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Co-relation of two point discrimination and balance in patients with type II diabetes mellitus: A cross sectional study

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Abstract

Background: Diabetes is considered as a pandemic in both developing and developed countries and also a factor for increase in the rate of falls as it has potential to affect nervous system. Loss of balance is identified as a leading cause of increase in the risk of falls. Two Point Discrimination (TPD) can be a cost effective tool in early detection of impaired balance due to its role in sensory integration through mechanoreceptors and in turn providing compensatory postural adjustments. Thus, this study was aimed to determine the correlation between TPD and balance in patients with Type 2 Diabetes Mellitus (T2DM).

Subjects and Methods: 149 patients aged 30-60 years having history of T2DM for 2 or more years able to perceive 10g of monofilament on the foot and being able to walk independently were included in this study. TPD was measured on plantar surface of toes for the patients in supine lying by Digital Vernier Caliper (DVC). Single Leg Stance Test (SLST) eyes open and eyes closed was measured for static balance. Timed Up and Go test (TUG) was measured for dynamic balance. Data was analysed using Spearman's correlation coefficient.

Results: TPD showed moderately negative correlation with SLST eyes open ($r = -0.296$) and SLST eyes closed ($r = -0.336$) and showed a weak positive correlation with TUG ($r = 0.188$) the p value < 0.05 for all.

Conclusion: This study concluded that there is a correlation between TPD perception and Balance in patients with Type II Diabetes Mellitus.

Keywords: Dynamic balance, digital vernier caliper, monofilament, static balance, two point discrimination, type 2 diabetes mellitus

1. Introduction

India leads the world with largest number of diabetic subjects earning the title of "Diabetes Capital of the World". According to the Diabetes Atlas 2006 published by the International Diabetes Federation, the number of people with diabetes in India currently around 40.9 million out of which 8.8% representing adults aged 20–79 years and is expected to rise to 69.9 million by 2025 and 79.4 million by 2030 unless urgent preventive steps are taken [1, 2]

The so called "Asian Indian Phenotype" refers to certain unique clinical and biochemical abnormalities in Indians which include increased insulin resistance, greater abdominal adiposity, lower adiponectin and higher high sensitive C-reactive protein levels [3]. Ecological and Migration studies indicate that a western lifestyle is associated with a higher prevalence of type 2 diabetes [4]. Type II Diabetes Mellitus is a heterogeneous disorder with hyperglycaemia as a common denominator [5]. Prevalence of T2DM increases with age [1, 3, 6]. Impaired balance is related to the progression of diabetes complications in both young and older adults [7].

There are evidences that diabetes affects both Central and Peripheral nervous systems [8]. The rate of falls is three times more in these patients than the normal population [9]. Loss of protective sensation is one of the most common complications seen in patients with Type II Diabetes Mellitus [10, 11]. Tactile sensitivity and presence of protective sensations can be measured best measured with Semmes–Weinstein Mono- filaments (10g) (San Jose, USA) [12, 13]. Interactions among several direct and indirect metabolic and vascular consequences of insulin deficiency, or hyperglycaemia, along with poorly defined genetic or environmental factors are required for affection of nerves in diabetes [14].

The affection can be classified as large nerve affection causes lower limb incoordination leading to unsteadiness of gait, especially in the dark or with the eyes closed and small nerve affection causes pain, paraesthesia [5, 6, 14]. Sensory nerve conduction velocity is significantly reduced in patients with T2DM [15, 16].

The term balance is used to describe the dynamic process by which the body's positions are maintained in equilibrium. Balance control is the primary underpinning function for maintaining upright posture and preventing falls [17]. The maintenance of balance is dependent on three components of performance: sensory, perceptual and motor. Sensory balance control in humans is integrated by 3 systems visual, somatosensory, vestibular. The somatosensory system provides information about the position and body parts both relating to each other and the surfaces, it includes proprioceptors, joint receptors and skin mechanoreceptors. When compared postural stability between fallers and non-fallers in normal elderly patients where they found significant changes the TPD values [18]. Mechanoreceptors can provide detailed spatial and temporal information about contact pressures on the foot and play a vital role for sensing changes to body orientation [17]. The mechanoreceptive sensation in the feet in both young and old adults is associated with the postural performance and it influences the degree to which subjects could adapt to repeated balance perturbations [19].

TPD test is used to evaluate a cortical pathway that discriminates between the sensations of two points touching the body surface and provides the information of subject's spatial acuity. TPD can be an effective tool in early detection of impaired balance due to its role in sensory integration through mechanoreceptors to provide compensatory postural adjustments that play a major role in maintaining balance both static and dynamic [20]. The stimulation of mechanoreceptors of the skin sends afferent input to area 5 of the posterior parietal cortex.

