Section: Physiology

Original Research Article

EARLY DETECTION OF DIABETIC POLYNEUROPATHY BY A SIMPLE CALIBRATED DIVIDER ASSESSING TWO-POINT DISCRIMINATION OVER BACK AND DISTAL LIMBS --- A CROSS-SECTIONAL STUDY IN A TERTIARY HEALTHCARE INSTITUTE

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ABSTRACT

Background: Two-point tactile discrimination is the distinction of two points of sensation applied to skin. Diabetic peripheral neuropathy (DPN) gives rise to a wide range of sensory changes, starting from paraesthesia and numbness to loss of limb and life. The assessment of sensation is commonly done for lower limbs, especially in the foot, to prevent ulcers. Sensory changes may also be present in the upper limb and back of the body, although its documentation is not routinely performed. Early detection of sensory deficits is crucial to arrest the progression of neuropathy. **Aims & objectives:** The back of the body bears the body weight at the supine position, especially the areas over the two scapulae and the areas overlying the lumbar spines and sacrum. In the elderly age group of diabetic debilitated patients, these sites are prevalent sites for developing skin sores. The fingertips are always exposed to various sensory modalities. The main objective of this study is to assess the two-point discrimination over the back (scapular region) and the fingertips of patients with type 2 diabetes mellitus. **Materials and Methods:** A case-control study was conducted in the Department of Physiology at Medical College, Kolkata, after obtaining approval by the Institutional Research and Ethics Committee on 100 cases & 70 control subjects. A calibrated divider with two sharp-pointed pointers was used. To measure the two-point discrimination thresholds at the back of the body and at the tip of the finger of diabetic patients and also of the control group, and evaluate its potential role in the early detection of diabetic polyneuropathy. **Result:** All data obtained by the methods described here are tabulated. Graphs and charts are drawn and analyzed by comparing the means. There is a highly significant difference in means between the cases and the controls. This is remarkable at the tip of the finger and also at the scapula. Women showed TPD values lower than those of men. **Conclusion:** The two-point tactile discrimination test, performed using a simple two-point calibrated divider, can be used to detect upper limb neuropathy and also in the trunk in patients with diabetes, which can be further confirmed with nerve conduction velocity tests.

INTRODUCTION

The human sensory system perceives an objective and material environmental change as a subjective sensation, relative to species specificity and individual specificity.[1] Evaluation of the sensory perception of a subject is, to some extent, difficult as its subjective feelings, biases, inconsistencies, and uncontrolled variability influence the assessment.[2] A sense of touch that allows the opportunity to explore, recognize, and manipulate objects in the surroundings also ensures effective communication and social interaction with other people.[3] In this study, the perception threshold of a sensory stimulus, two-point discrimination, was assessed in a population of normal subjects and patients with diabetes mellitus, as it is widely used in academic

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research and clinical practice because of the easy test application and interpretation of test results.

The number of patients with diabetes globally is expected to reach 783 million by 2045.[4] The number of people living with diabetes has increased from 200 million in 1990 to 830 million in 2022.[5] Prevalence has been rising more rapidly in low- and middle-income countries than in high-income countries.[6] By the year 2035, nearly 592 million people are predicted to die of diabetes.[7] According to the International Diabetes Federation (IDF), India at present has approximately 77 million individuals of 20–79 years of age suffering from diabetes, a number expected to surge to 134.2 million by 2045.[8] The impact is obvious, with more than 1 million deaths in India related to diabetes and its complications.[9] Diabetic neuropathy (DN) is one of the most prevalent chronic complications of type 1 and type 2 diabetes mellitus (T1DM and T2DM), significantly compromising patients' quality of life and contributing to increased morbidity and mortality rates.[10,11] The prevalence of diabetic neuropathy has assumed significant proportions in India.[12] Delayed diagnosis and poor adherence with the treatment have made the situation worse.[13] Testing of sensory perception is thus important in diabetic patients for early detection of any sensory loss, and to prevent any complications that may arise due to loss of sensation. Two-point discrimination was initially described by Weber in 1853.[14] Two-point discrimination has been used as a tool to measure the sensory loss and to determine the functional integrity of peripheral nerves in diabetes mellitus patients.[15] Two-point discrimination is to sense the distinction between two points of stimulus applied to the skin at the same time.[16] Weber in 1853 first described two-point discrimination.[17] Various factors can affect two-point discrimination values, including test site, sex, test modality, age, device, and applied force.[18] It is well established that sensory spatial acuity varies from one part of the body to another. Significantly, the oral area and fingers exhibit better sensory localization compared to other body parts such as the back, chest, and abdomen. Therefore, these sensory nerves are likely to bring a prominent loss of sensory acuity.[19]

