Effect of Virtual Reality on Balance in Elderly with Type 2 Diabetes Mellitus

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ABSTRACT

Background: Diabetes mellitus (DM) can result in micro and macrovascular problems that impact the anatomical, structural, and functional characteristics of several organs. **Objective:** The current study aimed to evaluate virtual reality (VR) exercise influences on the balance of elderly individuals diagnosed with T2DM.

Patients and methods: A total of sixty male and female patients suffered from T2DM who were recruited from the Outpatient's Clinic of Menouf Hospital. Their ages ranged from 65 to 75 years old, HBA1c level was ≥ 6.5 for 5 years ago and their BMI ranged from 25 to 32 Kg/m^2 participated in this study. All patients were randomly assigned into 2 equal groups (30 for each). Group A who received VR training for 30 mins plus traditional balance exercises for another 30 mins twice a week for ten weeks, and group B who received traditional balance exercises only for 30 mins twice a week for ten weeks. Balance was assessed using Biodex balance system and BBS before and after the treatment procedures. **Results:** The findings revealed a significant decrease in overall, anteroposterior, and mediolateral stability index in both groups post-treatments in the favour of group A and significant increase in BBS in both groups post-treatments in the favour of group A. The percentage of change in OASI, APSI, MLSI, and BBS of the group A was 60.11%, 52.76%, 55.15%, and 56.80%, respectively, while that in the group B was 23.25%, 18.60%, 23.98%, and 25.27% respectively. **Conclusion:** A VR-based workout program has been demonstrated to be an effective intervention for improving the balance of older adults diabetics who suffer from poor balance due to underlying diseases.

Keywords: Balance, Type 2 diabetes mellitus, Virtual reality.

INTRODUCTION

The health system is facing difficulties as a result of the rapid aging of the population, particularly in relation to treatments aimed at preserving functional ability and independence and expanding the scope of rehabilitation specialists. Musculoskeletal characteristics that enhance functional ability in the elderly include mobility, gait, joint and lower limb muscle flexibility, and body balance (both static and dynamic) [(1)]. As with falls, a significant public health concern is the loss or deterioration of balance. Interactions between the musculoskeletal, visual, and sensorimotor systems as well as associated functional tasks that change with aging, including sarcopenia, changes in proprioception, joint stiffness, postural alignment, latency, and temporal incoordination of muscle activation, cause the imbalance [(2)]. Compared to older adults without diabetes, those with diabetes have substantial balance problems [(3)]. According to a research, the prevalence of T2DM with DPN is linked to pre-older and elderly people's physical fitness and their risk of falling or having balance issues [(4)]. Because of its therapeutic potential for fall prevention and balance rehabilitation, VRT rehabilitation has drawn more and more attention from researchers and clinicians who understand its advantages. High levels of motivation, enjoyment, and immediate feedback on task completion are provided by the therapy's entertaining nature, easy application, and stimulants to the sensory and motor systems. Therefore, when used in combination, VRT encourages social connection, stimulates functional activity, and may help older adults stick to their rehabilitation regimens [(2)]. Furthermore, VR is a safe and entertaining rehabilitation technique that provides users with therapeutic advantages including enhanced motivation and sharper focus [(5)]. VRT distribution is still in its early stages, and conflicting findings have been documented in the literature [(6)].

Evidence of VR advantages and disadvantages may encourage physiotherapists to expand their practice in order to provide more comprehensive treatment for older patients undergoing rehabilitation. Therefore, the current study aimed to evaluate VR exercise influences the balance of elderly individuals diagnosed with T2DM. Both subjective and objective measures were employed to evaluate whether VR exercise can enhance balance function in this demographic.

PATIENTS AND METHODS

This single-blinded randomized controlled trial was conducted between June 4, 2024, and December 16, 2024.

Subjects: Sixty male and female patients who suffered from T2DM were chosen from Menouf Hospital's Outpatient Clinic.

Inclusion criteria: Age ranged from 65-75 years [(7)]**,** diagnosed with T2DM based on HBA1c analysis (glycated hemoglobin ≥ 6.5) since 5 years ago [(8)]**.** Clinically stable diabetic patients using hypoglycemic drugs [(8)]**.** Patients who suffered from peripheral neuropathy. Patients with BMI of 25-32 kg/m^2 [(9)] and who were able to communicate effectively.