Which integrates the information along with the proprioceptive input received from the muscles and joints. Area 5 along with area 7 analyse and integrate somatosensory information leading to optimal motor performance. This is achieved in 3 ways those are by determining the starting position that is required before movement occurs, detecting error as the movement is occurring and judging the efficiency with which the movement has occurred helping the mind to shape learning [18].

The mechanoreceptor density is higher in the regions of palm and soles as represented by the sensory homunculus. The larger area represented by the hand and the foot emphasizes it's importance in optimizing sensory input and thereby enhancing function of the area it represents. TPD detects changes in the sensory system and TPD threshold is proportional to the size of the area in the brain representing this region as an afferent component in maintaining balance being the sensory system, its testing can be an effective predictor for changes in balance [18-22]. International Consensus on the Diabetic Foot, recommends testing can be done on three sites on foot: great toe, metatarsal head 1, and metatarsal head. Measurement of TPD values in diabetic patients is an easy, cost-effective clinical method to evaluate the onset and progression of neuropathy [23].

Thus, co relation if found, between two point discrimination and balance it may be used to detect the changes in balance in subjects with T2DM. For future scope, if TPD and balance are proven relatable, Balance can be improved by enhancing TPD perception through techniques such as tactile co-activation using Hebbian's plasticity [24].

2. Subjects and methods

Study design was cross-sectional and the type of sampling was purposive. Patients diagnosed with T2DM for more the 2 years and on regular medication were the target population. Inclusion Criteria:

- Age 30-60 years
- Able to walk independently and
- Presence of protective foot sensations on foot.

Protective foot sensation was checked on the plantar surface of the foot by 10g monofilament [25-44]

Exclusion Criteria

- Diagnosed with any kind of diabetic neuropathy.
- Retinopathy.
- Open wounds on foot.
- Any neuro muscular disorder.

Over 250 patients were screened out of which those who were willing to participate and fulfilling the inclusion and exclusion criteria were included in the study. Detailed information sheet was given and informed consent was taken from all the patients. The procedure was explained in detail. Demographic data and relevant history pertaining to T2DM was recorded.

Recent reports of Glycosylated haemoglobin levels were noted and the patients' current diabetic status was inferred as controlled (HbA1c≤ 6-7.9%) diabetes mellitus or uncontrolled (HbA1C≥8%) diabetes mellitus [26].

TPD testing was performed by DVC. Patients were asked to lie down on the plinth comfortably in supine lying. The DVC was first applied to the palm with eyes closed, so that they could perceive the sensation and respond as one or two points. Once they were familiar with the procedure, it was done on the great toe. The distance between the points of DVC was kept highest at the start of test which was subsequently reduced till the moment the patient perceived two points as one, this reading (in mm) was noted. Three measurements were taken in the similar manner for both the sides and mean was calculated. For taking the measurement the DVC was held in a perpendicular manner in multiple directions on the great toe such that light indentations were visible on the skin surface [27, 28, 29].

Static balance was measured using SLST eyes open and eyes closed. The test was explained and demonstrated to the patients. The starting position was standing with feet closed without footwear and arms at side then they were asked to lift one leg above the ground. They were asked to fix their gaze at an imaginary point directly at the eye level, taking care that the head was not rotated or flexed. They were instructed at the beginning of the test that if they feel as if they were losing balance they should put their feet back to ground. Stopwatch was used to record the time (in seconds) from which the patients lifted the foot till the time they placed it back on the ground. This was done for both the limbs and mean of both the readings was noted for every patient both of SLST eyes open and SLST eyes closed respectively. For the patients who had difficulty in performing the test for the first time, another trial was given [30].

Dynamic balance was measured using TUG. The test was performed in a hallway were the 3 meter distance was measured and the points were marked on the ground. A chair without arm support was placed at one end and the other was highlighted. The test was explained and demonstrated to the patients. Patients were instructed to follow therapist's cues i.e. "start" indicated standing up from the chair and walking with normal pace in their footwear till the terminal point, turning and getting back to the chair and sitting down. The duration for the same was recorded (in seconds) was recorded using a stop watch The therapist walked close to the patient to provide assistance in case of event of sudden loss of balance. For the patients who were not able to understand the test in first time, another trial was given [31].

