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Original Research Article

Discrimination of two-point touch sense for the upper and lower extremity based on body mass index in young adults: an observational study

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ABSTRACT

Background: To establish normative values for two-point discrimination (TPD) across 11 dermatome regions in the upper and lower limbs while examining the correlation between TPD and body mass index (BMI) and the influence of gender-based variations on sensory perception.

Methods: A cross-sectional observational study conducted with 200 healthy participants (100 males, 100 females) to measure TPD thresholds and analyse correlations with BMI. This study was carried out in a controlled clinical setting, ensuring minimal environmental interference in sensory assessment. Participants were tested in quiet, temperature-controlled conditions to maintain reliability. Normative values for TPD in upper and lower limb dermatome regions, Correlation between TPD and BMI assessed using Karl Pearson's correlation test. Gender-based correlation differences evaluated using Karl Pearson's correlation test.

Results: A statistically significant positive correlation ($p<0.05$) was observed between TPD and BMI, indicating higher BMI is associated with increased TPD values across multiple dermatome regions. No significant differences ($p>0.05$) in TPD were found between males and females, suggesting BMI influences sensory perception similarly across genders. Regional variations in TPD were noted, emphasizing differences in tactile acuity across limb areas.

Conclusions: This study successfully established reference values for TPD, providing critical insights into sensory perception variations based on BMI. The findings challenge previous assumptions by confirming BMI as a significant factor in tactile sensitivity. Standardized testing protocols are recommended for clinical applications and future research in neurophysiology and rehabilitation.

Keywords: Aesthesiometer, BMI, Lower extremity, Normative values, Sensory perception, Tactile sensation, Two-point discrimination, Upper extremity

INTRODUCTION

Touch, pressure, and vibration applied to the skin are the main stimuli for tactile perception, and mechanoreceptors are sensitive to the skin deformation brought on by mechanical pressure. Sensory input acceptance and conduction to the central nervous system for interpretation and appropriate reaction is one of the two components of the peripherally situated section of the nervous system. Numerous distinct nerve terminals receive the stimuli and send them to the spinal cord. Touch is one of the primary input signals, and it may be further broken down into two categories of sensation: fine touch (represented by the gall and Burdach tract in the spinal cord) and crude touch (represented by the contralateral tract).[1]

The journey of sensory information from specialized mechanoreceptors to the brain involves intricate pathways through the spinal cord. As the right-hand fiber enters the spinal root, it promptly splits into two major branches: the medial and lateral branches, a critical step in relaying sensory data efficiently. The medial branch follows a distinctive course through the dorsal column, making a medial turn before ascending vertically towards the brain. This pathway ensures that tactile information, such as touch and pressure, is transmitted accurately to higher brain centres for further processing and interpretation. Somatosensory areas I and II, located in the anterior parietal lobe, are essential for processing bodily sensations, with their distinct spatial organization of body parts contributing to a finely tuned sensory system. While "somatosensory cortex" generally refers to area I due to its prominence and size, it is area II that also plays a significant role. Somatosensory area I is noted for its remarkable localization of various body parts.[2]

The two-point discrimination (TPD) test measures the threshold distance at which two neighboring items contacting the skin are recognized as separate points rather than one. It is often performed during neurological exams with two sharp points and is thought to reflect the degree of skin innervation. Several factors, such as test site, sex, test modality, age, equipment, and applied force, can influence TPD scores, with different bodily sites exhibiting varying spatial acuities. An aesthesiometer, a compact, portable device with a ruler and adjustable vinyl-coated points, is used to measure this sensitivity. The vinyl coatings reduce the impact of temperature on contact perception, enhancing test accuracy. The aesthesiometer quantifies tactile sensitivity by determining the minimum distance at which two skin contact points can be distinguished.[3]

Despite the contentiousness surrounding its reliability, the TPD test remains one of the most frequently utilized clinical assessments due to its simplicity in evaluating peripheral nerve injuries and sensory recovery. In conclusion, the TPD test's significance in evaluating peripheral nerve injuries and sensory recovery is balanced by the debate surrounding its reliability.[3]

Currently, several studies are based on the assessment of TPD on regions like upper extremity, lower extremity, and trunk regions. Even though there are studies based on correlation between TPD and BMI there is limited evidence which shows validity of TPD as a measure of BMI correlation in specific age groups, gender, and skin areas. Therefore, further research is needed for conclusive findings. The need of this study is to discriminate two points in 11 skin regions of upper extremity innervated by the branches of peripheral nerves from the brachial plexus and lower extremity innervated by branches of lumbosacral plexus based on body mass index.