Exclusion criteria: Patients with manifested musculoskeletal impairments impacting independent walking (e.g., strokes, severe arthritis) [(9)]**,** intellectual disabilities [(10)]**,** hearing problems [(9)]**,** otitis media and vestibular problems [(9)]. Patients engaged in less than 80% of the exercise program, had dizziness [(8)] and

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lower extremity joint surgery [10], or who were incapable of doing follow-up assessments.

Sample size calculation: According to **Park *et al.*** [11], the calculation of sample size was based on the difference in means of the BBS, with the intervention group having a mean and standard deviation of 50 ± 6.27, and the control group having a mean and standard deviation of 44.7 ± 7.47. Using a type 1 error (α) of 0.05 and a power (1-β) of 0.80, the sample size for each group was 27. Accounting for potential dropouts, 30 participants were allocated to each group with a total sample size of 60 (Figure 1).

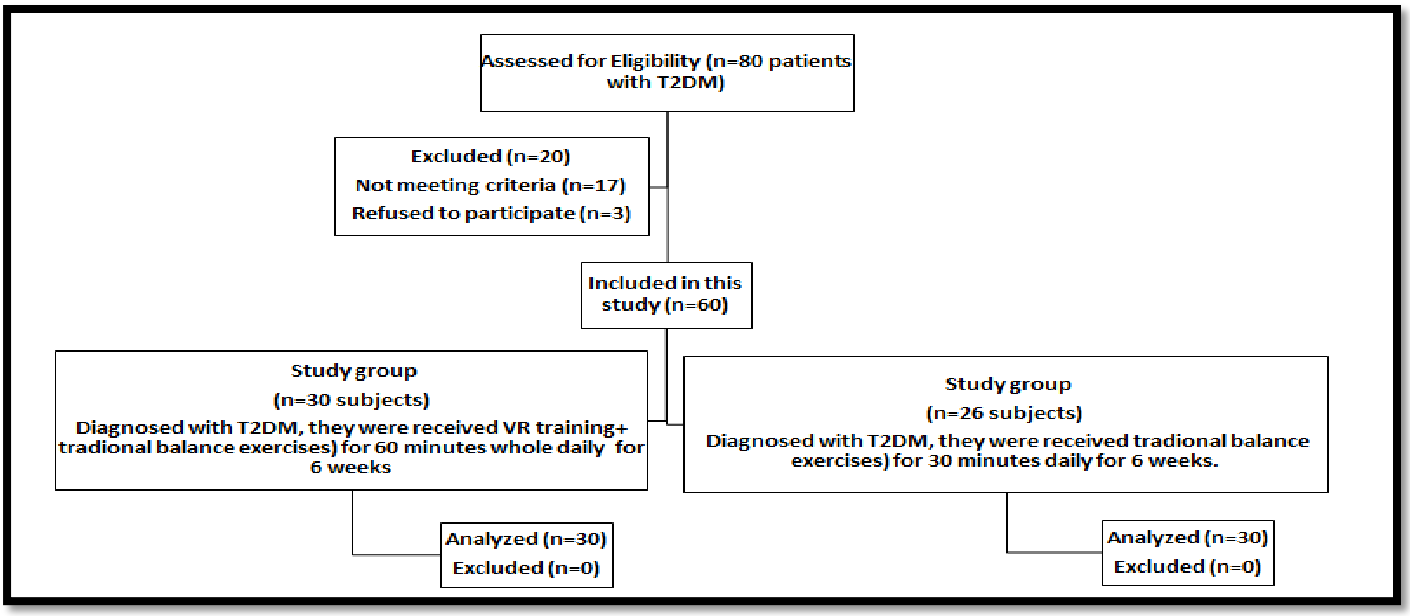

Figure (1): Flow chart for recruitment of the participants.

For all sixty male and female patients the balance was assessed by using Biodex balance system for assessing static and dynamic balance in the form of (overall stability index, antropostrior stability index and mediolateral stability index) also by BBS before and after the treatment procedures.

Procedures:

Assessment procedures: All participants completed a permission form acknowledging their approval of participation after being informed of the study's purpose and methodology prior to its execution. One experienced researcher conducted the evaluation and analysis.

Assessment for eligibility of subjects: Patients' comprehensive clinical and medical histories were obtained and entered into a recording data sheet. In order to include patients in the research based on predetermined criteria, a physical examination was conducted.