Image 1: Monofilament Testing

Image 2: Two Point Discrimination Testing

Image 3: Single Leg Stance Test

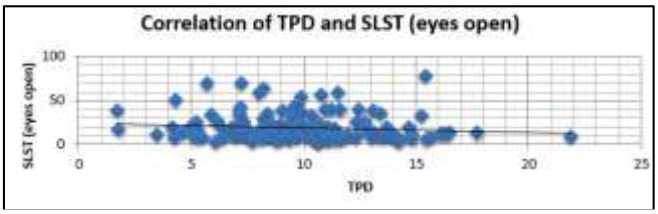
Image 4: Patient performing the TUG test

3. Statistical Analysis

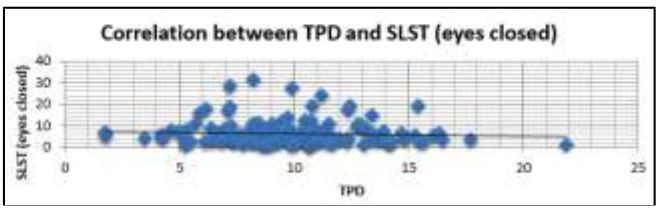
Descriptive statistics were performed for all the base line characteristics of the patients like age groups, gender, diabetic status and history of type 2 diabetes mellitus (years). All data was processed using SPSS Software (version 27). Data was analysed for normality. Based on the results of normality testing non parametric test i.e. Spearman's correlation test was applied. The mean of the all the components of the data were compared to the normal mean and the difference was noted.

4. Results

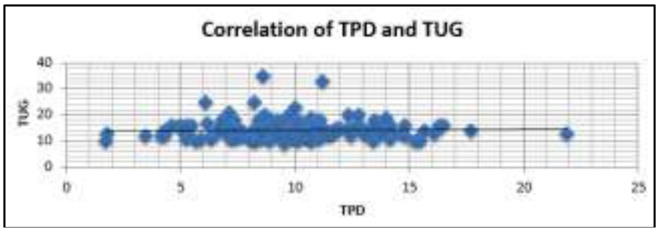
41, 45, 63 subjects belonged to 30-40 years,41-50 years, 51-60 years of age group respectively with mean age of 48.02(±9.05). 45% of the population were males and 55% females. 60% of the population had controlled DM and 40% had uncontrolled DM. Frequency distribution showed that majority of population had history of DM since 2-5 years. The Spearman's correlation coefficient for correlation between TPD and SLST (eyes open) with p value <0.001, r value was calculated to be -0.296 suggesting moderate negative correlation (Graph 1) The Spearman's correlation coefficient for correlation between TPD and SLST (eyes closed) with p value < 0.001, r value was calculated to be -0.336 suggesting moderate negative correlation (Graph 2). The Spearman's correlation coefficient for correlation between TPD and TUG the level of significance i.e. p <0.001, r value was calculated to be 0.188 suggesting weak positive correlation (Graph 3)



Graph 1: Scatter plot of correlation between TPD and SLST eyes open



Graph 2: Scatter plot of correlation between TPD and SLST eyes closed



Graph 3: Scatter plot of correlation between TPD and TUG

The mean of TPD values was compared with the normal TPD perception the difference between the means was found to be 3.22, suggesting that there is an increase in the mean of TPD perception in patients with T2DM [18, 32]. The means of SLST (eyes open) were calculated by dividing the population in 3 age groups, 30-39 years, 40-50 years and 51-60 years and were compared with the means of the respective age groups in the non-diabetic population and the difference between the means were 13.88, 23.48 and 22.26 respectively. The findings suggesting that there is decrease in the time of SLST (eyes open) in patients with T2DM. The means of SLST (eyes closed) were also calculated by dividing the population in 3 age groups, 30-39 years, 40-50 years and 51-60 years and were compared with the means of the respective age groups in the non-diabetic population and the difference between the means were 0.09,1.68 and 0.46 respectively. The findings suggesting that there is decrease in the time of SLST (eyes closed) in patients withT2DM.(30) The means of TUG were also calculated by dividing the population in 3 age groups, 30-40 years, 41-50 years and 51-60 years and were compared with the means of the respective age groups in the non-diabetic population and the difference between the means were 3.25,5.27 and 6.00 respectively. The findings suggesting that there is increase in the time of completion of TUG test in patients with T2DM [31].

5. Discussion

Monofilament testing one of the primary screening methods was used to measure cutaneous sensibility. Clinically, the sensibility was qualitatively assessed for normal touch, light touch, and protective sensation which ensured that TPD perception values were not influenced by altered touch sensation and loss of protective sensations [12, 13] In this study it was found that TPD perception was impaired in diabetic population. Majority of the population in the study had history of diabetes from 2 to 5 years. The TPD values were increased than normal which can be related to axonal loss and the cortical representation of the testing area, suggesting that it occurs as early as in 2-5 years of DM. One of the factors associated with an increased instability is decreased mechanoreceptive sensation on the soles of the feet (Lord and Ward 1994) suggesting that mechanoreceptors are responsible for maintaining balance [19].

