Static balance control" (Article title, Abstract, Keywords) OR "Postural stability" (Article title, Abstract, Keywords) AND "Observational Study" (Article title, Abstract, Keywords)

Web of Science
#1 TS= ("Diabetes Mellitus" OR "Diabetic Neuropathy" OR "Diabetic Peripheral Neuropathy")
#2 TS=("Postural Balance" OR "Balance" OR "Static balance" OR "Static balance control" OR "Postural stability")
#3 TS= ("Observational Study")
#4 #1 AND #2 AND #3

Source: the authors (2023).

Selection of studies

According to the eligibility criteria, two authors independently selected the articles following the following steps: 1- reading the title and abstract, 2- reading the full article. For divergences in selection, a third author was consulted.

Data extraction

An extraction form was developed by the researchers with the following data: title, year, purpose of the study, type of study, sample and division of groups, participant characteristics, inclusion and exclusion criteria, instrument used to assess balance, results most relevant and conclusion. To use the form, a pilot was carried out with the extraction of three articles, followed by adjustment. This step was performed by two independent authors. The information was compared and the differences were resolved by consulting the article again and with the help of the third author.

Assessment of study quality and risk of bias

The risk of bias in the studies was analyzed using an adaptation of the NOS (Newcastle-Ottawa Scale). Originally it was built with the purpose of evaluating cohort and case-control studies, however the adaptation allows the evaluation of cross-sectional studies. Articles can receive a maximum score of 7 stars, best score, according to the domains of group selection, comparability between groups and determination of outcomes or result of interest.

Data analysis

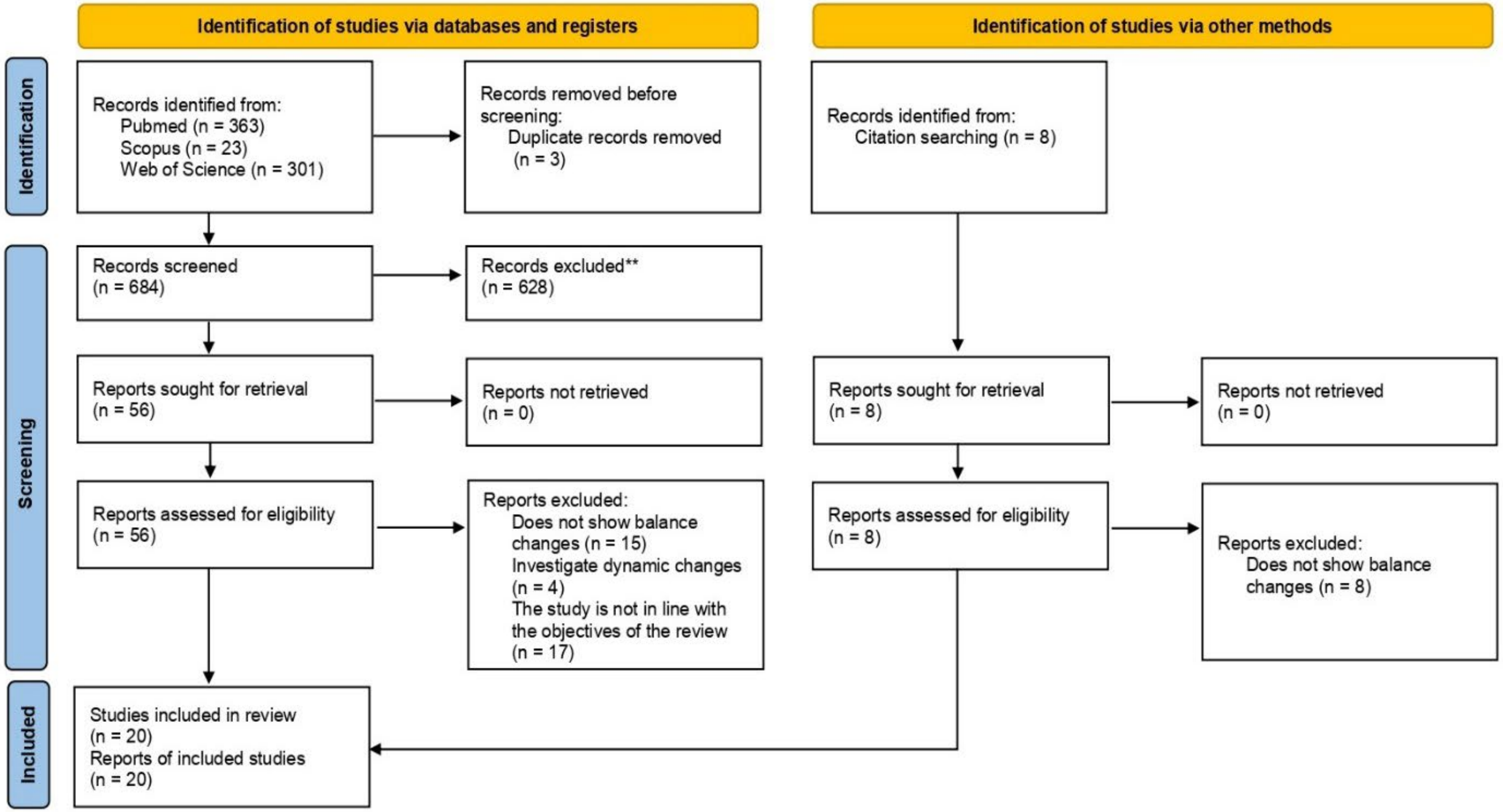
A descriptive analysis of the data was performed considering the heterogeneity of the studies. The average and standard deviation were used for data related to the characteristics of the subjects. The instruments used between the studies were reported in absolute numbers. The other results were presented in figure, table and charts.