Two-point discrimination (TPD) is a critical measure of tactile spatial acuity, reflecting the ability to distinguish between two separate points of contact on the skin. This sensory ability varies significantly across different regions of the body and is influenced by various factors, including age, sex, body mass index (BMI), and health conditions. Numerous studies have explored the nuances of TPD across different populations and anatomical areas, shedding light on its clinical relevance in both healthy and pathological states.

Research has consistently shown that females tend to exhibit higher discriminatory power than males, except at the fingertips, where no significant differences are observed.[3] TPD sensitivity also varies by skin area, with the fingertips exhibiting the highest discriminatory ability, while the cheek and forehead tend to be less sensitive.[1,4] Additionally, studies by Giulio Valagussa et al suggest that factors such as gender, dominance, height, and BMI have minimal impact on TPD in healthy subjects.[5]

Regional differences in sensitivity are pronounced, with some areas, such as the hand, showing superior discrimination ability compared to others like the upper arm. Notably, TPD also serves as a reliable diagnostic tool in clinical settings, as demonstrated by its utility in monitoring sensory recovery after nerve repair. Furthermore, TPD testing has proven to be both reproducible and reliable across different clinical and research settings, making it a valuable tool in assessing peripheral nerve function and neuropathy, particularly in conditions such as diabetes.[5-7]

In addition to its role in clinical diagnostics, TPD performance also offers insight into developmental trajectories. The ability to distinguish two-point stimuli develops with age, with significant improvements observed around age 6, particularly in the foot. Moreover, TPD values can predict outcomes such as pain relief following nerve decompression surgery in patients with diabetic peripheral neuropathy.[8,9]

This manuscript explores the intricacies of TPD, with a focus on the factors influencing its variability, its application in clinical practice, and its potential as a diagnostic and prognostic tool in neurological disorders. Through a review of existing literature, we aim to provide a comprehensive understanding of the role of TPD in sensory assessment, its practical applications, and future directions for research in this field. The objective of the study was to find out the normative value of two point discrimination on the 11 regions of upper limb and lower limb with corresponding BMI according to gender and to find out the relationship between BMI and TPD based on gender.

METHODS

This observational study was conducted at Tejasvini Physiotherapy College, Mangalore on 200 young and healthy volunteers, comprising of 100 females and 100 males aged between 18 to 25 years. History of previous surgery to the upper limb, upper extremity fracture (within five years), soft tissue injuries, diagnosed with any skin condition, peripheral nerve injuries were excluded. Prior to the test, all participants were provided with comprehensive information about the study's purpose and procedures. They were also given a demonstration of the testing method and had the opportunity to seek clarifications. Written informed consent was obtained from each volunteer, ensuring their willingness to participate.

The volunteer's upper limbs and lower limbs were examined for any history of previous or ongoing injuries, or any skin conditions. Crucially, none of the participants displayed any dermatological issues like scars, burns, or tattoos that could have impacted their skin's sensitivity. Additionally, no neurological impairments were reported among the participants.

The study was conducted on a span of 4 months (July 2023 to September 2023). To be examined were eleven skin regions that were innervated by brachial plexus and lumbosacral plexus-derived peripheral nerve branches. Skin areas selected for testing were both right and left side of upper limb and lower limb.

The study utilized a 2-point Dicrim-A-Gon® (Baseline® Evaluation Instruments) to investigate subject's tactile discrimination capabilities. The procedure involved carefully positioning the tips at zero separation on predetermined body locations of each participant. Subsequently, participants were prompted to audibly indicate the number of distinguishable points they could perceive when the tips made contact. Responses were categorized as 'one' if a single point was felt, 'two' if two separate points were discerned, and 'inaccurate' if subjects couldn't confidently discern one or two points.

