

# Auditory, Visual and Postural Reaction Time Among Middle Aged Type 2 Diabetics and Healthy Individuals – A Cross-Sectional Study

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**Received:** 28 September 2020

**Accepted:** 09 January 2021

**Published in February 2021**

## Abstract

**Objective:** Study aims to compare Auditory, Visual and Postural RT among middle aged type 2 diabetics and healthy individuals.

**Materials and Methods:** A Cross-Sectional Study which included 200 Participants that met inclusion and exclusion criteria, were divided into 2 groups. Diabetic group included 100 participants who were clinically diagnosed with type 2 Diabetes and healthy group included 100 healthy participants. Both the groups performed Auditory Reaction Time test (ART) and Visual reaction time test (VRT) using Inquisit 4.0 computer software, Ruler drop test (RDT), Wobble Board (WB) Test and Timed up and go test (TUGT) was performed.

**Results:** Statistical analysis (independent sample T-test) revealed a significant delay in VRT ( $P$ -value= 0.001), ART ( $P$ -value= 0.001), Wobble Board Test ( $P$ -value= 0.001) and TUGT ( $P$ -value= 0.001) among diabetic group compared to healthy group. There is no significant difference in Ruler drop test ( $P$ -value= 0.919) among both the groups.

**Conclusion:** There is a significant delay in RT among middle aged type 2 diabetic participants when compared to healthy participants. This is associated with reduced sensory stimuli from various systems and resulting in late response in diabetic group.

**Keywords:** Middle aged, Reaction time, Postural balance, Healthy volunteers, Gait

## Introduction

Diabetes mellitus (DM) is a group of metabolic diseases characterized by high blood sugar either because the body does not produce enough insulin or because cells do not respond to the insulin that is produced. (1) According to International Diabetes Federation, globally an estimated 425 million adults are living with DM of which 74 million cases are Indians. The average age of onset is 42.5 years (2).

Balance is defined as the ability to maintain the body's center of gravity within its Base of Support (BOS) and can be categorized by either static or dynamic balance (3). Both static and dynamic balance requires effective integration of visual, vestibular, and proprioceptive inputs to produce an efferent response to control the body within its BOS (4-5). Type 2 DM may involve peripheral as well as central nervous system and can often

cause changes in the somatosensory, vestibular, visual and auditory systems affecting reaction time (RT) of an individual (1). RT has physiological significance and is a simple and non-invasive test for peripheral as well as central neural structures.

Limited reports are available from India showing the effects of diabetes on the processing of signals and also on peripheral nerves. Keeping this in mind, the present study was planned. The aim of the present study was to compare Visual, Auditory and Postural RT among middle aged Type 2 diabetics and Healthy individuals.

### Materials and Methods

Sample size  $n=98$  per each group was calculated using G-power software keeping confidence level 95% and error 5%. 258 participants were screened from three tertiary care health set-up and 200 participants met the inclusion and exclusion criteria.

Written informed consent was obtained before commencement of study. Inclusion criteria were age group 45-60 years, both males and females, BMI ranging from 18.5-29.9  $\text{kg/m}^2$ , visual acuity normal or corrected: 6.6 or 5.6) and auditory acuity normal: 0-20 dB. 100 clinically diagnosed patients of T2DM who are on oral medication and of duration more than 5 years were included in the diabetic group and 100 healthy participants were included in the healthy group. Participants on insulin, reduced sensory and pain perception in the extremities of limbs, H/O neurological, cardiovascular, respiratory, chronic and acute musculoskeletal conditions that can affect the test and H/O Smokers and Alcoholics were excluded.

### ART

Test was done using Inquisit 4.0 computer software released in 2013 by Millisecond Software in Seattle, Washington. The

participant to be tested sits on a chair in front of the computer screen and is asked to wear the earphone which is attached to the computer. A white screen appears and only sound can be heard, the participant's task is to press the spacebar with his/her dominant hand as soon as the sound is presented. Fastest, slowest and average RT was recorded.