Balance assessment: It was assessed by using Biodex balance system and BBS:

a) Biodex balance system: It was used to assess balance in all patients from both groups. It utilizes a multi-axial force plate to measure static and dynamic balance by recording the individual's ability to stabilize a joint under dynamic stress. The platform can tilt up to 20 degrees, stimulating ankle joint receptors. Postural sway was assessed by examining the center of pressure route, which included anterior-posterior, medial-lateral, and total sway lengths. During assessment, participants stood barefoot on the platform for 30 seconds, feet parallel and arms at their sides, looking at a fixed point. Assessments were done with eyes open, repeated three times to calculate the mean score. Higher scores indicated greater sway and poorer balance. Both before and after the ten weeks intervention, measurements were obtained [12].

b) Berg balance scale (BBS): Throughout the intervention, it was used on every patient in both groups both before and after the treatment plans. A stopwatch or watch with a second hand, together with a ruler or other indicator that measures two, five, and ten inches, was necessary for the testing. The height of the chairs used for testing should be appropriate. For item #twelve, a step or a stool with an average step height can be utilized. The patient should be aware that while doing the tasks, they need to keep their equilibrium. The patient is left to decide how far to reach or which leg to stand on. Bad decision-making was having a negative impact on both performance and score [13].

Treatment procedures:

1. **VR mechanism:** The Xbox Kinect system, which contains both a Kinect sensor and a console, was utilized for VR training. The sensor detects body motions without the need for a controller, and the console executes the games. The setup involved placing the Kinect, console, and monitor in a specific area, with patients standing 1.5–2 meters from the sensor. A research assistant adjusted the sensor for accurate motion capture before starting. Game demonstrations from Kinect Sports and Kinect Sports 2 were provided. All games required both upper and lower limbs and were intended to keep stroke victims occupied. Details of used games are described in (table 1**).** All exercises were performed twice a week for 10 weeks [11].

Table (1): Component of VR training session

Game name	Description	Involved body movements
Ski	Weight shifting to the right and left or up and down is trained. The screen demonstrates a virtual slope and players should follow the slope without crashing into the barriers.	• Active movement of the lower extremity (flexion, abduction, and external-internal rotation of hip; flexion and extension of knees; dorsiflexion and plantar flexion of ankles) • Trunk rotation • Training weight-shifting and weight-bearing • Training balance
Penalty and goalkeeper	The usage of lower extremities, head, neck, and trunk while standing and kicking a ball in a virtual soccer field is practiced.	• Active movement of the lower extremities (flexion, abduction, and external-internal rotation of hip; flexion and extension of knees; dorsiflexion and plantar flexion of ankles) • Training weight-shifting and weight-bearing • Training balance
Darts	Players throw small missiles known as darts at a circle-shaped dartboard. Three darts are utilized per visit at the board to reduce 501 to 0.	The upper limb has unilateral movements along with static standing.

- **Session components:** the exercise session began with a 10-minute warm-up including full-body stretching to enhance circulation and relax muscles. Participants then engaged in various standing games like penalty kicks, goalkeeping, skiing, and darts, targeting different balance skills. All games involved both upper and lower body, with each lasting 3–5 minutes, for a total session time of 30 minutes.
- **VR application:** The activities were played by participants standing in front of the monitor on a floor mat without shoes. A study assistant guided each pair by explaining, demonstrating, and ensuring safe participation. Game scores were based on individual performance, and the assistant recorded the results to identify the highest scorer in each game.

2. Traditional balance exercises for group (B):

- Activities from the standard therapy program, such as stretching every muscle in an effort to increase blood circulation and relax muscles, were incorporated into the typical balancing exercise regimen. For thirty minutes, the balance-training program was including ten standing exercises. Finally, a five-minute cool-down period was concluding the session, incorporating stretching exercises and deep breathing techniques to help participants relax and recover. The program was performed for 30 minutes.

Both groups also participated in a group of balancing exercises that lasted for 35 minutes and consisted of 10 exercises performed in a standing position: During the first three weeks, participants practiced double-stance standing, heel and toe rising, and walking in place. In addition to the basic exercises, the next three weeks, crossed leg standing, tandem standing, and balancing board activities were practiced. In the last four weeks, participants were introduced to activities such step stand, sideways walking, conventional walking, and one-leg standing [10].

Ethical consent: The study followed the Declaration of Helsinki and was ethically approved by Cairo University's Faculty of Physical Therapy (Number: P.T.REC/012/005238). Prior to registration, all participants or their legal guardians signed informed consent forms.