Results

Selection of studies

The searches identified 687 studies, with exclusion of 628 after reading the title and abstract and 36 after reading the complete text. A total of 20 articles were selected to compose this Review, the process is detailed in Figure 1.

Figure 1. Selection of articles included in the systematic review Oscillations in static balance related to type 2 diabetes mellitus



Source: the authors (2023).

Characteristics of the studies

The studies gathered a total of 1583 volunteers, with a sample size ranging from 14 to 151 and age range from 18 to 80 years. The duration of diabetes ranged from 7 years to 19 years, encompassing 585 DM2 individuals and 520 neuropaths. The characteristics of the studies are described in Table 2.

Balance assessment measures

The force platform was the most used evaluation instrument, 9 articles; followed by the postural stability test, 3 articles; and unipodal support test and dynamometer, 2 of the articles.

Table 2. Articles included in the systematic review "Oscillations in static balance related to type 2 diabetes mellitus" (to be continued)

Author, year	Groups (N)	Age Mean±SD	Instrument / test	Results	NOS
Jiang *et al.*, 2022	DM (48) DPN subclinic (45) DPN confirmed (51) healthy (32)	(47.68) 58.5 (55.68) 61.5 (53. 68) 60.5 (58. 63) 60.5	-Triaxial accelerometer and gyroscope	When compared with healthy subjects, the CoM and ankle sway area and speed were greater in subclinical DPN and confirmed when they were in OE. On the other hand, with CE, the DM and subclinical and confirmed DPN groups presented greater hip oscillation, speed and oscillation of the CoM.	7
Chatzistergos *et al.*, 2019	Falha no PGT-DPN (35) Aprovado no PGT-DPN (34)	58+8 58+8	- Plantar pressure -Sway Analysis Module - Dynamometer - Paper grip test	There was greater postural sway in individuals who had lower muscle strength through the hallux, evidenced by the failure in the PGT compared to those who passed, in addition to presenting greater displacements in the AP direction, especially when wearing shoes and with CE.	5
Kim *et al.*, 2018	DM (8) NPD (6)	46.5+10.9 56.3±5.3	-Force platform	DPN group had significantly greater COP shifts during platform disturbance (8 directions) compared to DM group.	7

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Table 2. Articles included in the systematic review "Oscillations in static balance related to type 2 diabetes mellitus" (continuation)