Many studies have been performed to estimate TPD over the foot, toes, and fingertips to detect upper and lower limb affection in diabetic polyneuropathy. But very few studies to date have been done on the effect of polyneuropathy on the back. Neuropathy leads to loss of sensation, making individuals unaware of injury or pressure, and impaired wound healing. While less common than foot ulcers, neuropathy can also lead to skin breakdown and ulceration in areas exposed to pressure or friction, even in the back or scapular region.[20] The scapular area, particularly around the spine and bony prominences, can be a pressure point, especially in individuals who are bedridden or have restricted mobility. Friction and shear forces from clothing, bedding, or positioning can also contribute to skin breakdown in this area. If neuropathy develops in the back and scapular area, the individual may not perceive the pressure or friction, which increases the risk of ulceration.[21] Diabetes can cause peripheral neuropathy and peripheral artery disease (narrowing of blood vessels), both of which can impair circulation to the extremities, including the skin around the scapula.[22] In the present study, two-point discrimination test of the right index fingertip and also on the scapula was performed in both the control and cases to detect any alteration in sensory perception of TPD in two separate areas in all age groups.

MATERIALS AND METHODS

Study Setting: The present study was conducted in the Department of Physiology with the collaboration of the diabetic clinic under the Department of General Medicine.

Timelines: Twelve months. From January 2013 to January 2014

Study Design: A case-control study with a cross-sectional design.

The Institutional Ethics Committee's approval was obtained on 16.12.2012.

Study population

a. Normal subjects were randomly selected from students, teachers, and non-teaching employees with appropriate age and sex stratification.
b. Patients attending the diabetic clinic under the Department of Medicine, Medical College, Kolkata, during phase II of the study.

Sample size

The sample size for the present study was calculated with the help of the formula:

$n = Z^2pq/l^2$

where Z is the 95% confidence limit=1.96,

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where Z is the 95% confidence limit=1.96,

p=prevalence of diabetes mellitus (here it is 12%) [23].

As per recent studies, the prevalence of DM in Kolkata is 11.7%, approximately 12%

q is the complement of p,

l=precision (here, 5% absolute precision was assumed).

Thus, the sample size was 170 (as per the Epi info software for sample size calculation) in a finite population i.e. OPD patients of the diabetic clinic of Medical College, Kolkata.

Study Sample

70 normal subjects as control & 100 patients with diabetes mellitus.

A scheduled sampling protocol was followed to avoid selection bias.

Inclusion Criteria

i. Patients of diabetes mellitus according to the current WHO diagnostic criteria of diabetes. i.e., Fasting plasma glucose ≥ 126mg/dl or 2

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hour plasma glucose ≥ 200mg/dl who are attending the diabetic clinic outpatient department of Medical College, Kolkata.

ii. Impaired glucose tolerance test according to the current WHO diagnostic criteria of diabetes. fasting plasma glucose < 126mg/dl and 2-hour plasma glucose between 140-200mg/dl.

iii. Impaired fasting blood glucose according to WHO's current diagnostic criteria for diabetes. FBS 110-125mg/dl and 2-hour plasma glucose is <200mg/dl.

iv. Patients of the above descriptions remain admitted in the indoor department of General Medicine, Medical College, Kolkata.

v. Controls were randomly chosen from students, teaching, and non-teaching employees with appropriate age and sex stratification.

Exclusion Criteria

i. Patients developed life-threatening complications like diabetic ketoacidosis and coma.

ii. Patients suffering from neuropathies of etiologies other than diabetes mellitus.

Methods of Data Collection

Proper Informed consent was obtained from each study subject (control and cases), after providing detailed information about the present study.

1. History taking of patient interviewing, clinical examination of patients, from hospital data records and patients' ealth records.