### VRT

Test was also done using Inquisit 4.0 computer software. The participant to be tested sits on a chair in front of the computer screen. A fixation cross is presented on the screen that is followed after variable time intervals by a visual target stimulus (here red circle). The participant's task is to press the spacebar as soon as the fixation cross is converted into red circle. Fastest, slowest and average RT is recorded.

### In RDT

The participant was made to sit with their dominant forearm resting on a flat horizontal table surface, with the open hand at the edge of the surface. When the examiner suspends and releases the ruler vertically the participant is instructed to catch it as quickly as possible. The distance the ruler fell was recorded in centimeter. Three readings were taken and the mean was calculated. This distance was converted into time by using the formula,  $t=\sqrt{2d/g}$  where,  $d$  is the distance travelled by the ruler and  $g$  is the acceleration of gravity ( $9.8 \text{ m/s}^2$ ).

### Balance test using Wobble disc board

- WB stance wide base of support (BOS): The participant has to stand on WB with legs apart so that the feet touch the edge of the board and try to maintain the balance so that they don't fall.
- WB stance narrow BOS: The participant has to stand on WB with legs together so that the feet is in the center board and try to maintain the balance so that they don't fall.

## TUGT

The person to be tested has to stand up from a chair and walk 3 meters, turn around and walk back. Timer starts when the therapist says “Go” and stopped when the patient’s pelvis touches the chair. Three readings were recorded and the mean was calculated.

## Statistical analysis

The statistical analysis was done in SPSS 16 software. All data sets analyzed passed a normality test, therefore a parametric test was used. For comparing diabetic and healthy group ‘Independent sample T-test’ was done. For all tests, the level of significance used was  $P$ -value < 0.05.

## Ethical considerations

Ethical approval was obtained for the cross-sectional study from institutional ethical review board committee (N-EC/2019/SC/04/68).

## Results

### Demographic information participants

There were 200 participants participated in this study out of which 100 were diabetic and 100 were healthy. Their mean age was: Diabetic  $53.317 \pm 3.878$  years and Healthy  $52 \pm 4.681$  years, and mean BMI were: Diabetic  $25.364 \pm 1.516$  kg/cm<sup>2</sup> and Healthy  $23.221 \pm 2.554$  kg/cm<sup>2</sup> with  $P$ -value = 0.89 and  $P$ -value = 1.28 respectively suggesting both the groups are homogeneous 85 participants were females (36-diabetic group and 49-healthy group) and 115 participants were males (64-diabetic group and 51-healthy group).

In the diabetic group, the mean duration of DM was  $9.2 \pm 2.47$  years, their mean blood sugar levels were Fasting:  $120.7 \pm 16.80$  and

Post meals:  $169.8 \pm 16.18$ . Oral medication involves Metformin 250, Metformin 500 and Metformin 850 which were taken by 4, 86 and 10 participants respectively. 90 participants took the medication twice a day while 10 participants took the medication thrice a day (Table 1).

### Comparing the reaction time between diabetic and healthy participants.

**ART Total:**  $P$ -value  $\leq 0.0001$  for fastest ART and average ART shows that the test is statistically significant ( $P$ -value < 0.05), where ART in healthy group was faster compared to diabetic group.

**Fast ART:**  $P$ -value = 0.334 for fastest ART among diabetic females and males, and  $P$ -value = 0.764 among healthy females and males shows that the test is not statistically significant ( $P$ -value > 0.05) in both the groups. However,  $P$ -value = 0.001 for fastest ART among female diabetic and healthy participants, and  $P$ -value = 0.011 among male diabetic and healthy participants in both the groups shows that the test is statistically significant ( $P$ -value < 0.05).

**Slow ART:**  $P$ -value = 0.200 for slowest ART among diabetic females and males, shows that the test is not statistically significant ( $P$ -value > 0.05), while  $P$ -value = 0.023 among healthy females and males shows that the test is statistically significant ( $P$ -value < 0.05). However,  $P$ -value = 0.011 for slowest ART among female diabetic and healthy participants shows that the test is statistically significant ( $P$ -value < 0.05), while  $P$ -value = 0.546 among male diabetic and healthy participants shows that the test is not statistically significant ( $P$ -value > 0.05).

