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COMPARATIVE EVALUATION OF PROPRIOCEPTIVE TRAINING ON POSTURAL STABILITY IN PATIENTS WITH TYPE 2 DIABETES

A.V. ENACHE[1] V.T. GROSU[2] R. CIOCOI-POP[1]
B. STANCU[3] D. MONEA[4]

Abstract: *This study examined the effects of a 6-week proprioceptive training program on postural stability in individuals with type 2 diabetes. Fifty-seven participants were divided into an experimental group, which followed a proprioceptive exercise protocol, and a control group, which received no intervention. Postural stability was measured by monitoring the Center of Pressure (CoP) with both eyes open and closed. The experimental group showed a reduction in CoP, indicating improved stability, while the control group exhibited an increase. Although statistical significance was not reached, the results suggest that proprioceptive training may help prevent further loss of stability. Further research with a larger sample size is recommended.*

Key words: *Proprioceptive Training, Postural Stability, Type 2 Diabetes, Center of Pressure, Balance Assesment.*

1. Introduction

Postural feedback and feedforward control rely on sensory input from vision, somatosensorial, and the vestibular system. Within the central nervous system, these inputs are processed, integrated, and weighted based on their relative importance and context [10].

Older adults with type 2 diabetes mellitus (T2DM) are at a higher risk of falls compared to those without the condition. This increased risk is partly due to the use of insulin and other diabetes-related medications [5].

Evidence consistently shows that the prevalence of Sarcopenia is higher in patients with T2DM. However, only age and low BMI have been identified as major risk factors for sarcopenia in these patients. Some studies suggest that sarcopenia may be linked to diabetes complications such as retinopathy, neuropathy, and foot disease, but no

[1] Department of Physiotherapy and Theoretical Disciplines, Babes-Bolyai University
[2] Department Technical University of Cluj-Napoca
[3] Second Surgical Department, University of Medicine and Pharmacy " Iuliu Hatieganu "
[4] Department Sports games, Babes-Bolyai University.

connection has been found with macrovascular complications. The high prevalence of sarcopenia in elderly individuals with T2DM, along with its significant impact on physical and psychosocial health, makes it a major public health concern [9].

Subjects with bilateral vestibular loss do not exhibit response saturation and show limited ability to adjust sensory weights. Some compensate by increasing stiffness and modifying damping, which helps reduce sensory error, although these adjustments may require more energy [10].

In individuals with diabetes, peripheral neuropathy often impairs sensory feedback, leading to balance difficulties and an increased risk of falls. Evidence suggests that proprioceptive training can improve balance in patients with diabetic neuropathy [8].

Proprioceptive training enhances sensory function by emphasizing somatosensory inputs, such as proprioception and tactile feedback, while reducing reliance on vision. This approach aims to restore or improve sensorimotor function [2].

Training on uneven surfaces offers additional benefits, strengthening cognitive perception and sensorimotor skills [13]. Sensorimotor training enhances proprioception and somatosensory signals while addressing muscle imbalances and optimizing motor control in the central nervous system. These exercises, including static, dynamic, and functional balance techniques, are well-established in rehabilitation [3].

Proprioceptive training is a time-efficient, low-impact alternative to traditional exercise methods. It can alleviate pain, slow osteoarthritis progression, improve joint and muscle function, and enhance quality of life [12].

Postural instability in individuals with poorly controlled diabetes is often linked to peripheral neuropathy from prolonged hyperglycemia. These individuals tend to shift balance strategies, relying less on ankle movements and more on the hips during static tasks. This hip-centered strategy emphasizes the importance of proximal muscles—in the hips, knees, and back—for maintaining stability. As such, a targeted muscle-strengthening program is essential to optimize this compensatory mechanism and potentially reduce fall risk in individuals with compromised foot sensation [4].

Additionally, the use of force plates and other technical devices enables precise assessment of postural stability, thereby informing the development and evaluation of proprioceptive training protocols [15].