The interval between the two metal tips of 2-point Dicrim-A-Gon® was continuously adjustable and was measured in mm. Subjects experienced mild discomfort from the sharp tip, initially perceiving it acutely. Habituation to the stimulus occurred upon first perception, often requiring desensitization through rubbing, or stroking the affected area. When subjects struggled with the initial distance perception, a greater gap was introduced as the starting point.

Conducted within a tranquil environment, the two-point discrimination (TPD) assessment was administered by a single investigator. Sensitivity evaluations took place with subjects positioned in a reclined posture upon a couch. The participants were instructed to maintain closed eyelids throughout the entire examination process. This controlled setting aimed to minimize external influences that could interfere with the accuracy of the TPD test results. By ensuring a quiet room and a consistent testing approach led by a single investigator, the study aimed to enhance the reliability of the findings. The supine position on the couch allowed for comfortable and standardized testing conditions. The instruction for subjects to keep their eyes closed aimed to isolate the tactile sense and prevent visual cues from impacting the evaluation, thereby maintaining the test's integrity. All the test regions and their peripheral nerve with root values were summarized in Table 1.

Table 1: Peripheral nerve and its distribution.

Skin regions	Peripheral nerves	Spinal roots
Upper-lateral arm	Superior lateral brachial cutaneous	C5, C6
Lower-lateral arm	Inferior lateral brachial cutaneous	C5, C6, C7, C8
Mid-medial arm	Medial brachial cutaneous	T1, T2
Mid-posterior arm	Posterior brachial cutaneous	C5, C6, C7, C8
Mid-lateral forearm	Lateral antebrachial cutaneous	C5, C6
Mid-medial forearm	Medial antebrachial cutaneous	C8, T1
Mid-posterior forearm	Posterior antebrachial cutaneous	C5, C6, C7, C8
Over 1st dorsal interosseus muscle	Superficial radial	C5, C6, C7, C8
Palmar surface-distal phalanx, thumb	Median	C5, C6, C7, C8
Palmar surface-distal phalanx, long finger	Median	C5, C6, C7, C8
Palmar surface-distal phalanx, little finger	Ulnar	C8, T1
Proximal-anterior thigh	Intermediate cutaneous N. thigh	L2, L3, L4
Distal-anterior thigh	Intermediate cutaneous N. thigh	L2, L3, L4
Mid-lateral thigh	Lateral cutaneous N. thigh	L2, L3, L4
Mid-medial thigh	Obturator	L2, L3, L4
Mid-posterior thigh	Posterior cutaneous N. thigh	L4, L5, S1, S2
Proximal-lateral leg	Lateral cutaneous N. leg	L4, L5, S1, S2
Distal-lateral leg	Superficial Peroneal	L2, L3, L4
Medial leg	Saphenous	L4, L5, S1, S2
Tip of great toe	Medial plantar cutaneous	L4, L5, S1, S2
First-second metatarsal interspace	Deep peroneal	L4, L5, S1, S2
Fifth metatarsal	Sural	S1, S2

Statistical analysis

All the data was analysed by SPSS 21.0. The normality test evaluated by using Kolmogorov-Smirnov (sample is more 40) and found that data following normal distribution. All the quantitative data and descriptive analysis were expressed in mean and standard deviation, and qualitative data in percentage (age, dominance). Difference between TPD among the male and female is statistically tested by independent t-test. Relationship between BMI and TPD were evaluated by Karl Pearson coefficient correlation. Reference values of TPD were identified by calculating mean ± 2 standard deviations. Significant level of the study was 95% CI ($p<0.05$).

RESULTS

All the demographic data based on the gender were summarized in Tables 2 and 3, and Figures 1 and 2. Two-point discrimination (TPD) was assessed across 42 dermatome levels in 200 participants (100 males, 100 females). TPD values ranged from 2.25 mm (left palmar surface distal phalanx of little finger) to 30.61 mm (right mid medial arm). Upper limb measurements (22.08-30.61 mm) consistently exceeded lower limb values (5.84-28.09 mm), with hand regions showing the smallest TPD thresholds.