**Average ART:**  $P$ -value = 0.646 for average

**Table 1. Demographic information of participants**

Variables	Diabetic Group	Healthy Group	$P$ -value
Sex			
Female	36(36%)	49(49%)	0.078
Male	64(64%)	51(51%)	
Age (years)	53.31 ( $\pm 3.87$ )	52.0 ( $\pm 4.68$ )	0.89
BMI (kg/m <sup>2</sup> )	25.36 ( $\pm 1.51$ )	23.22 ( $\pm 2.55$ )	0.28
Duration of DM (yrs.)	9.2 ( $\pm 2.47$ )	-	-
Fasting blood sugar(mg/dL)	120.7 ( $\pm 16.80$ )	-	-
Post prandial blood sugar(mg/dL)	169.8 ( $\pm 16.18$ )	-	-

ART among diabetic females and males, and  $P$ -value= 0.229 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.001 for average ART among female diabetic and healthy participants, and  $P$ -value= 0.019 among male diabetic and healthy participants in both the groups shows that the test is statistically significant ( $P$ -value< 0.05).

**VRT Total:**  $P$ -value= 0.001 for fastest VRT, slowest VRT and average VRT shows that the test is statistically significant ( $P$ -value< 0.05), where VRT in healthy group was faster than diabetic group.

**Fastest VRT:**  $P$ -value= 0.333 for fastest VRT among diabetic females and males, and  $P$ -value= 0.956 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.001 for fastest VRT among female diabetic and healthy participants, and  $P$ -value= 0.001 among male diabetic and healthy participants in both the groups shows that the test is statistically significant ( $P$ -value< 0.05).

**Slowest VRT:**  $P$ -value= 0.794 for slowest VRT among diabetic females and males, and  $P$ -value= 0.539 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.001 for slowest VRT among female diabetic and healthy participants, and  $P$ -value= 0.001 among male diabetic and healthy participants in both the groups shows that the test is statistically significant ( $P$ -value< 0.05).

**Average VRT:**  $P$ -value= 0.995 for average VRT among diabetic females and males, and  $P$ -value= 0.513 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.001 for average VRT among female diabetic and healthy participants, and  $P$ -value= 0.001 among male diabetic and healthy participants in both the groups shows that the test is statistically significant ( $P$ -value< 0.05).

**RDT:**  $P$ -value= 0.919 shows that the test is not statistically significant ( $P$ -value> 0.05) among diabetic and healthy group. Similarly,  $P$ -value= 0.122 among diabetic females and males, and  $P$ -value= 0.415 among healthy females and males as well as  $P$ -value= 0.507 among female diabetic and healthy participants, and  $P$ -value= 0.977 among male diabetic and healthy participants in both the groups also shows that the test is not statistically significant ( $P$ -value> 0.05).

**WB stance wide BOS:** 1<sup>st</sup> time edge touches floor: -  $P$ -value= 0.841 among diabetic and healthy groups shows that the test is not statistically significant ( $P$ -value> 0.05). Similarly,  $P$ -value= 0.671 among diabetic females and males, and  $P$ -value= 0.318 among healthy females and males as well as  $P$ -value= 0.407 among female diabetic and healthy participants, and  $P$ -value= 0.553 among male diabetic and healthy participants in both the groups also shows that the test is not statistically significant ( $P$ -value> 0.05).

No. of times edges touches floor: -  $P$ -value= 0.001 among diabetic and healthy groups shows that the test is statistically significant ( $P$ -value< 0.05), where the edges of the WB touched the floor more times in the diabetic group compared to healthy group.

$P$ -value= 0.392 among diabetic females and males, and  $P$ -value= 0.913 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both groups. However,  $P$ -value= 0.001 among female diabetic and healthy participants, and  $P$ -value= 0.003 among male diabetic and healthy participants shows that the test is statistically significant ( $P$ -value< 0.05) where the females and males in the diabetic group touched the edges of the WB more times than healthy females and males.