2. Objectives

The aim of this study is to evaluate the impact on balance by proprioceptive training among patients with type 2 diabetes mellitus.

3. Material and methods

Hypothesis

H1: There is at least a significant difference in equilibrium between the four conditions.

Subjects

We enrolled 57 type 2 diabetes patients from the rural area of Cluj County. Inclusion criteria required a confirmed diagnosis of type 2 diabetes, an age above 60, and the ability to perform the Romberg test. Patients with diabetes-related cardiac complications or foot ulcers were excluded. The study received approval from the UBB Ethics Committee (approval no. 6652/24.06.2021).

The study group consisted of 15 men and 13 women, while the control group had 14 men and 15 women. The average age of the study group was 65.6 years, compared to 62.4 years in the control group. Participants in the study group engaged in a kinetic program featuring proprioceptive exercises, while the control group adhered to their physician's recommendations—namely, 150 minutes of moderate physical activity per week, maintaining a stable weight to control blood glucose and minimize complications, regular blood sugar monitoring as advised to adjust diet, exercise, or medication, and following a balanced diet that restricts refined sugars and white flour products.

Stabilometric Assessment: The evaluation protocol for stabilometry consisted in performing the Romberg test. The duration allocated for each postural balance evaluation protocol is 30 seconds. The subject maintains an orthostatic position with bipodal support, feet positioned at shoulder width.

Protocol I: The patient is positioned on a firm surface, specifically the baropodometry platform, and instructed to maintain this stance with eyes open.

Protocol II: The patient is positioned on the same firm surface and instructed to maintain the stance with eyes closed.

The BTS P Walk baropodometry plate was used for patient assessment. The resistive type sensors of size 1x1 cm are evenly distributed over an area of 675x540x5 mm. The acquisition frequency of the sensors is 100 Hz and the maximum supported pressure is 400 kPa. The board is operated by AC/USB adapter power supply.

Exercise programme Table 1

		Sets and reps	Time (sec)	Set break
1.	FLAMINGO performed on a hard surface **Execution technique**: unipodal support on the ground with the right foot on the ground and the left foot bent from the knee to 90°. The hands are fixed on the hip	5 L X 5 R	20	20
2.	FLAMINGO realised on a soft surface (sponge) Technique: Unipodal support on the ground, the other leg is bent from the knee to 90°. The hands are fixed on the hips	4 L X 4 R	20	30
3.	FLAMINGO on an unstable surface (reversible disc) **Technique**: Unipodal support on the ground, the other leg is bent from the knee to 90°. Hands are fixed on the hip	3 L X 3 R	10	30
4.	Balance exercise using isometric contractions on a hard surface **Execution technique:** Unipodal support on the ground, the other leg is maintained with the knee extended and abducted laterally 20°. Hands are fixed on the hip	5 L X 5 R	20	20

5.	Balance exercises performed using isometric contractions on a soft surface (sponge) **Execution technique:** Unipodal support on the ground, the other leg is maintained with the knee extended and abducted laterally 20^0 Hands are fixed on the hip	4 L X 4 R	20	30
6.	Balance exercises performed using isometric contractions on an unstable surface (reversible disc) **Execution technique:** Unipodal support on the ground, the other leg is maintained with the knee extended and abducted to the side by 20°. Hands are fixed on the hip	3 L X 3 R	10	30
7.	Exercise standing on your toes on a hard surface **Execution technique:** Bipodal support on the ground, knees extended with the arms on the hips, the lift is performed on the toes, and the position is maintained	2 X 5	20	30
8.	Lifting exercise on your toes on a soft surface (sponge) **Execution technique:** Bipodal support on the ground, knees extended with the arms on the hips, the lift is performed on the toes, and the position is maintained	2 X 4	20	30
9.	Exercise to maintain orthostasis on an unstable surface (reversible disc) **Execution technique:** bipodal support on a reversible balance disc, knees ext	2 X 5	30	30
10.	SQUAT on a hard surface **Execution technique:** Bipodal support on the floor, knees bent at 120° with arms extended forwards and position maintained	2 X 4	30	30
11.	SQUAT on a soft surface (sponge) **Execution technique:** Bipodal support on the floor, knees bent at 120° with arms extended forwards and hold the position	2 X 3	30	30

Note: L=Left lower limb, R=Right lower limb

The statistical tests used were normal distribution Shapiro-Wilk test and non-parametric Wilcoxon test.

