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Original Research Article

Hand anthropometry: A predictive tool for gender differentiation in forensic anatomy among medical students of central India

Razia Khatoon[1], Surajit Kundu[1], Richa Gurudiwan[1]*, Gireesh Dashhare[1], Seema Tigga[1]

[1]Dept. of Anatomy, Late Shri Lakhiram Agrawal Memorial Government Medical College, Raigarh, Chhattisgarh, India.

Abstract

Introduction: Forensic Anatomy plays a crucial role in identifications of unknown gender using hand dimensions as a key aspect in the medico-legal field. However, complications arise in cases where the body is dismembered or mutilated.

Aim & Objectives: Present study aims to derive cut off points for Hand length (HL), breadth (HB) and Hand index (HI) to differentiate accuracy in gender prediction with these parameters.

Materials and Methods: Values of HL, HB & HI were measures using standard vernier callipers (up to nearest 0.1 cm) among 82 (50 female and 32 males) willing participants (MBBS Batch 2023 – 100 students, with age group between 17-22 years) of Late Shri Lakhiram Agrawal Memorial Government Medical College Raigarh Chhattisgarh. Cut off point (sectioning point) and sexual dimorphism were calculated. The dimension between sexes were compared by independent sample t-test, and the level of statistical significance was set at $P < 0.05$.

Results: Accuracy to differentiate sex are RHL – male /female is 84.38% / 86%, LHL – male/ female is 87.5% / 90%, RHB – male / female is 84.38% / 84%, LHB – male /female is 87.5% / 86%, RHI – male /female is 53.12% /48% and LHI – male / female 56.3% / 56% respectively.

Conclusion: The present manuscript investigates the measurements of hand length, hand breadth, hand index and finally concluded presence of sexual dimorphism based upon anthropometric variables. The variables may be considered suitable for identification of gender, even in cases wherein isolated hand have been obtained.

Keywords: Hand dimension, Gender, Sexual dimorphism. Sectioning point, Central India

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1. Introduction

Gender estimation is a critical component of forensic identification, particularly in medico-legal investigations involving dismembered or mutilated remains. While identification using external or internal genitalia is straightforward when available, forensic anthropologists often face challenges in cases involving fragmented bodies due to natural disasters, criminal mutilation, or mass casualties. The “Big Four” of biological profiling—stature, sex, age, and ethnicity—remain central to reconstructing identity, with sex determination being paramount.[1-3]

Although DNA analysis is widely used, its cost, time requirements, and need for skilled personnel make anthropometric methods a practical alternative.[4] Numerous studies have explored gender estimation using facial features, dental traits, and long bones such as the humerus, tibia, ulna, and femur.[5-6] Traditionally, pelvic and cranial bones were preferred for sex determination, but recent research has shifted toward long bones and peripheral body parts like the hand.[7-8]

The human hand, a complex and sexually dimorphic structure, offering valuable clues for gender estimation, especially in cases involving isolated limbs. Digit ratios, influenced by prenatal hormone exposure, show consistent sex-based differences.[9-10] Anthropometry enables the identification of sectioning points through threshold values that help classify individuals as male or female based on hand measurements. However, the degree of sexual dimorphism varies with ecological, genetic, and ethnic factors, necessitating population-specific reference data.[3,8]

Corresponding author: Richa Gurudiwan
Email: richadubey2685@gmail.com

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2. Objectives of the Present Study

This study focuses on a Central Indian population and aims to:
Investigate sexual dimorphism using hand length, hand breadth, and hand index.
Identify the most reliable indicator of gender among these variables.
Determine sectioning points for gender classification based on hand dimensions.
Highlight the most frequent hand index category among male and female respondents.

3. Materials and Methods

A Cross-sectional descriptive study conducted among 82 (50 female and 32 males) willing participants (MBBS Batch 2023 – 100 students, with age group between 17-22 years) (informed consent obtained) of Late Shri Lakhiram Agrawal Memorial Government Medical College Raigarh Chhattisgarh. We adopted Random sampling technique with prior ethical approval of Institutional ethical committee (IEC) (S.No./Med./Ethics commi./2024/02, dated 23rd February 2024).

3.1. Inclusion and exckusion criteria

Students providing informed consent without bony deformities or accidents or surgical procedures involving limbs & belonging to Chhattisgarh region (central India) were included and students belong to other part of India (all India and central pool quota), refusal to enrol in the study & individuals with congenital anomaly of limb(s) and vertebral column, contractures, missing limbs, history of trauma to hand and foot, with features suggestive of dysmorphic syndromes, chronic illness, hormonal therapy were considered under exclusion criteria.