Strong positive correlations (Table 4) existed between TPD and BMI across all tested anatomical regions ($r=0.191-0.388$, $p<0.05$). Statistical analysis revealed no significant gender differences (Table 4) in TPD measurements ($p>0.05$). Reference ranges were established for each dermatome level, providing normative data for clinical assessment (Table 5).

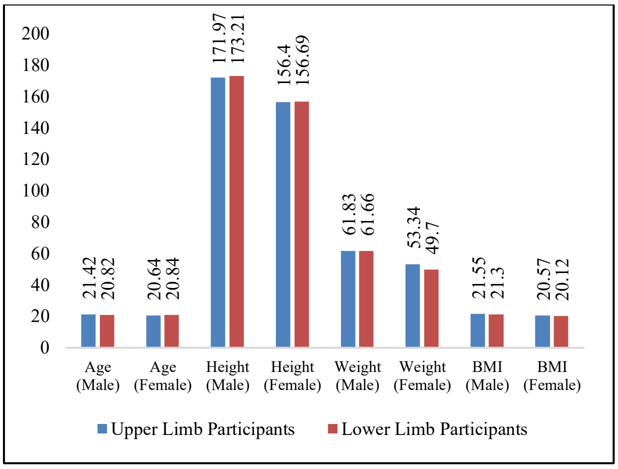

Figure 1: Gender wise demographic characteristics of study participants.

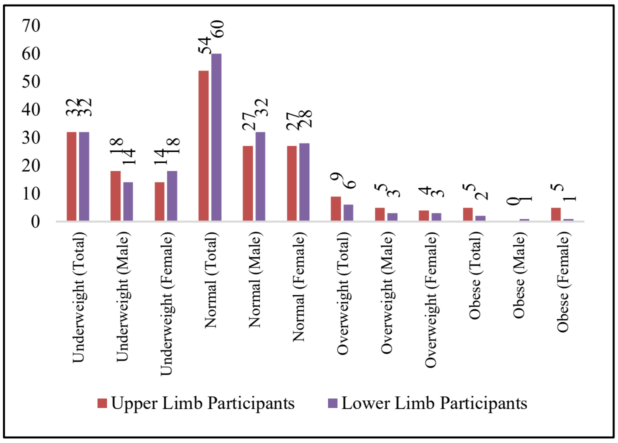

Figure 2: BMI distribution of study participants.

Table 2: Demographic data of the study participants.

Variables	Mean±SD (n=200)	
	Upper limb participants	Lower limb participants
Age (years)	21.03±1.83	20.83±1.44
Height (cm)	164.18±10.31	164.95±10.10
Weight (kg)	57.59±13.19	55.68±13.22
BMI (kg/m^2)	21.21±3.97	20.71±3.54

Table 3: TPD (mm) average values at upper limb dermatome and lower limb dermatome.

Body segment	Dermatome level	Total sample (n=200)	Males (n=100)	Females (n=100)
Upper limb	Right upper lateral arm (RULA)	30.04±8.72	30.68±8.14	29.39±9.31
	Left lower lateral arm (LULA)	30.58±8.36	32.66±8.83	28.50±7.37
	Right lower lateral arm (RLLA)	27.72±7.87	27.06±7.23	28.38±8.48
	Left lower lateral arm (LLLA)	28.04±8.12	28.23±8.22	27.86±7.02
	Right mid medial arm (RMMA)	30.61±9.53	30.41±10.56	30.81±8.47
	Left mid medial arm (LMMA)	27.62±8.12	27.38±8.08	27.86±8.22
	Right mid posterior arm (RMPA)	28.18±7.16	28.10±7.49	28.26±6.88
	Left mid posterior arm (LMPA)	29.07±7.64	28.41±7.02	29.74±8.24
	Right mid lateral forearm (RMLF)	26.63±7.52	26.42±7.36	26.85±7.76
	Left mid lateral forearm (LMLF)	25.93±6.07	26.03±6.28	25.84±5.92

Continued.