**WB stance narrow BOS:** 1<sup>st</sup> time edge touches floor: -  $P$ -value= 0.139 among diabetic and healthy group shows that the test is not statistically significant ( $P$ -value>0.05). Similarly,  $P$ -value= 0.986 among diabetic females and males, and  $P$ -value= 0.489 among healthy females and males as well as  $P$ -value

$P$ -value= 0.731 among female diabetic and healthy participants, and  $P$ -value= 0.239 among male diabetic and healthy participants in both the groups also shows that the test is not statistically significant ( $P$ -value> 0.05).

No. of times edges touches floor:  $P$ -value= 0.000 among diabetic and healthy groups shows that the test is statistically significant ( $P$ -value< 0.05), where the edges of the WB touched the floor more times in the diabetic group compared to healthy group.

$P$ -value= 0.784 among diabetic females and males, and  $P$ -value= 0.580 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.001 among female diabetic and healthy participants, and  $P$ -value= 0.001 among male diabetic and healthy participants shows that the test is statistically significant ( $P$ -value< 0.05), where the females and males in the diabetic group touched the edges of the WB more times than healthy females and males.

**TUGT:**  $P$ -value= 0.023 for TUGT shows that the test is statistically significant ( $P$ -value<0.05), where the healthy group performed better than diabetic group.  $P$ -value= 0.485 for TUGT among diabetic females and males, and  $P$ -value= 0.369 among healthy females and males shows that the test is not statistically significant ( $P$ -value> 0.05) in both the groups. However,  $P$ -value= 0.029 for TUGT among female diabetic and healthy

participants shows that the test is statistically significant ( $P$ -value< 0.05), while  $P$ -value= 0.305 among male diabetic and healthy participants shows that the test is not statistically significant ( $P$ -value> 0.05) (Table 2).

## Discussion

The results of our study suggested that; the fastest ART and average ART values were statistically significant among diabetic and healthy groups, where the healthy group performed better than the diabetic group. The delay in DM group may be due to increase in blood glucose level that increases blood viscosity leading to circulatory disorders affecting both large and microscopic size blood vessels, especially involving stria vascularis that in turn causes damage at multiple neural units (hair cells) at structural level. The extent of tissue ischemia and hypoxia in DM group can lead to beginning of auditory nerve damage and hence delayed ART (6). Similar studies found a 30ms difference in ART values between diabetics and the control group (7).

Our study result states that fastest VRT, slowest VRT and average VRT were statistically significant among diabetic and healthy groups, where the healthy group performed better than the Diabetic group. The delay in DM group may be due to constant

**Table 2. Comparison of reaction time between diabetic and healthy groups.**

Components	Diabetic Mean ( $\pm$ SD)	Healthy Mean ( $\pm$ SD)	$P$ -Value
ART fast (sec)	2.19 ( $\pm$ 17.38)	1.86 ( $\pm$ 11.46)	0.00
ART slow(sec)	2.85 ( $\pm$ 28.18)	2.66 ( $\pm$ 21.98)	0.17
ART average (sec)	2.59 ( $\pm$ 22.00)	2.36 ( $\pm$ 12.88)	0.00
VRT fast(sec)	2.71 ( $\pm$ 38.26)	2.21 ( $\pm$ 12.95)	0.00
VRT slow(sec)	3.53 ( $\pm$ 56.46)	2.91 ( $\pm$ 22.63)	0.00
VRT average(sec)	3.02 ( $\pm$ 39.19)	2.57 ( $\pm$ 13.37)	0.00
Ruler Drop Test(sec)	0.18 ( $\pm$ 0.27)	0.12 ( $\pm$ 0.28)	0.91
WB stance wide BOS- 1 <sup>st</sup> time edge touches floor(sec)	8.12 ( $\pm$ 2.68)	12.25 ( $\pm$ 2.68)	0.84
WB stance narrow BOS- 1 <sup>st</sup> time edge touches floor(sec)	9.64 ( $\pm$ 2.50)	15.21 ( $\pm$ 2.75)	0.13
WB stance wide BOS- no. of times edges touches floor (n)	8.65 ( $\pm$ 2.62)	5.62 ( $\pm$ 1.53)	0.00
WB stance narrow BOS- no. of times edges touches floor (n)	6.56 ( $\pm$ 2.22)	3.66 ( $\pm$ 1.04)	0.00
TUGT (sec)	14.75 ( $\pm$ 1.51)	9.77 ( $\pm$ 1.17)	0.02

hyperglycemia causing narrowing of the retinal arteries resulting into reduced retinal blood flow leading to dysfunction of neurons at inner retina which later extends to outer retina as well. This may cause beginning of retinal dysfunction and degeneration of the neurons and glial cells resulting in delayed response (8-9). Similar studies show doubling of VRT in diabetics versus that measured in healthy individuals (17).