3.2. Study tools

Standard vernier calliper

3.3. Hand dimensions and measurements (Parameters)

a) Hand length is the distance from the midpoint of the distal crease of the wrist joint to the most anterior projecting point on the tip of the middle finger

b) Hand breadth is the distance from the most laterally placed point on the head of the 2nd metacarpal to the most medially placed point located on the 5th metacarpal

c) Hand index is obtained by dividing (Ratio) hand breadth with the hand length and multiplying by 100 (Chandra A et.al 2013).[12]

d) Sectioning Point is the

Mean Male Value + Mean Female Value/2

e) Sexual Dimorphism (Demarking Point) is calculated as Mean Male Value / Mean Female value X100.[2]

All measurements, expressed in centimetre and taken by the same individual to minimize inter-observer error.

Based on the standard Krogman hand index classification, which is detailed in a Ghanaian study,[11], the distribution of the hand indices has been examined. Hand indices can be classified into five groups, per Chadra et al.[12]

1. Hyperdolicholicheri [40.9]
2. Dolichocheri [41.0–43.9],
3. Mesocheri [44.0–46.9],
4. Brachycheri [47.0–49.9] and
5. Hyperbrachycheri [50.0].

A prior pilot study involving 20 participants was conducted by the same researcher to assess intra-observer error, and none of the measured parameters showed statistical significance ($p > 0.05$). This suggested that the measurements were both valid and reliable.

The obtained data were calculated and evaluated by Microsoft Excel Platform within Anatomy Department Descriptive statistics like mean, SD were applied for all hand dimensions. The hand dimension between sexes were compared by independent sample t-test, and the level of statistical significance was set at $P < 0.05$.

The Demarking or Sectioning point, was calculated accordingly & males were categorized with greater values and females with lesser values of demarking poin.[2,13]

Sectioning Point has been found to be more accurate and of higher sensitivity.[13]

4. Results

4.1. Hand length & hand breadth

Table 1 & 2 shows that male hand lengths were significantly greater than female values ($p < 0.05$), with no notable side-wise differences ($p > 0.05$). Mean right-hand length was 19.07 cm in males and 17.07 cm in females; left-hand length was 19.20 cm in males and 17.11 cm in females—indicating a ~2 cm difference between genders. The table also shows that male hand breadths were significantly greater than female values ($p < 0.05$), with no significant side-wise differences ($p > 0.05$). Mean right-hand breadth was 8.50 cm in males and 7.64 cm in females; left-hand breadth was 8.28 cm in males and 7.41 cm in females—indicating a difference of 0.86 cm and 0.87 cm, respectively.

4.2. Hand index

Table 2 presents hand index values across genders. In males, mean right-hand index was 44.60 cm and left-hand index 43.08 cm; in females, the values were 44.64 cm and 43.31

cm, respectively. While gender differences were statistically significant ($p < 0.05$), no side-wise variation was noted within each gender ($p > 0.05$). Right-hand index was 0.15 cm higher in females, whereas left-hand index was 1.71 cm higher in females compared to males.

Table 3 and Chart 1 summarize hand dimensions and their gender prediction accuracy using sectioning points. Hand length and breadth emerged as the most reliable indicators, each yielding over 84% accuracy. Specifically, left-hand length showed the highest predictive accuracy: 87.5% for males and 90% for females. Right-hand length followed closely (84.38% for males, 86% for females), with similar performance observed for hand breadth. In contrast, hand index showed lower accuracy (53–56%), indicating limited utility for gender differentiation.

Minor bilateral differences were noted across hand dimensions, suggesting no need for side-specific sectioning points. The optimal cut-off values were 18.07 cm for hand length, 8.07 cm for hand breadth, and 44.62 for hand index. Overall, the precision ranking was: LHL > LHB > RHL > RHB > LHI > RHI, with consistently higher accuracy observed among females.

Table 1–4 show consistently higher hand measurements in males, indicating marked sexual dimorphism. The sexual dimorphism index—calculated as (male mean / female mean) × 100—confirmed this, with values above 100 denoting strong gender differentiation.