Body segment	Dermatome level	Total sample (n=200)	Males (n=100)	Females (n=100)
	Right mid medial forearm (RMMF)	25.91±7.97	26.81±9.25	25.01±6.42
	Left mid medial forearm (LMMF)	23.07±6.22	22.30±5.99	23.85±6.42
	Right mid posterior forearm (RMPF)	24.75±6.74	24.15±7.62	25.36±5.73
	Left mid posterior forearm (LMPF)	22.08±6.71	21.97±5.90	22.20±7.50
	Right first dorsal interosseous muscle (RFDIM)	9.83±4.14	9.44±3.98	10.22±4.31
	Left first dorsal interosseous muscle (LFDIM)	9.30±3.31	9.33±3.25	9.27±3.40
	Right palmar surface distal phalanx of thumb (RFMCP)	2.59±0.61	2.60±0.58	2.58±0.64
	Left palmar surface distal phalanx of thumb (LFMCP)	2.38±0.51	2.43±0.53	2.33±0.48
	Right palmar surface distal phalanx of long finger (RTMCP)	2.37±0.56	2.39±0.52	2.34±0.60
	Left palmar surface distal phalanx of long finger (LTMCP)	2.29±0.55	2.40±0.58	2.19±0.50
	Right palmar surface distal phalanx of little finger (RLMCP)	2.29±0.63	2.28±0.64	2.29±0.63
	Right palmar surface distal phalanx of little finger (LLMCP)	2.25±0.60	2.24±0.63	2.25±0.58
Lower limb	Right proximal -anterior thigh (RPAT)	26.37±5.85	25.50±4.79	27.24±6.68
	Left proximal- anterior thigh (LPAT)	26.59±6.18	25.57±5.24	27.62±6.90
	Right distal-anterior thigh (RDAT)	24.02±4.31	23.38±3.56	24.66±4.91
	Left distal-anterior thigh (LDAT)	23.82±4.25	22.83±3.06	24.80±5.01
	Right mid-lateral thigh (RMLT)	28.09±6.18	28.12±5.78	28.06±6.61
	Left mid-lateral thigh (LMLT)	27.67±5.96	27.04±5.17	28.30±6.65
	Right mid-medial thigh (RMMT)	27.09±5.57	26.70±5.09	27.49±6.03
	Left mid-medial thigh (LMMT)	26.77±5.97	26.23±5.71	27.30±6.23
	Right mid-posterior thigh (RMPT)	27.41±7.42	26.96±6.03	27.86±8.62
	Left mid-posterior thigh (LMPT)	26.81±7.47	26.28±5.39	27.34±9.12
	Right proximal-lateral leg (RPLL)	26.57±5.78	25.86±4.83	27.29 ± 6.57
	Left proximal-lateral leg (LPLL)	27.60±6.14	26.97±5.95	28.22±6.34
	Right distal-lateral leg (RDLL)	27.43±6.34	27.06±5.47	27.80±7.15
	Left distal-lateral leg (LDLL)	27.51±6.75	26.61±5.70	28.41±7.61
	Right medial leg (RML)	26.74±6.56	26.37±5.55	27.10±7.47
	Left medial leg (LML)	26.35±6.67	25.47±4.54	27.23±8.23
	Right tip of great toe (RTGT)	6.15±1.05	6.48±1.22	5.81±0.73
	Left tip of great toe (LTGT)	5.84±1.03	6.14±1.18	5.54±0.75
	Right first- second metatarsal interspace (RFSMTIS)	13.81±2.73	13.88±2.23	13.74±3.17
	Left first- second metatarsal interspace (LFSMTIS)	13.79±3.13	13.80±2.40	13.78±3.75
	Right fifth metatarsal (RFMT)	14.20±2.49	14.21±2.20	14.19±2.78
	Left fifth metatarsal (LFMT)	13.66±2.84	14.09±2.67	13.23±2.97

Difference between TPD among male and female statistically tested by independent t test and shows no significant difference (p>0.05)

Table 4: TPD and BMI relationship based on the region and gender.

