Institute of Experimental Morphology, Pathology and Anthropology with Museum
Bulgarian Anatomical Society

Acta morphologica et anthropologica, 28 (3-4)
Sofia ● 2021

Intra and Inter-Sexual Variation in Second (2D) and Fourth (4D) Digit Length and Ratio (2D:4D) among the Bhantus of Andaman and Nicobar Islands, India: A Cross-sectional Study

Koel Mukherjee[1], Kaustav Das[2]*

[1] *Anthropological Survey of India, Andaman and Nicobar Regional Centre, Port Blair, India*
[2] *Department of Anthropology, Bangabasi College, Kolkata, India*

*Corresponding author e-mail: koelanthro@gmail.com

This study aimed to determine sex and bilateral variation from digit length and ratio among the Bhantu people living in the Andaman and Nicobar Islands of India.Total of 305 adults aged 18-60 years were included.Required anthropometric measurements were taken following standard techniques. Based on digit ratio, hand pattern was classified into three types: A (2D<4D), B (2D=4D), and C (2D>4D). Results revealed males have longer mean 2D and 4D lengths than females. Hand pattern A was the predominant characteristic in this population. Significant bilateral variation was found in 4D length ($p<0.01$) and 2D:4D ($p<0.05$) ratio of females, but not in males. Unlike other studies, the 2D:4D ratio did not show any sex variation, statistically significant sex differences ($p<0.01$) were observed for only digit lengths in both hands but not in digit ratio. Further studies should be conducted on a larger sample and different populations.

Key words: 2D (index finger), 4D (ring finger), 2D:4D (digit ratio), Hand pattern, Bhantu

Introduction

Biomarkers are emerging emphases in persistent disparities and global challenges in health that readily ally with human biology and anthropology. They have proven to be valuable tools for investigating biocultural pathways to health and disease and can be used to probe the causal matrix generated by cumulative socially determined circumstances, lifetime experience and exposures, and biodynamics that shape health over the life course [10, 48]. For a long time, several anthropologists put efforts to contemplate the substantial well-demarcated differences in ethnic groups by utilizing various biomarkers and perceive the full range of mechanisms through which ethnicity and their ancestry can correlate with numerical biological traits and health outcomes [7].

For the last couple of decades, researchers use the second (2D, index finger) to fourth (4D, ring finger) digit ratio (2D:4D) as a potential proxy marker showing variations in different ethnic and geographic groups [8, 17, 33, 42, 50, 55, 60, 83]. Existing literature proposed a relationship between prenatal androgen exposure and the length of the digit [38, 42, 65]. The 2D:4D ratio is assumed to be stable during the prenatal stage or after two years of age, which become constant throughout life [15, 38, 42, 51, 65]. It has been seen that the digit ratio is negatively correlated with testosterone but positively to estrogen exposure, which means males are expected to have a comparatively lower 2D:4D ratio than females [42, 60, 65]. Thus, it has been well established that the 2D:4D ratio is sexually dimorphic in humans [21, 42], but the developmental mechanism underlying sexually dimorphic digit development remains unknown [85].

In addition to the significant sexual dimorphism [3, 21, 22, 37, 42, 82], several studies revealed evidence of the relationship between 2D:4D ratio and various human phenotypic traits [6, 56]. The low 2D:4D is showing a correlation with left-handedness [44, 75], increased risk of anxiety [43], heterosexual preference [15], aggression in males[49, 75], and females [5], etc. On the other hand, studies also revealed high 2D:4D had been linked with increased risk of heart diseases [56], low sperm count [44], preference of homosexuality [15], risk of obesity [56], etc. Despite these findings, androgen-related outcomes like increased risk of autism [39], psychiatric disorder [14], facial asymmetry [11], enhanced athletic ability [46] have also been found associated with digit ratio. In recent years, researchers also explored the use of the 2D:4D ratio in the field of medical sciences to diagnose breast cancer risk, lung cancer, risk of severe osteoarthritis, and brain tumour [4, 20, 27, 29].

In India, the studies on digit lengths and ratios are mostly conducted to explore population variation in ethnicity and sex among different communities [8,28,33,69]. Further, numerous studies have also been done to find out the association of digit ratios with physical attributes [21,25], body composition indicators [41], coronary heart disease [84], dental carries [62], polycystic ovarian syndrome [67], myopia [34], preliminary infertility in males [35], depression [24], dyslexia [63], schizophrenia [77], effect on birth order [40], performance and ability of sportspersons [72], stature estimation [23,70], etc.