Table 5 present gender-wise distribution of participants based on classification groups I–V, as per Chandra A et al.[12] A highly significant association was observed between hand index and sex ($p = 0.000$). Most males fell into Group 4 (47–49.9, Brachycheri) for RHI, while most females belonged to Group 3 (44–46.9, Mesocheri). For LHI, both sexes predominantly clustered in Group 2 (41–43.9, Dolicholicheri).

Table 6 ranks the parameters by dimorphism as: LHL > LHB > RHL > RHB > RHI > LHI.

Table 7 shows comparison of hand dimensions and hand index among different population. Hand dimensions and index vary across populations, influenced by genetic and environmental factors. Some groups show longer, narrower hands (low index), while others have broader palms (high index). These differences aid in gender estimation and have forensic and ergonomic relevance.

Table 8 reflects the Sectioning Point of a few previous studies.

These points vary across ethnic groups and are crucial for forensic identification, with higher accuracy when tailored to regional anthropometric data.

Our study gave percentages of 84.38% for right hand length (male), 86% for right hand length (female), 87.5% for left hand length (male), 90% for left hand length (female), 84.38% for right hand breadth (male), 84% for right hand breadth (female), 87.5% for left hand breadth (male), 86% for left hand breadth (female), 53.12% for right hand index (male). 48% for right hand index (female), 56.3% for left hand index (male) and 56% for left hand index (female) for calculating accuracy in determination of gender based upon sectioning or cut off point, as value more than "pre-determined" cut off point denotes male and less than that denotes female.

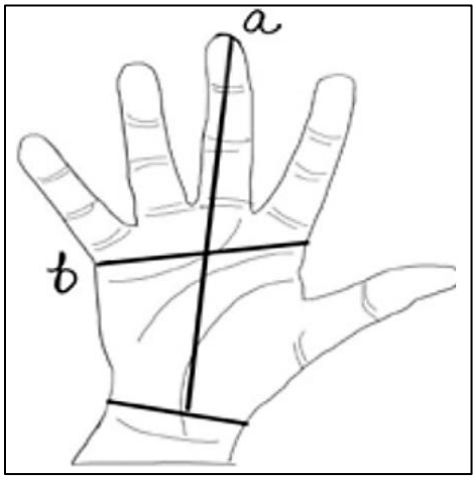

Figure 1: Diagrammatic representation of (a) The measurement from the center of the distal crease of the wrist joint to the furthest anterior point on the tip of the middle finger, which is referred to as hand length. (b) The measurement from the outermost point on the head of the 2nd metacarpal to the innermost point found on the head of the 5th metacarpal, designated as hand breadth. Adapted from.[2]

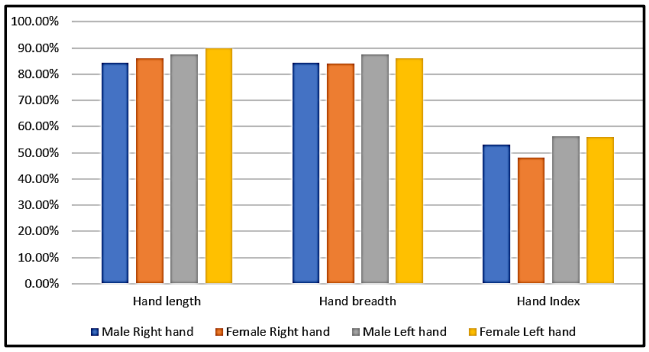

Chart 1: Percentage accuracy in determination of gender

Table 1: Descriptive statistics: Hand length & breadth in male & female

Hand length in male & female				
Male (N=32)				
Variables	**Minimum**	**Maximum**	**Mean**	**SD**
RHL	17.73	20.96	19.07	0.90
LHL	17.63	21.02	19.20	0.92
Female (N=50)				
RHL	15.38	18.740	17.07	0.78
LHL	15.84	19.15	17.11	0.73
Hand Breadth in male & female				
Male (N=32)				
Variables	**Minimum**	**Maximum**	**Mean**	**SD**
RHB	7.12	9.68	8.50	0.43
LHB	6.98	9.48	8.28	0.44
Female (N=50)				
RHB	6.65	8.63	7.64	0.35
LHB	6.83	8.96	7.41	0.41

Table 2: Descriptive statistics: Hand index in male & female

Male (N=32)				
Variables	**Minimum**	**Maximum**	**Mean**	**S.D.**
RHI	40.16	46.22	44.60	1.89
LHI	39.61	45.08	43.08	2.02
Female (N=50)				
RHI	43.30	46.07	44.64	2.25
LHI	43.12	46.79	43.31	2.20