Region	Dermatome level	BMI					
		Total sample		Males		Females	
		r value	Sig.	r value	Sig.	r value	Sig.
Arm	RULA	0.266	0.007*	0.667	0.000*	0.492	0.000*
	LULA	0.280	0.006*	0.667	0.000*	0.493	0.000*
	RLLA	0.195	0.050*	0.434	0.002*	0.351	0.012*
	LLLA	0.214	0.033*	0.433	0.002*	0.368	0.009*
	RMMA	0.277	0.005*	0.372	0.008*	0.402	0.004*
	LMMA	0.286	0.001*	0.373	0.008*	0.403	0.004*
	RMPA	0.232	0.005*	0.525	0.000*	0.368	0.008*
	LMPA	0.275	0.006*	0.457	0.001*	0.369	0.008*
Forearm	RMLF	0.192	0.006*	0.377	0.007*	0.342	0.015*
	LMLF	0.191	0.006*	0.350	0.009*	0.297	0.036*
	RMMF	0.244	0.014*	0.303	0.019*	0.380	0.007*
	LMMF	0.271	0.008*	0.325	0.021*	0.287	0.007*
	RMPF	0.214	0.033*	0.325	0.021*	0.283	0.046*
	LMPF	0.229	0.032*	0.328	0.021*	0.284	0.046*
Hand	RFDIM	0.243	0.015*	0.513	0.000*	0.492	0.000*

Continued.

Region	Dermatome level	BMI					
		Total sample		Males		Females	
		r value	Sig.	r value	Sig.	r value	Sig.
	LFDIM	0.241	0.014*	0.508	0.000*	0.451	0.001*
	RFMCP	0.213	0.034*	0.308	0.030*	0.404	0.009*
	LFMCP	0.274	0.006*	0.293	0.036*	0.406	0.009*
	RTMCP	0.207	0.038*	0.403	0.020*	0.396	0.037*
	LTMCP	0.212	0.034*	0.457	0.023*	0.404	0.034*
	RLMCP	0.269	0.007*	0.742	0.046*	0.786	0.043*
	LLMCP	0.289	0.004*	0.807	0.042*	0.886	0.032*
Thigh	RPAT	0.302	0.002*	0.347	0.014*	0.335	0.017*
	LPAT	0.388	0.000*	0.383	0.006*	0.469	0.001*
	RDAT	0.289	0.004*	0.393	0.005*	0.378	0.005*
	LDAT	0.271	0.006*	0.390	0.005*	0.399	0.004*
	RMLT	0.287	0.004*	0.378	0.007*	0.393	0.005*
	LMLT	0.297	0.005*	0.398	0.005*	0.424	0.002*
	RMMT	0.211	0.035*	0.411	0.003*	0.491	0.000*
	LMMT	0.226	0.024*	0.341	0.015*	0.456	0.001*
	RMPT	0.197	0.048*	0.285	0.045*	0.393	0.005*
	LMPT	0.196	0.048*	0.285	0.045*	0.393	0.005*
Leg	RPLL	0.307	0.003*	0.284	0.045*	0.365	0.009*
	LPLL	0.297	0.002*	0.280	0.045*	0.364	0.009*
	RDLL	0.314	0.018*	0.331	0.019*	0.446	0.001*
	LDLL	0.222	0.027*	0.333	0.019*	0.436	0.002*
	RML	0.302	0.019*	0.310	0.028*	0.455	0.001*
	LML	0.301	0.019*	0.310	0.028*	0.472	0.001*
Foot	RTGT	0.345	0.000*	0.756	0.000*	0.626	0.000*
	LTGT	0.359	0.000*	0.636	0.000*	0.666	0.000*
	RFSMTIS	0.196	0.045*	0.406	0.003*	0.412	0.003*
	LFSMTIS	0.198	0.045*	0.345	0.009*	0.358	0.011*
	RFMT	0.232	0.025*	0.370	0.008*	0.436	0.002*
	LFMT	0.216	0.031*	0.358	0.009*	0.486	0.000*

*Karl Pearson Correlation test was performed and shows statistically significant positive correlation (p<0.05)

Table 5: Upper limb and lower limb TPD reference value for the age group between 18-25 years.