Author, year	Groups (N)	Age Mean±SD	Instrument / test	Results	NOS
Lee *et al.*, 2017	Healthy young people (20) Healthy elderly (20) Elderly-DM (20)	22.1±1.7 70±4.9 71.9±5.6	- Force platform - Dynamometer	The DM elderly group showed greater displacement, speed and amplitude in the ML direction, in relation to the healthy elderly and young people.	6
Kukidome *et al.*, 2017	Healthy young people (60) Young people -DM (37) Healthy elderly (117) Elderly-DM (125)	41.2 ± 6.5 40.3±6.1 60.9 ± 8.3 63.3 ± 9.0	- Unipedal stance test - Stabilometer	Both young and elderly diabetics had worse static balance and shorter unipodal support time when compared to the healthy groups.	6
Timar *et al.*, 2016	DM (141) DPN (57)	59±12 64.5±10.5	- Unipedal stance test	The DPN group had a shorter time in the unipodal stance test compared to the DM group.	7
Dixit *et al.*, 2015	Men-DPN(43) Women-NPD(18)	62.3±8.84 56.1±5.99	-Sistema Metitur Good Balane	The DPN group showed increased sway velocity, moment of velocity, ML and AP displacements with OE and CE on foam and firm surfaces with no difference between genders. However, the changes were more significant in the ML direction, on foam surface with CE.	5

Table 2. Articles included in the systematic review "Oscillations in static balance related to type 2 diabetes mellitus" (continuation)

Author, year	Groups (N)	Age Mean±SD	Instrument / test	Results	NOS
Toosizadeh *et al*., 2015	DPN (18) Healthy (18)	65 ± 8 69 ± 3	-Accelerometer and gyroscope -Pendulum -Stabiligram	The DPN group compared to healthy individuals showed greater sway in the local balance control stage and less sway in the central control stage.	5
Lim, Kil-Byung *et al*., 2014	DPN (17) DM (25) Healthy (18)	60 ±11.2 55.5 ± 8. 2 52.0 ± 6.8	-Balance Master System	The NPD group had a significantly higher mean COP sway velocity compared to the DM and healthy groups in the unipodal support test in the OA condition.	7
Mehdikhani *et al*., 2014	DM (18) Healthy (18)	66.1±1.2	-Biodex Balance System Platform (BBS)	The DM group showed greater oscillation in the ML direction in the CE condition when compared to the healthy group.	7
Rangel *et al*., 2014	DM (119) DPN (32) BMI< 30 (92) BMI 30 a <35 (42) BMI ≥35 (17)	59 ± 9.2 55.4 ± 9.4 51.6 + 8.1	- Force platform	Male patients are more influenced by DPN and the CE condition in balance compared to female patients. The BMI ≥30 group showed greater oscillation in the CE condition on hard surfaces, when compared to the BMI<30 group on a soft surface.	7

Table 2. Articles included in the systematic review "Oscillations in static balance related to type 2 diabetes mellitus" (continuation)

Author, year	Groups (N)	Age Mean±SD	Instrument / test	Results	NOS
Palma *et al.*, 2013	DPN (10) DM (10)	49.4±3.44 50±3.05	-WBB platform	The DPN group had the highest mean COP oscillation in the CE condition.	7
Vaz *et al.*, 2013	DM (19) DPN (13) Healthy (30)	53.8±7.7 54.6±5.5 54.1±5.7	-Polhemus device	On the foam surface, the DPN and DM groups presented greater AP displacement in the CE condition compared to the healthy ones.	7
Fulk *et al.*, 2010	DM (7) DPN (18) Polyneuropathies (14) Healthy (30)	60.8 ±6.6 58.1 ±7.2 57.8 ±6.3 58.4 ±7.4	-Linear Research Platform -Horizontal translation force platform	The DM group only detected platform displacement in the presence of higher accelerations, with no differences regarding the presence of DPN.	7
Goldberg *et al.*, 2008	DPN (8) Healthy (8)	60.1±2.4 60.0±2.6	-Unipedal stance test	The healthy group remained in single-leg support twice as long as the DPN group.	6
Cimbiz e Cakir, 2005	DPN (30) Healthy (30)	57.5±3.9 55.6±6.1	-Force platform	The DPN group had lower results in the single-leg static balance test with CE and shorter time in single-leg support on the dominant limb compared to the healthy group.	7