Statistical analysis

We used SPSS version 25.0 for Windows to do the statistical analysis. Subject characteristics were compared between groups using an unpaired t-test. For comparing the distribution of sexes among groups, the X^2-test and Mean ± SD were used. To verify if the data was normally distributed, the Shapiro-Wilk test was used. To determine if the groups were homogeneous, Levene's test for homogeneity of variances was used. To find out how therapy affected OASI, APSI, MLSI, and BBS, a mixed MANOVA was used. Multiple comparisons were then performed using Post-Hoc testing using the Bonferroni adjustment. A significance criterion of $p \leq 0.05$ was established for all statistical tests.

RESULTS

Study group: The mean age, weight, height and BMI of study group were 69.93 ± 3.30 years, 92.62 ± 10.65 kg, 174.54 ± 8.72 cm, and 30.26 ± 2.24 kg/m² respectively. Mean HbA1c was 7.88 ± 0.92%.

Control group: The mean age, weight, height and BMI of control group were 70.27 ± 3.54 years, 93.28 ± 7.33 kg, 174.84 ± 8.02 cm, and 30.53 ± 1.60 kg/m² respectively. Mean HbA1c was 7.79 ± 1.00%. A comparison of the general characteristics of participants in both groups found no significant change in age, weight, height, BMI, and HbA1c ($p > 0.05$).

Table (2): Comparison of age, weight, height, BMI and HbA1c between study and control groups

	Study group (n=30)	Control group (n=30)			
	Mean ± SD	Mean ± SD	Mean difference	t- value	p-value
Age (years)	69.93 ± 3.30	70.27 ± 3.54	-0.34	-0.38	0.71
Weight (kg)	92.62 ± 10.65	93.28 ± 7.33	-0.66	-0.28	0.78
Height (cm)	174.54 ± 8.72	174.84 ± 8.02	-0.3	-0.14	0.89
BMI (kg/m²)	30.26 ± 2.24	30.53 ± 1.60	-0.27	-0.53	0.59
HbA1c (%)	7.88 ± 0.92	7.79 ± 1.00	0.09	0.35	0.73
Sex, N (%): Females	14 (47%)	15 (50%)	(χ^2 = 0.07)		0.79
Males	16 (53%)	15 (50%)			

Effect of treatment on OASI, APSI, MLSI and BBS: A mixed MANOVA was used to determine the influence of treatment on OASI, APSI, MLSI, and BBS. There was a significant interaction between treatment and time (p=0.001). There was a substantial main impact for time (p=0.001). The main impact of treatment was substantial (p=0.001) (Table 3).

Table (3): Mixed MANOVA for the effect of treatment on OASI, APSI, MLSI and BBS

Mixed MANOVA		
Interaction effect (treatment * time)		
F = 112.32	**p = 0.001**	**Partial Eta Squared = 0.89**
Effect of time		
F = 656.09	**p = 0.001**	**Partial Eta Squared = 0.97**
Effect of treatment		
F = 8.88	**p = 0.001**	**Partial Eta Squared = 0.39**

Within group comparison: Post-treatment, both groups showed substantial decreases in OASI, APSI, and MLSI, as well as increases in BBS (p<0.001). In the study group, the percentages of change in OASI, APSI, MLSI, and BBS were 60.11%, 52.76%, 55.15%, and 56.80% respectively, whereas in the control group, they were 23.25%, 18.60%, 23.98% and 25.27% (Table 4).

Between group comparison: Pre-treatment showed no discernible difference between the groups (p>0.05). Concerning post-treatment, the study group's BBS significantly increased and their OASI, APSI, and MLSI significantly decreased when compared to the control group (p<0.001) (Table 4).

Table (4): Mean OASI, APSI, MLSI and BBS pre and post treatment of study and control groups

		Pre treatment	Post treatment			
		Mean ±SD	Mean ±SD	Mean difference	% of chang	p value
OASI	**Study group**	3.56 ± 0.77	1.42 ± 0.46	2.14	60.11	0.001
	Control group	3.57 ± 0.77	2.74 ± 0.62	0.83	23.25	0.001
	MD	-0.01	-1.32			
		p = 0.96	***p = 0.001***			
APSI	**Study group**	2.54 ± 0.74	1.20 ± 0.52	1.34	52.76	0.001
	Control group	2.58 ± 0.76	2.10 ± 0.70	0.48	18.60	0.001
	MD	-0.04	-0.90			
		p = 0.85	***p = 0.001***			
MLSI	**Study group**	1.65 ± 0.55	0.74 ± 0.37	0.91	55.15	0.001
	Control group	1.71 ± 0.51	1.30 ± 0.49	0.41	23.98	0.001
	MD	-0.06	-0.56			
		p = 0.66	***p = 0.001***			
BBS	**Study group**	35.00 ± 4.73	54.88 ± 4.36	-19.88	56.80	0.001
	Control group	35.02 ± 5.20	43.87 ± 4.95	-8.85	25.27	0.001
	MD	-0.02	11.01			
		p = 0.98	***p = 0.001***			