Body segment	Dermatome level	Reference value in mm (n=200)	For males in mm (n=100)	For females in mm (n=100)
Upper limb	Right upper lateral arm (RULA)	12.58-47.50	14.40-46.97	10.76-48.02
	Left lower lateral arm (LULA)	13.86-47.30	14.99-50.32	13.75-43.25
	Right lower lateral arm (RLLA)	11.96-43.48	12.59-41.53	11.38-45.37
	Left lower lateral arm (LLLA)	12.81-43.27	11.78-44.69	13.80-41.91
	Right mid medial arm (RMMA)	11.54-49.68	9.27-21.55	13.86-47.76
	Left mid medial arm (LMMA)	11.38-43.86	11.20-43.55	11.40-44.32
	Right mid posterior arm (RMPA)	13.86-42.50	13.10-43.09	14.49-42.04
	Left mid posterior arm (LMPA)	13.77-44.37	14.36-42.45	13.25-46.23
	Right mid lateral forearm (RMLF)	11.58-41.69	11.70-41.14	11.32-42.37
	Left mid lateral forearm (LMLF)	13.78-38.09	13.45-38.60	13.99-37.69
	Right mid medial forearm (RMMF)	9.96-41.86	8.31-45.31	12.16-37.86
	Left mid medial forearm (LMMF)	10.61-35.53	10.32-34.28	11.00-36.70
	Right mid posterior forearm (RMPF)	11.27-38.23	8.90-39.4	13.88-36.83
	Left mid posterior forearm (LMPF)	8.65-35.52	10.15-33.79	7.20-37.20
	Right first dorsal interosseous muscle (RFDIM)	1.53-18.13	1.47-17.41	1.59-18.84
	Left first dorsal interosseous muscle (LFDIM)	2.67-15.93	2.83-15.84	2.46-16.09
	Right palmar surface distal phalanx of thumb (RFMCP)	1.37-3.82	1.44-3.77	1.28-3.88
	Left palmar surface distal phalanx of thumb (LFMCP)	1.36-3.40	1.36-3.49	1.36-3.30

Continued.

Body segment	Dermatome level	Reference value in mm (n=200)	For males in mm (n=100)	For females in mm (n=100)
	Right palmar surface distal phalanx of long finger (RTMCP)	1.24-3.49	1.35-3.44	1.13-3.54
	Left palmar surface distal phalanx of long finger (LTMCP)	1.19-3.40	1.23-3.57	1.18-3.21
	Right palmar surface distal phalanx of little finger (RLMCP)	1.02-3.56	1.01-3.57	1.02-3.56
	Right palmar surface distal phalanx of little finger (LLMCP)	1.03-3.46	0.97-3.51	1.09-3.42
Lower limb	Right proximal -anterior thigh (RPAT)	14.66-38.08	15.91-35.10	13.87-40.61
	Left proximal- anterior thigh (LPAT)	14.23-38.96	15.09-36.06	13.82-41.43
	Right distal-anterior thigh (RDAT)	15.39-32.66	16.26-30.51	14.84-34.49
	Left distal-anterior thigh (LDAT)	15.31-32.33	16.71-28.97	14.76-34.84
	Right mid-lateral thigh (RMLT)	15.73-40.46	16.55-39.69	14.84-41.29
	Left mid-lateral thigh (LMLT)	15.74-39.62	16.69-37.40	14.99-41.63
	Right mid-medial thigh (RMMT)	15.95-38.24	16.51-36.89	15.42-39.58
	Left mid-medial thigh (LMMT)	14.82-38.72	14.80-37.66	14.84-39.77
	Right mid-posterior thigh (RMPT)	12.58-42.26	14.89-39.05	10.62-45.12
	Left mid-posterior thigh (LMPT)	11.86-41.77	15.50-37.08	9.10-45.59
	Right proximal-lateral leg (RPLL)	15.01-38.15	16.19-35.54	14.15-40.44
	Left proximal-lateral leg (LPLL)	15.30-39.90	15.07-38.87	15.55-40.91
	Right distal-lateral leg (RDLL)	14.74-40.14	16.12-38.01	13.50-42.12
	Left distal-lateral leg (LDLL)	14.01-41.02	15.20-38.03	13.19-43.64
	Right medial leg (RML)	13.62-39.86	15.27-37.48	12.15-42.06
	Left medial leg (LML)	13.01-39.71	16.39-34.57	10.77-43.71
	Right tip of great toe (RTGT)	4.03-8.27	4.03-8.94	4.35-7.28
	Left tip of great toe (LTGT)	3.78-7.91	3.78-8.52	4.04-7.08
	Right first- second metatarsal interspace (RFSMTIS)	8.35-19.28	9.41-18.36	7.40-20.10
	Left first- second metatarsal interspace (LFSMTIS)	7.52-20.07	8.99-18.61	6.28-21.30
	Right fifth metatarsal (RFMT)	9.21-19.20	9.81-18.63	8.62-19.76
	Left fifth metatarsal (LFMT)	7.97-19.36	8.75-19.44	7.28-19.19