2. Parameters Assessed

a) Patient profile (clinical workout)

b) Tactile discrimination testing

Methodology

i. Instruments: Calibrated Divider.[24]

ii. Methodology: The instrument is calibrated in mm and consists of two sharp-pointed pointers. The calibrated divider was placed over the tip of the right index finger of the patient by keeping the two pointers at different distances over the tip. The hands were fully supported on the examining table, while the vision was occluded.[25] The testing was done with a five mm distance between the two points. One or two points were applied lightly to the fingertips in a random sequence in a longitudinal orientation to avoid a crossover from the overlapping digital nerves. The testing was stopped at 10 mm if the responses were inaccurate at that level. In the case of the scapula, the testing was started from 30mm and was stopped at 65mm. Each patient was asked whether he or she felt that the two points of the instruments were at two different distances, or could feel only one point. The distance between the two pointers was noted by the calibration of the instrument. The patient was also asked if he/she couldn't realize any tactile sensation that should also be mentioned. Occasionally, without the subject's knowledge, the subject was touched with only one prong. This prevented the subject from knowing whether or not a two-point stimulus was always delivered. When the subjects consistently perceive one point rather than two points, the TPD is reached and was recorded in the datasheet. The distance used in the TPDT varies according to which part of the body is measured; it is 2–6 mm on the tips of fingers, and 40–60 mm on the back.[26,27]

All data obtained are tabulated. Graphs and charts are drawn and analyzed by standard statistical methods using SPSS. The mean and standard deviation were used to calculate the quantitative data (including age and two-point discrimination value. In an independent sample t-test, the two two-point discrimination values of male and female participants were compared. The P-value cutoff was set at 0.05 or below to ensure statistical significance. ANOVA was used to compare the average TPD values between age groups.

RESULTS

The age-wise and sex-wise distribution of controls and cases is stated in Table 1. It shows an overall concordance of the normal distribution of population subgroups as per NFHS (2009).

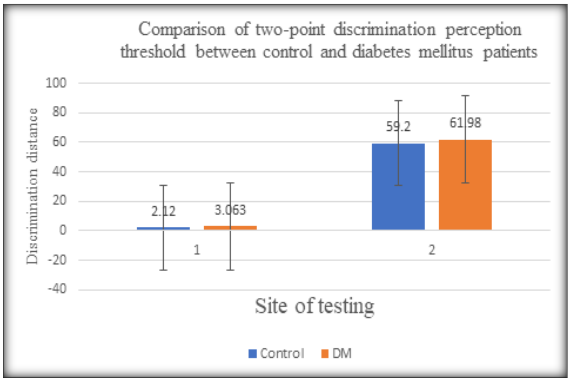

Figure 1: Comparison of two-point discrimination perception threshold between control and diabetes mellitus patients

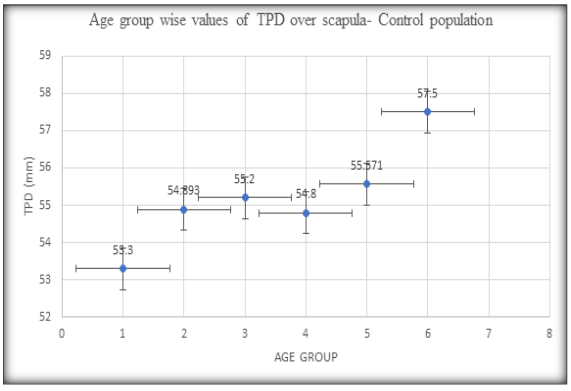

Figure 2: Age group wise values of TPD over scapula-Control population

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Table 1: Age-wise and Sex-wise distribution of Control and Cases

	Control (n=70)		Diabetes Mellitus (n=100)	
Age group	**Male**	**Female**	**Male**	**Female**
20-30 yrs-group 1	4	2	1	2
31-40yrs Group 2	9	5	3	12
41-50yrs Group 3	12	14	12	22
51-60yrs Group 4	8	6	16	15
61-70yrs Group 5	3	4	8	6
71-80 yrs Group 6	3	0	0	3

Table 2: Disease duration-wise distribution of Cases

Parameter		Group P	Group E	P-value
Duration of surgery (minutes)	Longest duration	240	210	-
	Shortest duration	150	120	-
Intraoperative vitals (Mean ± SD)	Systolic BP	135.2 ± 18.43	132.43 ± 17.7	0.556
	Diastolic BP	92.26 ± 7.99	92 ± 7.39	0.894
	Pulse rate	95.4± 13.34	92.56 ± 11.6	0.385
	SPO2	98.9 ± 1.02	99.03 ± 0.61	0.545
	MAP	106.57 ± 9.16	105.47 ± 8.6	0.634
VAS score (immediate postoperative)	VAS 1	16	18	-
	VAS 2	14	12	-
VAS score at 24 hours (Mean ± SD)		3.93 ± 0.52	3.83 ± 0.69	0.532