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Table 2. Articles included in the systematic review "Oscillations in static balance related to type 2 diabetes mellitus" (conclusion)

Author, year	Groups (N)	Age Mean±SD	Instrument / test	Results	NOS
Lafond *et al.*, 2004	DPN (11) Healthy (20)	69.1±5.1 72.3±5.8	-Dual force platform	The DPN group showed higher RMS values of COP displacement (ankle and hip) in the AP and ML directions compared to the healthy group.	7
Corriveau, Helene *et al.*, 2000	DPN (15) Healthy (15)	68.8±5.5 69.3±5.1	-Force platform	The DPN group showed greater COP oscillation in the OE and CE conditions in the AP and ML directions compared to the healthy ones, correlated with the greater severity of DPN.	7
Oppeheim *et al.*, 1999	Healthy DPN (28) Healthy (30) Elderly healthy (8)	50.5+ 11.90 51.1 + 6.00 58.8 ± 3.59	-IBS (four separate platforms)	The group with severe DPN has greater postural sway compared to the healthy ones. DPN group has a significant oscillation power within the frequency range of 0.5–1.00 Hz compared to healthy ones.	6
Boucher *et al.*, 1995	DPN (17) Healthy (12)	62.5±7.4 60.6±5.6	-Kistler piezoelectric force platform	The DPN group presented, for the three conditions (OE, CE, recovery), greater ranges of oscillation in ML, during vision recovery in relation to the controls.	6

Note: DPN - diabetic peripheral neuropathy; DM - diabetes mellitus; OE – open eyes; CE - closed eyes; COP - center of pressure; CoM – center of mass; AP - anteroposterior; ML - mediolateral; PGT - paper grip test.
Source: the authors (2023).

1. Postural sway in bipedal stance

Studies that evaluated volunteers with DM in bipedal stance found changes in measures of postural stability, such as amplitude and speed of oscillation and displacement of the COP.[15,16] In the study of Mehdikhani et al.[15], it can be seen that the volunteers with DM showed balance changes in different foot positions, when compared to a healthy group, and that these mainly affect ML stability. Lee et al.[16] reported that elderly people with DM, when compared to healthy young people and non-diabetic elderly people, present greater AP and ML instability than non-diabetic elderly people.

Studies have demonstrated changes in the moment of oscillation velocity and displacement of the COP in the AP and ML directions in DPN subjects.[17-22] According to Lafond et al.[22], displacements in the AP and ML directions were greater in the DPN group compared to the healthy group, corroborating with Chatzistergos et al.[17] and Dixit et al.[19], who found AP and ML displacements, particularly AP displacement was greater than ML.[17,20] Findings from this review with DM and DPN subjects report that changes in COP displacement occur both in the AP and ML direction in OE and CE conditions.[15,17,19,20,23-26] According to Mehdikhani et al.[15], stability was worse in DM individuals when they were on CE, for Chatzistergos et al.[17] oscillations were worse in both visual conditions.

According to Vaz et al.[20], in the groups, displacement was greater with CE on foam surface when compared to healthy ones, corroborating with Dixit et al.[19], while Rangel et al.[24] reported that DPN patients had greater oscillation in the CE condition on hard surfaces compared to the DM. Jiang et al.[27], when comparing DM and DPN individuals to healthy ones, they reported that the area and speed of oscillation of the COP and ankle were greater in the DPN when they were in OE, whereas the hip oscillation, speed and oscillation of the COP were greater in the DM and DPN, respectively, when they were on CE.

On the other hand, in the study of Fulk et al.[28] both DM and DPN individuals require greater force to identify a sensory stimulus and higher accelerations to detect displacement than non-DM individuals. Second Toosizadeh et al.[29], DPN group showed greater body sway, greater sway in the local balance control stage and less sway in the central control stage in relation to healthy individuals.