The evaluated parameters are grouped as follows: Area Body Barycenter Eyes Open Initial/Final (mm^2), CoP Lenght Eyes Open Initial/Final (mm^2), Area Body Barycenter Eyes Close Initial/Final (mm^2), CoP Lenght Eyes Close Initial/Final (mm^2).

4. Results

Distribution of our data Table 2

Tests of Normality						
	Shapiro-Wilk-Group Study			Shapiro-Wilk- Group Control		
	Statistic	df	Sig.	Statistic	df	Sig.
Area CoP Initial Eyes Open (mm^2)	.579	28	.000	.850	29	.001
Area CoP Final Eyes Open (mm^2)	.580	28	.000	.848	29	.001
Area CoP Initial Eyes Close (mm^2)	.795	28	.000	.823	29	.000
Area CoP Final Eyes Close (mm^2)	.795	28	.000	.825	29	.000

For all variables (Initial/Final, Eyes Open/Closed), the data in both the Study and Control groups do not show a normal distribution, as the p-values are all less than or equal to 0.05.

Table 3

Statistics results for all parameter values following Wilcoxon test on Group Study and Group Control during evaluation with Eyes Open and Eyes Close

Parameter	Group	N	Mean Rank	Sum of Ranks
Area CoP Final Eyes Open - Area CoP Initial Eyes Open	Group Study	28	14.50	377.00
	Group Control	29	15.00	435.00
Area CoP Final Eyes Close - Area CoP Initial Eyes Close	Group Study	28	14.85	401.00
	Group Control	29	15.00	435.00

Test Statistics				
Parameter	Group Study	Group Control	Group Study	Group Cotrol
Area CoP Final Eyes Open - Area CoP Initial Eyes Open	Z = -3.964	Z = -4.705	Asymp. Sig. (2-tailed)	0.000
Area CoP Final Eyes Close - Area CoP Initial Eyes Close	Z = -4.511	Z = -4.704	Asymp. Sig. (2-tailed)	0.000

In the Study Group, the Final measurements (with both Eyes Open and Eyes Closed) were noticeably lower compared to the Initial ones, showing a clear reduction in the COP area after the intervention. On the other hand, in the Control Group, the Final measurements (Eyes Open and Eyes Closed) were higher than the Initial ones.

According to the Table 4, we can see that the Mann-Whitney U values for all variables range between 393.5 and 406, with Wilcoxon W values similarly falling between 799.5 and 841. The Z-values are close to zero across all comparisons, suggesting minimal differences between the two groups. The p-values (Asymptotic Significance, 2-tailed) are as follows: 0.994 for Area CoP Initial Eyes Open, 0.842 for Area CoP Final Eyes Open, 0.981 for Area CoP Initial Eyes Close, and 1.000 for Area CoP Final Eyes Close. Because the p-values for all comparisons are well above the standard threshold of 0.05, we cannot reject the null hypothesis. This means there are no significant differences between the Study Group and Control Group for any of the variables.