Table 3: Descriptive statistics (cm) of hand dimensions with percentage accuracy using sectioning points

	Male		**Female**	
Hand Length (Mean)				
	Right hand	**Left hand**	**Right hand**	**Left hand**
	19.07	19.20	17.07	17.11
Hand Breadth (Mean)				
	8.50	8.28	7.64	7.41
Hand Index (Mean)				
	44.60	43.08	44.64	43.31

	Right hand			**Left hand**		
Variable	**Sectioning point**	**Male**	**Female**	**Sectioning point**	**Male**	**Female**
Hand length	18.07	27/32 84.38%	43/50 86%	18.16	28/3 87.5%	45/50 90%
Hand breadth	8.07	27/32 84.38%	42/50 84%	7.85	28/32 87.5%	43/50 86%
Hand index	44.67	17/32 53.12%	24/50 48%	43.20	18/32 56.3%	28/50 56%

Table 4: Statistical comparison of male and female hand dimensions and hand index

Parameter	Mean		t value	p value
	Male	Female		
Right hand length	19.07	17.07	10.82	0.000 (HS)
Left hand length	19.2	17.11	10.83	0.000 (HS)
Right hand breadth	8.51	7.63	10.42	0.000 (HS)
Left hand breadth	8.27	7.4	9.62	0.000 (HS)
Right hand index	44.6	44.64	8.67	0.000 (HS)
Left hand index	43.08	43.31	6.78	0.000 (HS)

S=Significant; *P value <0.05 is significant and P value <0.001 is highly significant

Gender difference in hand dimensions and hand index is statistically confirmed by applying t-test as shown in

Table 4. Highly significant (HS) gender difference is found in hand dimensions and hand index (P<0.001)

Table 5: Classification of right-& left-hand index (Chandra A et. al 2013) & gender wise distribution of respondents and their classifications of right & Left -hand index.

Classification of Right-hand index (RHI)				
Classification of RHI	**Gender**			
	Male	**Female**	**Total**	**P-value**
less than 40.9 Hyperdolicholicheri (1)	4	2	6	0.000
41 - 43.9 Dolicholicheri (2)	7	18	25	
44 - 46.9 Mesocheri (3)	9	22	31	
47 - 49.9 Brachycheri (4)	12	8	20	
more than 50.0 Hyperbrachycheri (5)	0	0	0	
	32	50	82	
Classification of Left-hand index (LHI)				
Classification of LHI	**Gender**			
	Male	**Female**	**Total**	**P-value**
less than 40.9 Hyperdolicholicheri (1)	8	3	11	0.000
41 - 43.9 Dolicholicheri (2)	13	32	45	0.000
44 - 46.9 Mesocheri (3)	9	13	22	0.000
47 - 49.9 Brachycheri (4)	2	2	4	0.000
more than 50.0 Hyperbrachycheri (5)	0	0	0	0.000
	32	50	82	NA

Table 6: Sexual dimorphism

Parameters	Sexual dimorphism
Right hand length (RHL)	111.72
Left hand length (LHL)	112.23
Right hand breadth (RHB)	111.4
Left hand breadth (LHB)	111.75
Right hand index (RHI)	99.91