2. Postural sway in unipedal stance

Four studies identified alterations in the balance of volunteers with DM and DPN in the unipodal posture.[30-33] Timar et al.[30] verified in DM individuals that the presence and severity of DPN found in some volunteers was associated with a shorter time of unipodal support, in addition to that orthostatic hypotension, a probable marker of cardiac neuropathy, was related to a decrease in the time of unipodal support, corroborating with the findings of Goldberg et al.[31] in which the DPN individuals remained half the time in unipodal support during static balance when compared to the control group.

In the study of Cimbiz et al.[32], during the static and dynamic balance tests in unipodal support, the DPN group compared to the healthy group performed worse on the dominant leg with CE and better on the dominant leg with OE; in the study by Lim et al.[33], the sway speed was higher in the NPD group during the one-leg stance test with OA compared to the DM group. Kukidome et al.[26] also reported worse performance of unipodal support in young and elderly diabetics compared to healthy young and elderly, being related to DPN, progression of retinopathy, nephropathy and history of falls.

Discussion

Diabetes Mellitus causes changes in postural stability due to delay in nerve conduction of motor and sensory pathways, reduced muscle strength and joint mobility, becoming more significant with DPN.[9-12] The aim of the study was to describe static balance changes in individuals with DM. The results showed that DM causes changes in postural control in the AP and ML directions, with and without the presence of visual information, and with greater impact when associated with DPN, thus, it may also cause an increased risk of falls in this population. In individuals with DM, AP and ML oscillation may be related to situations in which there is a reduction in the support base, such as bringing the heels together, in addition to reduced muscle strength and decreased plantar sensitivity.[15,16]

DPN is one of the most prevalent complications in DM[28,30,34], therefore, the present review showed a total of 19 studies that showed greater changes in static balance in the population with NPD and only 1 study where these changes were not found. DPN affects sensory input from proprioceptors and motor nerves, and according to Sacco et al.[35] the distal sensory deficit is the main contributor to the alteration of postural control, since balance is the junction of the sensory and motor systems, therefore, a cutaneous sensory deficit present in diabetics would allow greater balance changes.[36,37]

DPN affects peripheral afferent and efferent pathways and central sensory pathways, resulting in a greater deficit in peripheral nerve conduction in the lower limbs and consequent changes in postural stability.[18,20,21,28] In addition, hyperglycemia is one of the contributors to the development of DPN, also leading to postural instability.[38] Individuals with DPN demonstrate alterations in postural stability measures, such as sway velocity, moment of velocity, and COP displacement.[18,19,21,23]

DPN causes a slow sensory reconfiguration after the removal of the vision and its placement, in the period known as recovery, causing greater instability even if the vision is available, as found in the study by Boucher et al.[18], this can be explained by a somatosensory sensitivity deficit and a distal sensory deficit. In the studies by Dixit et al.[19], the COP measurements were impaired and the result was amplified when the individuals were in CE, with the probable explanation being the reduction of peripheral sensations typical of DPN, in addition to the fact that a soft surface incapacitated volunteers to modify postural strategies.

Changes in COP displacement occur both in the AP and ML direction under OE and CE standing conditions.[15,19-23] Corriveau et al.[21] reported that oscillations occur, in both directions and visual conditions cited, by increasing the amplitudes of the center of pressure. In the findings of Lafond et al.[22] ankle and hip postural mechanisms reinforce the AP and ML directions in different ways, showing predominance in the AP direction, which was correlated with the inversion of the biomechanics of activating the motor control of the ankle flexors and dorsiflexors.

In the unipodal posture, balance oscillation occurs mainly in the dominant limb and becomes even more severe in CE conditions.[32] In addition, the lower glucose tolerance may be related to the shorter time spent in the unipodal posture, since this is associated with the distal somatosensory deficit of the foot and trunk position, which are essential for balance.[32]

Maintaining balance requires both local control and central control, one dependent on local postural muscle control, without recruitment of the visual, vestibular and/ or somatosensory systems, while the other is dependent on central nervous sensory feedback, respectively.[39] In the study of Toosizadeh et al.[29] demonstrated that DPN affects the amount of body sway in short time intervals of local control, possibly caused by reduced strength of the lower limbs and postural muscles. In addition, as a compensatory response, there is also less central control oscillation, which causes an adaptive disability on uneven surfaces due to muscle stiffness or fatigue.