Our study results states VRT is more delayed than ART in both the groups, (10-13) the common reason on comparison with healthy individuals could be due to increase in blood glucose level in DM group, that causes glucose oxidation and release of free radicals (like peroxynitrite) leading to axonal fragmentation and degeneration of both type nerve fibers, decreasing nerve diameter and delayed transmission of nerve impulses leading to delayed response (10,13-15). RT is dependent on several factors from arrival of stimuli, processing unit to muscle response depending on different parameters (16).

In VRT, the arrival of stimulus involves 6 step chemical changes that convert photons to bioelectric stimuli along with activation of many collateral pathways in association with visual areas. Whereas ART involves single step chemical changes that convert pressure wave to bioelectric stimuli. Studies have shown that auditory stimulus takes only 8-10 milliseconds to reach the brain, whereas visual stimulus takes 20-40 milliseconds in healthy individuals (17).

In DM, dysfunction and degeneration of retinal cells causes delay in 6 step chemical changes to bioelectrical stimuli along with delay in activation of associated pathways leads to reduced and delayed VRT when compared to ART, ART response is much quicker among diabetic group. Our findings are supported by many recent studies stating that ART is significantly faster than VRT among diabetic individuals when compared to healthy groups (18-19).

Our study showed that RDT was not statistically significant. This states that there is

no marked change in hand-eye coordination among diabetic and healthy groups. A comparative study by S. Bhat and S. Kumar between middle age and geriatric type 2 diabetic groups concluded the RT and coordination among middle aged DM group was significantly faster than geriatric DM group (20). The mean time taken by middle aged group was 0.19 ( $\pm 0.01$ ) seconds (20) which was in hand with our study that is 0.18 ( $\pm 0.27$ ) seconds.

In the present study, the result for WB stance wide BOS and narrow BOS- 1<sup>st</sup> time edge touches floor in both diabetic and healthy groups is not statistically significant. WB stance wide BOS and narrow BOS - number of times the edges touch the floor is statistically significant in both the groups. This could be associated with beginning of somatosensory dysfunction in lower limb among diabetic group that decreases ankle joint proprioception and vibration senses that leads to inappropriate timing and faulty activation of ankle strategy on dynamic wobble board surface.

This in-coordination along with hyper activation of hip strategy (21) caused repetitive touching of edge of WB to the floor in DM group. The reason for delayed postural reaction and reduced balance performance could be due to initiation of somatosensory dysfunction leading to delayed response from CNS, late activation of ankle-hip strategies causing impaired dynamic balance in DM group leading to high risk of falls (22-23). This study finding is supported by El-Kader who conducted study on elderly type 2 diabetics stating, reduced balance performance and high risk of fall using Biodex Balancing System (24).

According to our result there was a statistical significance among diabetic and healthy groups in TUGT suggesting time taken in diabetic group was longer compared to healthy group when surface is static. This could be due to somatosensory dysfunction and poor contraction of leg muscle strength could be the reason for decrease in speed while performing the test in DM group. Supported by a

longitudinal study by Park et al. concluded that type 2 diabetes is associated with an accelerated loss of leg muscle strength in older adults (25).

It was also observed that along with slowness in speed, time taken during turning phase was relatively more in diabetic group than healthy group. This could be due to in the early stage, poor glycemic control in DM group that causes somatosensory and vestibular dysfunction. Vascular damage to vestibular systems leads to degeneration of type 1 hair cells, nerve myelin sheath thinning, reduced axonal fiber diameters eventually causing beginning of vestibular dysfunction. Similar results were found by Alvarenga et al. stating elderly with diabetes presented worse performance in both functional mobility and dual task, whereas in our study middle aged diabetic group were only included and showed similar when compare with healthy group suggesting high risk of falls among diabetic group (26).