Left hand index (LHI)	99.46

Table 7: Comparison of hand dimensions and hand index among different population

Author	Study population	Age in years	Gender	Hand length		Hand Breadth		Hand Index	
				Right	Left	Right	Left	Right	Left
1) Ishak NI et. al 2012[14]	Australia	18-68	M	19.54 ± 0.93	19.56 ±0.92	9.10 ± 0.48	9.04 ± 0.49	---	---
			F	17.59 ± 0.82	17.60 ±0.82	7.93 ± 0.45	7.84 ± 0.45	---	---
2) Agnihotri et al 2005[15]	Mauritius	18-30	M	18.89 ± 0.88	18.90 ± 0.87	8.45 ± 0.40	8.42 ± 0.40	44.02 to 45.05	44.15 to 44.80
			F	17.22 ± 0.92	17.22 ± 0.93	7.48 ± 0.38	7.42 ± 0.37	43.06 to 43.79	42.65 to 43.56
3) Danborno et al 2007[16]	Nigerian	19-35	M	19.85 ± 0.86	19.93 ± 0.93	8.90 ± 0.95	8.68 ± 0.92	44.92 ± 5.15	43.65 ± 5.15
			F	19.47 ± 0.92	19.50 ± 0.92	8.13 ± 0.39	8.14 ± 0.40	41.78 ± 1.51	41.79 ± 1.44
4) Aboul Hagag et al. 2011[17]	Egyptian	>18	M	19.47 ± 0.92	19.50 ± 0.92	8.14 ± 0.40	8.14 ± 0.40	41.79 ± 1.44	41.79 ± 1.44
			F	18.17 ± 0.91	18.17 ± 0.91	7.17 ± 0.40	7.17 ± 0.41	39.54 ± 1.50	39.51 ± 1.59
5) Asha et al. 2012[18]	North Indian	20-30	M	19.53 ± 1.16	19.46 ± 1.12	8.17 ± 0.43	8.17 ± 0.43	42.46 ± 2.26	42.03 ± 2.09
			F	17.80 ± 0.93	17.74 ± 0.90	7.33 ± 0.43	7.27 ± 0.41	41.25 ± 2.46	41.02 ± 2.22
	South Indian	20-30	M	19.44 ± 1.13	19.38 ± 1.02	8.25 ± 0.41	8.19 ± 0.37	42.53 ± 2.46	42.32 ± 2.17
			F	17.47 ± 1.00	17.47 ± 1.01	7.31 ± 0.32	7.23 ± 0.31	41.95 ± 2.49	41.47 ± 2.48
6) R. Varu P et. al 2016[19]	Gujarat (India)	>20	M	17.98 ± 0.95	17.80 ± 0.98	8.26 ± 0.53	8.09 ± 0.60	45.96 ± 1.85	45.48 ± 2.55
			F	16.65 ± 0.84	16.57 ± 0.87	7.27 ± 0.33	7.15 ± 0.43	43.72 ± 1.69	43.17 ± 2.58
7) Kumar RA et. al 2022[20]	Uttar Pradesh India	18-24	M	17.71	17.69	7.79	7.56	---	---
			F					---	---
8) Chandra A et. al 2013[12]	Haryana India	18 -62	M	84.29		186.52		45.19	
			F						
9) Gupta R et. al 2022[2]	Western India	22- 40	M	16.89 ± 1.02	18.05 ± 2.52	8.33 ± 0.71	8.35 ± 0.69	49.34 ± 0.11	46.86 ± 0.45
			F	15.83 ± 0.74	16.29 ±1.72	7.97 ± 0.42	7.95 ± 0.45	50.31 ± 0.51	49.10 ± 0.68
10) Present study	Raigarh Central India	17 - 22	M	19.07 ± 0.90	19.20 ± 0.92	8.50 ± 0.43	8.28 ± 0.44	44.60 ± 1.89	43.08 ± 2.02
			F	17.07 ± 0.78	17.11 ± 0.73	7.64 ± 0.35	7.41 ±0.41	44.64 ± 2.25	43.31± 2.20

Table 8: Sectioning point of a few studies

Author	Population	Sectioning point / Demarking point / Cut off point
Gupta R et. al[3]2022	Western India	RHL = 16.36 & LHL = 17.17 RHB = 08.15 & LHB = 08.15

		RHI = 49.85 & LHI = 47.98
R. Varu et. al 2016	Gujarat India	HL = 17.2 HB = 7.7 HI = 44.6
Aboul-Hagag KE et. al 2011	Egypt	RHI =40.65 LHI = 40.65
Present study	Raigarh Central India	RHL = 18.07 & LHL = 18.15 RHB = 08.07 & LHB = 07.84 RHI = 44.67 & LHI = 43.20

5. Discussion

The human hand, recognized as one of the most versatile anatomical structures, was central to the present study's approach for gender estimation in unidentified deceased individuals, with a focus on young population groups from the Raigarh region of central India. Numerous studies[21-24] have previously explored hand morphology across diverse global populations, and

Table **7** presents a comparative analysis of hand dimensions and hand index values between our findings and those reported in international literature.