Table 3: Blood Sugar values of the diabetic patients under study (n=100)

Fasting Blood Sugar (mg/dL)	**PP Blood Sugar (mg/dL)**
147.91±59.056	233.361±101.85
p< 0.0	

Table 4: A comparison of two-point discrimination perception threshold between cases and controls of diabetes mellitus

	Control	**Diabetes mellitus(DM)**	**Control SD**	**DM SD**
Tip of the finger	2.12	3.063	0.182852.	1.2731
Sapula	59.2	61.98	2.1267	16.6114

Table 5: Comparison between two-point discrimination values of the finger-tip (right index) in diabetic and non diabetic groups

Age Group	**Control**	**Diabetes**	**P Value**
20-30 yrs	2.1	3.4	0.0210*
31-40yrs	1.8	2.94	0.0015**
41-50yrs	2	3.307	< 0.0001**
51-60yrs	2	3.2	< 0.0001**
61-70yrs	2.5	2.9	0.0812
71-80 yrs	2.5	3.53	0.012*

Table 6: Comparison between two-point discrimination values on the back (right scapula) in diabetic and non diabetic groups

Age Group	**Control TPD(mm)**	**Diabetes TPD(mm)**	**T value**	**P value**
20-30 yrs	53.33	61	4.3466	0.0491*
31-40yrs	54.893	56.6983	1.2382	0.2375
41-50yrs	55.264	56.55	1.5029	0.1469
51-60yrs	54.893	58.686	3.2884	0.0059**
61-70yrs	55.571	58.500	3.0117	0.0236*
71-80 yrs	57.5	60.267	2.7379	0.1115

*Significant **Highly significant

Table 7: Independent Sample t test for Difference(mm) of Two Point Discrimination over the right index finger among genders within the disease group

Gender	**Mean±SD**	**Independent sample test**	**P value**
Male Female	3.55±0.6058 3.28±0.5843	t = 2.2518 df = 98 standard error of difference = 0.154	0.0266*

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Table 8: Independent Sample t test for Difference(mm) of Two Point Discrimination (right scapula) among genders

Gender	Mean±SD	P vaue
Male Female	59.233±0.8959 49.17±0.9685	< 0.0001**

DISCUSSION

In the present study, the human sensory system was investigated concerning a specific sensory modality–tactile discrimination modality in a study population comprising a control(n=70) group and patients with diabetes(n=100) at the tip of the right index finger and right scapula. The age-wise and sex-wise distribution of controls and cases is stated in Table no1. In sensory nerve damage, as the sensory loss progresses upwards and reaches approximately mid-calf, it starts appearing in the hands. This gradual evocation causes the typical 'stocking-glove' sensory loss, which reflects preferential damage according to axon length, with the longest axons being affected first.[28]

Table 4 and Figure 1 depict a comparison of tactile discrimination perception threshold between cases and controls of diabetes mellitus. A close look at this finding reveals a significant difference between the means of the cases and controls based on the standard two-point discrimination test.[29,30]

A shorter distance is associated with increased receptor density, resulting in a more sensitive TPD perception.[31]

Table 5 presents a comparison of two-point discrimination values at the fingertips between diabetic subjects and a control group. In all six age categories within the diabetic population, increased two-point discrimination was observed in the 20-30 years age group ($p = 0.0210$), 31-40 years ($p = 0.0015$, highly significant), 41-50 years ($p < 0.0001$, highly significant), 51-60 years ($p < 0.0001$, highly significant), and in the 71-80 years age group ($p = 0.012$, significant). These TPD values were statistically significant across these age groups. Nonetheless, for individuals aged 61 to 70, the information does not show a notable difference; the value has increased, although it is not statistically significant (p=0.0812). This aligns with the findings of Periyasamy R et al.[32] In the current research, a non-significant strong positive correlation was observed between age and two-point discrimination of the right index finger in the control group (r=0.732), while within the disease group, a non-significant very weak positive correlation between age and TPD values was found (r = 0.1232). The findings from this study contradict those of another study, which indicated that an individual's acuity for 2-point discrimination is influenced by their age.[33,34] A different study pointed out that the decrease in tactile sensitivity as age advances is due to blood supply and other factors.[35]