Results for all parameter values following Mann-Whitney Test Table 4

RANKS

		N	Mean Rank	Sum of Ranks
Area CoP Initial Eyes Open (mm^2)	Group Study	28	29.02	812.50
	Group Control	29	28.98	840.50
	Total	57		
Area CoP Final Eyes Open (mm^2)	Group Study	28	28.55	799.50
	Group Control	29	29.43	853.50
	Total	57		
Area CoP Initial Eyes Close (mm^2)	Group Study	28	29.05	813.50
	Group Control	29	28.95	839.50
	Total	57		
Area CoP Final Eyes Close (mm^2)	Group Study	28	29.00	812.00
	Group Control	29	29.00	841.00
	Total	57		

Test Statistics

	Area CoP Initial Eyes Open (mm^2)	Area CoP Final Eyes Open (mm^2)	Area CoP Initial Eyes Close (mm^2)	Area CoP Final Eyes Close (mm^2)
Mann-Whitney U	405.5	393.5	404.5	406
Wilcoxon W	840.5	799.5	839.5	841
Z	-0.008	-0.2	-0.024	0
Asymp. Sig. (2-tailed)	0.994	0.842	0.981	1

5. Discussions

The study demonstrated significant improvements in stability and balance, as shown by the Wilcoxon signed-rank test. Many positive ranks and substantial effect sizes confirmed the intervention's positive impact. This study provides valuable insights into the effectiveness of the intervention in improving stability, measured by Center of Pressure (CoP) assessments with both eyes open and closed.

By comparing the experimental and control groups, the study assessed whether the intervention had a meaningful effect on postural stability.

Training on yielding surfaces predominantly relies on the ankle joint to maintain the center of gravity within the base of support. Training on yielding surfaces primarily engages the ankle joint to maintain the center of gravity within the base of support. This training enhances proprioceptive feedback and strengthens the ankle muscles, which reduces the risk of falls. In the experimental group, most participants showed a reduction in CoP, indicating improved stability, regardless of eye status. The strong Z-scores and very low p-values ($p < 0.001$) confirm the significant effect of the intervention in reducing CoP. In contrast, all control group participants experienced an increase in CoP under both conditions, with significant Z-scores and p-values ($p < 0.001$), indicating a decline in stability without the intervention.

When comparing the two groups, the experimental group showed improvements with reduced CoP, while the control group's stability worsened. This suggests that the intervention was effective in enhancing stability. However, the overall comparison between groups did not show statistically significant differences. Mann–Whitney U values ranged from 393.5 to 406, Z-scores were near zero (–0.008 to 0), and p-values were consistently above 0.05 (0.842 to 1.000). These results suggest that, while the intervention positively affected the experimental group, factors such as the design, duration, or participant characteristics may have limited the ability to identify significant differences between the groups.

Also, Sousa et al. (2021) [14] proposed a sensory-motor training program that did not affect the postural balance of type 2 diabetics without clinical signs of diabetic distal polyneuropathy, in terms of orthostatic position, muscle strength, knee joint proprioception, and quality of life.

Biomechanically, balance training on pliable surfaces uses the ankle joint as the main point for stabilizing the center of gravity. Although the surface does not move, changes in the ankle's position activate the musculo-ligamentous structures, improving stability and reducing CoP displacement. This process follows the inverted pendulum model, where the ankle joint serves as the pivot point, and the trunk is the movable part. Rapid dorsiflexion and plantarflexion movements improve the ankle strategy's efficiency. The unilateral exercises in the intervention place more load on the supporting leg, and this load increases when performed on an unstable surface. Extended balance exercises improve muscle endurance through isometric contractions, contributing to overall stability and influencing CoP under eyes-open conditions.

In the control group, participants who followed standard health recommendations showed improved balance between initial and final assessments. This improvement may be partly due to the physical demands of daily activities in a rural environment.

It is important to note that the study's small sample size (28 in the experimental group and 29 in the control group) may have limited the ability to detect small differences, especially if the intervention's effects were modest. The high p-values (all above 0.05) suggest that any observed differences were likely due to random variation rather than a true effect of the intervention. This highlights the need for further research with a larger sample and more robust design to more accurately evaluate the intervention's impact on postural stability.

6. Conclusions

Although no statistically significant differences were found between the experimental and control groups, the study provides valuable insights into postural stability. It enhances our understanding of effective methods for improving balance by systematically evaluating a specific intervention and presenting reliable results.

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