DISCUSSION

This study aimed to establish normative values for two-point discrimination (TPD) across 11 upper limb and lower limb regions, considering gender-specific BMI variations. The findings demonstrated a statistically significant correlation between TPD and body mass index according to gender, highlighting how BMI can influence sensory perception in these regions of the upper limb and lower limb.

In our extensive study, we identified a noteworthy positive correlation between two-point discrimination (TPD) and body mass index (BMI). This implies that as BMI increases, TPD tends to increase as well, and conversely, as BMI decreases, TPD tends to decrease. It also shows statistically significant.[10,11]

Our findings align with the research conducted by Desai et al, who also explored the relationship between TPD and BMI. However, there are distinctions in the strength and direction of this correlation across different body regions.[3] For instance, in our study, we observed a strong positive correlation between TPD and BMI in the arm, forearm, hand, thigh, leg and foot regions for both genders. These findings emphasize the complexity of the relationship between sensory discrimination and BMI, highlighting regional variations. Our research contributes to a deeper understanding of how body composition may affect tactile perception in specific upper extremity regions, providing valuable information for future studies and clinical applications.

Studies found that values obtained from men and women were similar for most skin areas tested although in three regions, women showed a significantly greater two-point discrimination ability than did men.[12,13] Shibin et al in their study found that the normative values of both men and women for a given area were compared and there was no such significant difference exist except in palmar surface distal phalanx little finger ($p=0.05$) there female have more sensitivity than male.[4] In current study difference between TPD among male and female statistically tested by independent t-test and shows no significant difference ($p>0.05$), and shows a positive correlation between BMI and TPD. Valagussa et al had conducted a study to determine the Two-point discrimination in lower limb in healthy people; Average values and influence of gender, dominance, height, and body mass index (BMI), and they proved that TPD mean values are not influenced by gender, dominance, height, and BMI in healthy subjects.[5] In all other previous studies showing women having more significantly greater two-point discrimination ability than men and proving TPD mean values are not influenced by BMI. In our study shows there was no significant difference between female and male and showing positive correlation between TPD and BMI.[14-16]

Two-point discrimination sensitivity, a measure of tactile acuity, is influenced by various factors. Environmental changes, pressure levels, area being measured, and temperature all impact TPD.[17-19] Higher sensitivity occurs in controlled, stable environments, with lighter pressure and smaller measurement areas yielding finer discrimination.[20,21] Temperature affects nerve conduction speed, altering perception. In addition, cooperation, and concentration on the part of both subject and examiner are necessary to ensure accurate and reliable measurements.[22,23]

Limitations and other suggestions

The two-point discrimination test faces a significant challenge due to the lack of standardized pressure application. Applying excessive pressure can alter results by involving more skin receptors and causing skin deformation. Precision is vital; applying pressure points simultaneously is crucial. Increasing the sample size in the same study would likely result in more statistically robust and reliable findings. The timing of two-point discrimination testing, whether during the day or night, and variations in climate can introduce differences in value. These factors highlight the test's sensitivity to environmental conditions, emphasizing the need for controlled settings to ensure accurate and reliable results in assessing tactile sensitivity.

CONCLUSION

This study successfully established reference values for two-point discrimination in the upper extremity and lower extremity, shedding light on the variation of sensory perception based on the tested skin area. Notably, a strong correlation was observed between two point discrimination (TPD) and body mass index (BMI), implying that an individual's body composition can influence their tactile acuity.

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