We found that among diabetic and healthy group RT was not statistically significant whereas within diabetic and healthy group RT was statistically significant in males and females for ART, VRT, TUGT (females) and WB test, suggesting DM affects equally irrespective of gender causing delayed RT later resulting in impaired balance and high risk of falls.

The gender component is contradictory with a recent study concluding the impairments due to diabetes strongly affect women than men (27-28). Our study included 42% women in diabetic group with normal BMI this could be one of the reasons where no significant changes were seen in terms of RT.

In our study we had included middle aged T2DM participants who showed delay in ART, VRT, Ruler drop test, WB test and TUGT when compared to healthy participants. Although there was a significant difference in all the components and test, all the participants didn't show any clinical signs and symptoms in terms with vision, auditory function and balance impairment. This finding is suggesting

the vascular damage caused by DM is slow and severe over the time.

Delayed RT in middle age type II DM could be consider as one of the signs for beginning of pathological changes occurring in visual, auditory and balance function which could result in functional impairment.

The limitation of our study was use of simple RT to assess visual, auditory and hand-eye coordination. Consideration of Choice RTs could show variation in the result as it's more functional based. In ruler drop test, use of 12 inches ruler (30 cm) could be one of the drawbacks as few participants were unable to catch hold of ruler on command (the trial was repeated until they catch it). Also, the minimal unavoidable human error during the test while measurement of distance travelled by the ruler. This could be the reason there was no significant difference seen in the test.

Clinical implication of the study would be early balance assessment should be considered at the time of diagnosis of T2DM. Conventional balance intervention should be considered and recommended to the patients after the diagnosis of T2DM irrespective of age and gender to prevent long term deterioration in balance and to reduce risk of falls. Future recommendation from our study could be adding up intervention and finding its effect among DM population in terms of RT.

## Conclusions

Our study concludes that in diabetic group there was a significant delay in VRT, ART and postural RT when compared to healthy individuals due to reduced response of sensory stimuli and receptor in visual, auditory, somatosensory and vestibular system. There was no significant difference in Ruler drop test between both the groups. There was no significant difference in terms of gender in RT stating DM impairments affects equally in all gender.

## Acknowledgments

The authors would like to thank participants for taking part in this study.

## Funding

self-funded study.