There is evidence of correlation of TPD with EMG and NCV. There is correlation between TPD values and increase distal latencies of motor and sensory nerves suggesting that there is both axonal loss and demyelination in T2DM also TPD method is a less painful, practical, cost effective, and more easily applicable method that is completed in less time than nerve conduction studies thus, making it a tool of choice to test the axonal loss and demyelination.

Higher TPD values in the lower extremities are indicative of nerve damage and can easily determine neuropathy starting in the early stages of diabetes [29]. TPD values are higher in DM patients compared to the controls and the values don't obey "law of mobility" especially in lower limbs. The law of mobility shows the degree of axonal loss [22].

As postural imbalance is the most important factor causing falls studying the role of sensory perception in promoting postural stability is of essence [15]. TPD values are increased in the fallers when compared with non-fallers because of reduced plantar cutaneous sensation that contribute, in part, to the impaired balance. From this it can speculate that impaired plantar cutaneous sensation in people would delay compensatory step or grasp reaction times when a fall is initiated, owing to impaired ability to sense the COP movement under the feet [17].

Quiet standing is said to be controlled by sensory feedback on the basis of closed loop system (Nashner, 1976) in which the centre of foot pressure moves in phase with the centre of mass [33]. Also, static balance relies more on feedback mechanism [34]. A wide spectrum of literature suggested occurrence of axonal degeneration of sensory nerves in patients with type II DM which may lead to alterations in control of static balance [9, 10, 15, 16] Owing to these factors we correlated TPD with SLST (Eyes open, Eyes closed) and found that a moderate Negative correlation existed between them, suggesting that with increasing TPD values, the SLST time reduced, more for eyes closed than eyes open.

SLST test commenced with a starting position requiring the patients to stand with a narrow base of support which proved quite challenging for the diabetic population. In SLST eyes open) maintaining balance, although difficult was still possible to a greater extent of time than SLST eyes closed because balancing under static conditions was strongly associated with the ability to perceive and process visual information, which is important for feedback based mechanisms for control of balance and partly with other sensory systems. Also lot of literature suggests visual acuity seems to be more prevalently reduced in diabetic patients [34, 35]. Therefore, increased in TPD values led to decrease in SLST eyes open time.

In SLST eyes closed when the visual system was not able to contribute for maintain balance, the patients needed to rely more on other sensory input [18]. Therefore, while performing SLST eyes closed test patients demonstrated an increased difficulty in maintaining balance and considerably reduced SLST time and also exhibited fear of fall. As the sensory input from the feet was decreased suggested by the increased TPD values, the SLST eyes closed time also reduced.

In this study it was found that there was a weak positive correlation between TPD values and TUG test time. Balancing under dynamic task conditions requires the use of feed forward control which are predictive in nature, hence these predictions result in anticipatory postural adjustments that enable the mover to maintain stability (Massion, 1992). The reason for lack of correlation between static and dynamic balance is likely due to the challenge imposed on systems necessary for maintaining of postural control are different. In order to maintain equilibrium associated with the motor response speed, also suggests that there is use of feedforward mechanism with dynamic balance [33].

Dynamic postural control often involves compilation of various tasks, like proprioception, range of motion, strength and also the ability of the subjects to remain steady and upright.(36) In this study the ability to maintain steady and upright posture was assessed using SLST but the other components were not taken into consideration, thus this can be a contributing factor for existence of weak correlation between TPD and dynamic balance. It is thought that muscle fatigue leads to decreased ability to contract with correct amount of force or accuracy contributing to a large number of falls, thus contributing to weak correlation, as the test was performed only once. Proprioceptive and kinaesthetic feedback, are also altered with fatigue of muscles which may result in altered sensory input, affecting the conscious joint movement during dynamic functions. TUG has been studied to be affected in patients having DM for more than 10 years [37] as a small number of population in this study had history of DM from more than 10 years can be another reason that there was a weak positive correlation between TUG and TPD.

Thus, the findings of the present study and previous studies when compiled together prove that there exists correlation between TPD perception and balance (static and dynamic) in patients with T2DM.

6. Conclusion

This study concluded that there is a correlation between TPD perception and Balance in patients with T2DM.

7. Limitations

This study did not quantify deep sensations (kinesthesia, vibration and proprioception). The history of T2DM till how many years was not specified in the study.

8. Suggestions

This study can be done in early age group for targeted results. It can be replicated within normal population. Long term follow up can be done and the change in TPD values can be noted and then be correlated with static and dynamic balance.

9. Conflict of Interest: None

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