Other studies, when evaluating DM and DPN individuals[20,23-25,28,30,33], demonstrated more significant COP changes in the ML direction. This posture is affected the more severe the DPN and is related to changes in nerve conduction velocity.[30] Also, males seem to be more affected, and obesity is a factor that can aggravate the balance, so that people with a BMI above 30 kg/m^2 have a greater COP oscillation.[24]

The study of Fulk et al.[28] showed that regardless of having DPN or not, individuals showed a reduction in nerve conduction velocity in the lower extremities of the tibial, peroneal and sural nerves, requiring higher accelerations to identify surface displacement. According to Gregg et al.[40] and Leinninger et al.[41] the progression of DM decreases muscle strength, alters feet and tissues, gait, motor functions, decreasing the functional performance of the lower limbs, and thus affects the maintenance of balance, causing greater risks of falls.[35]

The findings of this review revealed balance changes in both the ML and AP directions[15-20] and in both directions[21,22], however, a larger number of studies[15,16,18,19] showed significant changes in the ML direction. In view of this, the literature demonstrates that in static balance tasks, people with DM recruit more the hip strategy than the ankle one due to the plantar sensory deficit, requiring proximal muscle activation. In these individuals, the hip plays a significant role in late posture, with considerable flexion movement during gait, presumably due to the smaller participation of the ankle in this phase.[42]

Regarding individuals with DPN, the ML impairment may be due to the decrease in peripheral sensation due to the neurological deficit, requiring more of the hip strategy, recruiting abductors and adductors to maintain stability.[19] The study of Simmons et al.[36] supports by demonstrating that the strategic transition from ankle to hip in individuals with DPN is related to peripheral distal sensory deficit. Increased oscillation in the ML direction specifically at DPN was also found by Ahmmed and Mackenzie et al.[38] when comparing DPN and healthy.

The postural strategy is used with the objective of controlling the instability resulting from the displacement of the support base or the body.[37] The ankle strategy is applied when there are small and slow postural disturbances, recruiting muscles in distal-proximal order, in the AP direction. In larger and/or faster perturbations, the muscle activation order is reversed, becoming proximal-distal and characterizing as a hip strategy, recruiting mainly hip, spine and abdominal muscles.[43-45]

This review has some limitations. First, the relatively small number of studies that met the proposed objective, although the objective focuses on DM, most studies address DPN as a factor that causes major changes in balance. Second, the heterogeneity of the studies regarding the instruments and way of assessing balance, and regarding the restriction of individuals without DM complications. Finally, the notes made in this review serve as a basis for carrying out new preventive studies and encouraging better life habits for people who have and do not have DM2.

Conclusion

Our results demonstrated that DM2 leads to changes in postural stability with COP displacement in the AP and ML directions, being more significant in the ML direction, with and without the presence of visual information. Greater changes in static balance were also observed in the presence and severity of DPN. These results allow a greater understanding of the implications that may lead to a worsening of balance according to the severity and progression of the disease, as well as prevention measures for the risk of falls in this population.

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Conflict of interest

No financial, legal or political conflicts involving third parties (government, companies and private foundations, etc.) have been declared for any aspect of the submitted work (including, but not limited to, grants and funding, participation in advisory boards, study design, preparation manuscript, statistical analysis, etc.).

Author contributions

Oliveira VS, Santos TES and Souza WC participated in the design of the research question, data collection and interpretation, interpretation of results and writing of the scientific article. Alves RF and Rocha RB worked on the design of the research question, methodological design, interpretation of results and writing of the scientific article. Cardoso VS contributed to the design of the research question, methodological design, interpretation of results and writing of the scientific article. All authors reviewed and approved the final version and are in agreement with its publication.

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