This study employed t-tests, sectioning point analysis, and evaluation of sexual dimorphism to differentiate male and female subjects based on anthropometric hand measurements. Male participants exhibited mean values for right-hand length, left-hand length, right-hand breadth, and left-hand breadth as 19.07 ± 0.90 cm, 19.20 ± 0.92 cm, 8.50 ± 0.43 cm, and 8.28 ± 0.44 cm, respectively. Corresponding values for female participants were 17.07 ± 0.78 cm, 17.11 ± 0.73 cm, 7.64 ± 0.35 cm, and 7.41 ± 0.41 cm. These findings suggest that male hand dimensions are consistently larger, with right-hand length approximately 2.0 cms and left-hand length 2.09 cms greater than those of females. Similarly, right-hand breadth and left-hand breadth were 0.86 and 0.87 cms higher in males, respectively. These trends align with previous studies by Agnihotri et al.[15] Aboul-Hagag et al.[17] and Varu et al.[19] which also reported pronounced sexual dimorphism in hand measurements. The relatively smaller dimensions observed in females may be attributed to earlier epiphyseal union and skeletal maturation.

Interestingly, the average hand index in males was 44.6 for the right hand and 43.08 for the left, while in females, it was 44.64 and 43.31, respectively. Contrary to findings by Dey and Kapoor[24] Gupta et al.[2] and others, our study observed significantly higher hand index values among females. While hand length and breadth are influenced by overall body dimensions, the hand index appears to be more stable and potentially independent of stature and age, making it a more consistent parameter for sex determination.

Consistent with the observations of Dey et al.[24] Agnihotri et al.[15] Aboul-Hagag et al.[17] and Varu et al.[19] our study did not reveal statistically significant differences between the right- and left-hand dimensions within each gender group, suggesting bilateral symmetry in hand morphology.

Sectioning points or demarking thresholds calculated in this study are presented in **Table 8**, alongside comparative data from Gupta et al.[2] Aboul-Hagag et al.[17] and Varu et al.[19] Some sectioning point values in our cohort exceeded those reported for North and South Indian populations and Egyptian samples, while others were lower. These variations underscore the influence of race, ethnicity, and regional factors on hand dimensions and hand index values. As such, anthropometric standards for gender estimation should be population-specific, given the demonstrable ethnic variability and the limitations of generalizing across diverse groups.[2]

6. Conclusion

This manuscript examines hand length, breadth, and hand index to assess sexual dimorphism using anthropometric variables. These measurements demonstrate potential for gender identification, even in cases involving isolated hands. Independent t-tests revealed significant differences in hand dimensions between male and female participants. Classification based on right and left-hand index facilitated categorization into Hyperdolicholicheri, Dolicholicheri, Mesocheri, Brachycheri, and Hyperbrachycheri types. Sexual dimorphism was ranked as LHL > LHB > RHL > RHB > RHI > LHI, indicating that left hand length showed the greatest dimorphism, while left-hand index showed the least.

7. Relevance of the Study

This study on morphological approach of hand to discriminate sex, might be considered as a successful attempt to establish standard hand dimensions among central India sample, to be serving as a template and a useful tool in forensic investigation, clinical practice, in establishing grip strength of hand in physical medicine and rehabilitation and finds relevance to establish ergonomic design applications of hand-held devices for industrial applications.

8. Limitations

1. Independent ethnic dissimilarities of each population must be considered for calculation of hand dimensions. Our values are population specific and may not be accurate in other geographical regions.
2. Population specific cut off points must be generated with a larger sample size considering multiple states of India for a standard comparison.
3. Accuracy judgements might vary when values are contrasted as living Vs deceased (Embalmed / dismembered) hand.
4. We have excluded Individuals with congenital anomaly of limb(s) and vertebral column, contractures, missing limbs, history of trauma to hand and foot, with features suggestive of dysmorphic syndromes, chronic illness, hormonal therapy.
5. Diurnal variations (if any) may be elucidated.

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10. Conflict of Interest

The authors declare that there is no conflict of interest, financially or otherwise regarding the publication of this manuscript.

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12. Author contributions

Dr Surajit Kundu and Dr Richa Gurudiwan, being the guide and co-guide respectively for Dr Razia (PG Student), conceived the original idea and designed the theoretical model of the manuscript and were instrumental in final writing of the paper and encouraging the post graduate student. They were in charge of overall direction and planning.

Dr Razia communicated and prepared the subjects, obtained consent, collected data, performed analysis, interpreted calculations and took the lead role in framing the draft of the paper, obtaining inputs and consulting all the authors.

Dr Gireesh and Dr Seema helped in preparation of the subjects, overall supervision of the paper and provided critical feedback.

All authors commented on the critical points and helped to shape the research, analysis and manuscript to its present form.

Ethical No: *S.No./Med./Ethics Commi./2024/02 dated 23rd February 2024.*

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