Table 6 shows a comparison between two-point discrimination values on the back (scapular region) in diabetic and control groups of six age groups. Diminished TPD was detected in all the age groups compared with the respective allocated age groups of the control population. But only in the three age groups 20-30 years (p=0.0491),51-60 years (p=0.0059,highly significant) and 61-70 years (p= 0.0236) findings are statistically significant. While there's no specific "normal" value for the scapula except very few [36], it's generally accepted that the scapular area will have a higher 2PD threshold (meaning a larger distance is needed to distinguish two points) compared to areas like the fingertips, which have a much higher density of sensory receptors.

The scapula, or shoulder blade, is not typically a primary area for the two-point discrimination test due to its relatively sparse nerve supply compared to areas like the fingertips. However, it can be tested to assess overall sensory function. The sensory nerve supply to the skin of the scapular region is primarily provided by branches of the suprascapular nerve, the axillary nerve, and the dorsal scapular nerve. The suprascapular nerve takes its origin from the C5 and C6 roots of the upper trunk of the brachial plexus, supplies the acromioclavicular and glenohumeral joints, and also the skin overlying these areas. The dorsal scapular nerve, originating from the C5 root, primarily innervates the rhomboid and levator scapulae muscles but also has a sensory component that contributes to the innervation of the skin in the scapular region.[37] Diabetes mellitus is one of the important secondary causes of suprascapular neuropathy, which is an uncommon but recognizable cause of shoulder pain and also sensory impairment over the scapular region.[38]

In the population, the number of elderly persons continues to increase, and the number of older adult patients of various chronic diseases, especially diabetes [37] and has increased significantly. Diabetic ulcers over the scapula are not a typical location, which are more commonly found on the feet.[39] Causing poor circulation and nerve damage, diabetes can lead to skin problems and ulcers in various sites of the body. If a diabetic patient develops an ulcer over the scapula, it could be due to a pressure ulcer, a neuropathic ulcer, or a skin infection related to diabetes. However, researchers have identified older age, cognitive impairment, and comorbid conditions affecting tissue healing.[40] Loss of sensory perception is also one of the common risk factors.[41]

The TPD values over the scapular area in the control group show a correlation with age in the control group, a significantly large positive relationship between Age Group and TPD(mm), [$r(4) = .892$, $p = .017$], supporting these studies.[33,34,35]

But TPD acuity in the diabetic population in the present study does not show any definite relation with the age groups. A nonsignificant small positive

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relationship between Age Group and TPD(mm), (r(4) = .114, p = .829) , not corroborative with.[33,34,35]

Table 7 illustrates the results of the independent sample t-test analyzing the difference in two-point discrimination (measured in mm) on the right index finger between genders within the disease group. For males, the two-point discrimination is recorded at 3.55±0.6058 mm, while for females, it is noted at 3.28±0.5843 mm, with a significance level of p=0.0266.[42]

Table 8 depicts the independent sample t-test for the difference(mm) of two-point discrimination over the scapula among genders within the disease group, showing females have greater acuity for two-point discrimination.[43]

CONCLUSION

Two-point tactile discrimination testing was conducted, and the findings were analyzed by comparison between the means. There is a highly significant difference in means between cases and controls. This is especially remarkable at the tip of the right finger, having a difference of means to the extent of 44%. Discrimination testing at the scapula also yields a highly significant difference in results, although the difference in mean between cases and controls for discrimination testing at the scapula is at the order of around 5. Additionally, a considerable degree of variation is seen in the discrimination threshold at the scapula for diabetes patients, which may suggest that the diabetic patient chosen for this study has a wide range of somatic neuropathy sensitivity.It can be concluded, therefore, that diabetic somatic neuropathy affects peripheral sensory nerves innervating the distal limbs more than those of the axial trunk. It is most likely due to a larger population of sensory receptors on the cutaneous surface of the distal limb. However, undergraduate MBBS students can also perform this easy, affordable, non-invasive study as part of their ECE sessions, as well as at remote peripheral health care facilities, serving as a useful method to evaluate the neurological aspects of diabetic patients.

Conflict of interest: None

Limitations of the study: Detailed quantitative sensory profiling of every patient of the study population could not be carried out during the study period. It should be done I all cases of suspected somatic neuropathy as a diagnostic, prognostic, and research tool

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