## References

- Mittu S, Sidhu J. Comparative study of reaction times in type 2 diabetics and non-diabetes. *Australasian Medical Journal*. 2013;6(4).
- International Diabetes Federation. *IDF Diabetes Atlas, Eighth Edition*. International Diabetes Federation; 2017. [www.diabetesatlas.org](http://www.diabetesatlas.org). Accessed January 16, 2018.
- Ross SE, Guskiewicz KM. Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. *Clinical Journal of Sport Medicine*. 2004;14(6):332-8.
- Irrgang JJ, Whitney SL, Cox ED. Balance and proprioceptive training for rehabilitation of the lower extremity. *Journal of Sport Rehabilitation*. 1994;3(1):68-83.
- Guskiewicz KM, Perrin DH. Research and clinical applications of assessing balance. *Journal of Sport Rehabilitation*. 1996;5(1):45-63.
- Xipeng L, Ruiyu L, Meng L, Yanzhuo Z, Kaosan G, Liping W. Effects of diabetes on hearing and cochlear structures. *Journal of Otology*. 2013;8(2):82-7.
- Mohan M, Thombre DP, Das AK, Subramanian N, Chandrasekar S. Reaction time in clinical diabetes mellitus. *Indian Journal of Physiology and Pharmacology*. 1984;28(4):311-4.
- Xu H, Curtis T, Stitt A. *Pathophysiology and Pathogenesis of Diabetic Retinopathy*. Amsterdam: Diapedia, The Living Textbook of Diabetes. 2014.
- Pardianto G. Understanding diabetic retinopathy. *Mimbar Ilmiah Oftalmologi Indonesia*. 2005;2:65-71.
- Richerson SJ, Robinson CJ, Shum J. A comparative study of reaction times between type II diabetics and non-diabetics. *Biomedical engineering online*. 2005;4(1):1-8.
- Giard MH, Peronnet F. Auditory-visual integration during multimodal object recognition in humans: a behavioral and electrophysiological study. *Journal of cognitive neuroscience*. 1999;11(5):473-90.
- Sartucci F, Piaggese A, Logi F, Bonfiglio L, Bongioanni P, Pellegrinetti A, et al. Impaired ascendant central pathways conduction in impotent diabetic subjects. *Acta neurologica scandinavica*. 1999;99(6):381-6.
- Ryan CM, Geckle MO. Circumscribed cognitive dysfunction in middle-aged adults with type 2 diabetes. *Diabetes care*. 2000;23(10):1486-93.
- Ceriello A. Oxidative stress and glycemic regulation. *Metabolism*. 2000;49(2):27-9.
- Kaur P, Paul M, Sandhu JS. Auditory and visual reaction time in athletes, healthy controls, and patients of type 1 diabetes mellitus: A comparative study. *International Journal of Diabetes in Developing Countries*. 2006;26(3):112-5.
- Pain MT, Hibbs A. Sprint starts and the minimum auditory reaction time. *Journal of sports sciences*. 2007;25(1):79-8.
- Kemp BJ. Reaction time of young and elderly subjects in relation to perceptual deprivation and signal-on versus signal-off conditions. *Developmental Psychology*. 1973;8(2):268.
- Dobrzanski T, Rychta T. Studies on the time of simple reaction and selective reaction in diabetes and in schizophrenia. *Polish medical journal*. 1968;7(2):442-8.
- Parekh N, Gajbhiye IP, Wahane M, Titus J. The study of auditory and visual reaction time in healthy controls, patients of diabetes mellitus on modern allopathic treatment, and those performing aerobic exercises. *J Indian Acad Clin Med*. 2004;5(3):149-56.
- Bhat S, Kumar S. Comparison of Reaction Time in Older Versus Middle-aged Type II Diabetic Patients-An observational Study. *Indian Journal of Physiotherapy and Occupational Therapy*. 2013;7(1):250.
- Fahmy IM, Ramzy GM, Salem NA, Ahmed GM, Mohammed AA. Balance disturbance in patients with diabetic sensory polyneuropathy. *Egyptian Journal of Neurology, Psychiatry and Neurosurgery*. 2014;51(1):21-9.
- Gu Y, Dennis SM. Are falls prevention programs effective at reducing the risk factors for falls in people with type-2 diabetes mellitus and peripheral neuropathy: a systematic review with narrative synthesis. *Journal of Diabetes and its Complications*. 2017;31(2):504-16.
- Rojhani-Shirazi Z, Barzintaj F, Salimifard MR. Comparison the effects of two types of therapeutic exercises Frenkele vs. Swiss ball on the clinical balance measures in patients with type II diabetic neuropathy. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. 2017;11:S29-32.
- El-Kader SM. Impact of Ankle Joint Mobility on Balance Performance in Elderly Type 2 Diabetic Subjects. *MOJ Gerontol Ger*. 2018;3(2):00082.
- Park SW, Goodpaster BH, Strotmeyer ES, Kuller LH, Broudeau R, Kammerer C, et al. Accelerated loss of skeletal muscle strength in older adults with type 2 diabetes: the health, aging, and body

## Conflict of Interest

Nil.



- composition study. *Diabetes care*. 2007;30(6):1507-12.
26. Alvarenga PP, Pereira DS, Anjos DM. Functional mobility and executive function in elderly diabetics and non-diabetics. *Rev Bras Fisioter*. 2010;14(6):491-6.
27. Wei M, Kampert JB, Barlow CE, Nichaman MZ, Gibbons LW, Paffenbarger Jr RS, et al. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *Jama*. 1999;282(16):1547-53.
28. Denton M, Prus S, Walters V. Gender differences in health: a Canadian study of the psychosocial, structural and behavioural determinants of health. *Social science & medicine*. 2004;58(12):2585-600.