DISCUSSION

According to the IDF Atlas, DM is on the rise and affects 463 million people globally, or 8.8% of the adult population. About 10% of them have T1D, whereas the remaining 90% have T2D. According to the WHO, diabetes doubles a person's chance of dying young and caused 4.2 million deaths in 2019 [(14)]. With an overall incidence of 1.25 falls per person year, the group with diabetes was found to be at high risk for falls. It has been demonstrated that brief strength and balance training does not enhance the quality of life for diabetic individuals. Nonetheless, the functional result in this group is positively impacted by these activities [(15, 16)].

With the falling cost of headsets, VR has been increasingly popular recently and is now affordable for usage at home and in healthcare. As demonstrated by the MMVR series, the benefits of VR health care are becoming more widely recognized. These benefits include orthopedics, anesthesia, paramedics, resuscitation, and medical examination scoring, among many other areas [(17)]. Because the physiological features are highly adaptable to patients' changing lifestyles, physical conditions, and cognitive abilities, VR is a particularly good tool for diabetes education. Since more individuals are developing diabetes than there are diabetologists, diabetes treatment is constantly becoming digital, emphasizing VR training as a means of assisting diabetics in bettering their self-management [(18)]. The current study aimed to evaluate VR exercise influences on the balance of elderly individuals diagnosed with T2DM.

Results of this study revealed a significant reduction in OASI, APSI and MLSI in both groups post-treatments. But there was significant change in all of them in study group more than in control group. This comes consistent with the study done by **Sveistrup** [(19)] and **Cakar *et al.*** [(20)] who found that weight bearing actions in VR, such as turning, moving, walking, and sprinting, help to enhance balance. In the actual world, participants may underestimate their capabilities and fear falling, but in a virtual world, they may accomplish the activities without such doubts or anxieties. Also, our study is consistent with a study by **Tieri *et al.*** [(21)] who found that VR programs aid in achieving the main objective of rehabilitation, which is to enhance the quality of independent living and the effective execution of everyday tasks by boosting stability. In a study done by **Lee and Song** [(10)], they demonstrated that the VR group's post-intervention A-P postural sway path length decreased by thirty two percent and thirty one percent with eyes open and closed respectively, while the M-L postural sway path length was reduced by thirty seven percent and thirty nine percent with eyes open and closed respectively using a force plate.

However, this study demonstrated that both groups experienced a considerable increase in BBS following treatments, with the study group experiencing a greater change than the control group. This study finding agrees with the study done by **Lee and Shin** [(9)] who found substantial increases in one-leg stand, BBS, functional Reach test, and TUG scores (all P=.001), with enhanced velocity, cadence, and MFES score. Additionally, after a single session around 15-minute, **Grewal *et al.*** [(22)] reported improved balance and coordination in both the upper and lower limbs, demonstrating the potential benefits of VR combined with visual and auditory FB, even in the short term. **Chandrashekhar *et al.*** [(23)] also reported similar outcomes from a 10-minutes haptic Facebook intervention once a day. Although these results are encouraging, more research with larger sample sizes and a controlled randomized design is required to compare the effectiveness of different dosages of therapy with standard care.

A Systematic review study done by **Baptista *et al.*** [(24)] concluded the positive effects of VR on gait performance among older adults. VR exercise programs improved various biomechanical parameters of gait, including balance, muscle strength, gait stability, walking speed, and fall risk. Also, they reported that older individuals' gait performance improved as a result of VR. VR workouts enhanced a number of gait biomechanical characteristics, such as walking speed, muscle strength, balance, gait stability, and fall risk.

Based on the findings of the current study, it was found that VR was an excellent rehabilitation modality on the treatment of balance and risk of fall among older adults with T2DM.

LIMITATIONS

This was the only study that compared the effect of VR with traditional balance exercises on balance in T2DM patients. The primary drawback of this study was the small sample, as the majority of patients were questioned only at Menuf Hospital's Outpatient Clinic. Consequently, it's possible that the findings of this study would not apply to T2DM patients, such as those without DPN.

CONCLUSION

For older adults with diabetes who have reduced balance due to underlying illnesses, the VR-based fitness program had been demonstrated to be an effective solution. Therefore, VR may be a highly useful technique for balance therapy in individuals with T2DM who also have DPN.

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