Andaman and Nicobar Islands have a long history of human occupation with remarkable ethnic and cultural diversity. It has three strands- several tribal groups, descendants of criminals under sentence of transportation for life from India and Burma, and immigrants after the 1947 partition of India [78]. Therefore, Andaman is home to people from different regions, religions, languages, castes, and cultures who migrated from different parts of the mainland during the 20th century [26]. Bhantus are originally the inhabitants of Uttar Pradesh, India. But due to their criminal activities of theft and robbery like neighboring communities of Bauriyas, Karwals, Sansiyas, they were also declared as "*Criminal Tribe*" by the British Government [80], and many of them were sent to the Cellular Jail of Andaman for imprisonment during the 1920s [53,68]. After their punishment period, many were settled in the Andaman Islands [53]. However, to the best of our knowledge, no study has been conducted to investigate ethnic or sex variation among any community living in the Andaman or any other islands in India.

Therefore, given the present situation, this research work is the first attempt to: a) study bilateral variation as well assex variation from digit lengths and their ratio and b) examine the association of age, anthropometric, and derived variables with the 2D:4D ratio amongthe Bhantu community living in Andaman and Nicobar Islands, India.

Materials and Methods

This community-based cross-sectional study was conducted among 305 adult Bhantu individuals (males: 134; females: 171) aged 18-60 years residing in the rural areas of South Andaman district, Andaman and Nicobar Islands, India. The present study was carried out during July-August 2019. Necessary permissions had been obtained from local administration, and the community leaders were informed before initiating the study. Only those volunteers were considered having no physical disability, previous history of surgical episodes, and apparently healthy at the time of the investigation. They were explained about the objectives of this study, and consent was obtained from them. This work was carried out following the principles of the Declaration of Helsinki.

All the anthropometric measurements were taken following the standard protocol [81]. A sliding calliper was used to measure the length of the 2D and 4D of both hands. Before performing the hands' measurements, participants were asked to free their fingers for any rings or jewellery. The length was measured on 2D and 4D from the finger's tip to the base (most proximal to palm) on the ventral surface of the hand without putting any pressure on the fingers. Matrin's anthropometer rod and Omron Body composition Monitor (HBF-212) machine were used to measure the height (cm) and weight (kg) of the individuals. Hip (cm), waist (cm), and neck (cm) circumferences were measured by using calibrated, non-elastic fiber tape. Body mass index (BMI) was computed using the formula of BMI= weight (kg) / height (m^2). The waist-to-hip ratio (WHR)and 2D:4D ratio of both hands were also calculated. Based on digit ratio, hand pattern was classified into three types: A (2D<4D), B (2D=4D), and C (2D>4D).

The statistical analysis was performed in the Statistical Package for Social Sciences software (SPSS, IBM; version 26.0). Descriptive statistics of mean, standard deviation (SD), range, and standard error of the mean (SE) were generated for age and all anthropometric and derived variables. Chi-square test (χ^2) was applied to find out the significant difference in the prevalence of different hand patterns in both hands of all the participants. Paired *t*-test and independent-sample *t*-test have been performed to test mean differences in digit lengths and their ratios in both hands within and between sexes. Pearson correlation was also carried out to see the relationship between 2D:4D ratios, age, anthropometric, and derived variables. The p values of <0.01 and <0.05 were considered to be statistically significant.

Results

Table 1 depicted the descriptive statistics of age; anthropometric variables such as height (cm), weight (kg), waist circumference (cm), hip circumference (cm), neck circumference (cm); derived variables like BMI (kg/m^2) and WHR; and length of the 2D, 4D and their ratios (2D:4D) in both hands among the study population of either sex. The mean age of both males (40.17±14.96 years) and females (40.05±16.13 years) was similar. Except for hip circumference, all anthropometric variables had shown higher mean values in males than females. For BMI, females showed a comparatively higher mean value (24.21±5.16 kg/m^2) than males (23.30±4.10 kg/m^2). On the contrary, males

Table 1. Descriptive statistics of age, anthropometric variables, 2D and 4D length and their ratios of both hands of males and females among the Bhantu community

Sex	Variables		Mean	SD	Minimum	Maximum	SE
Male (n= 134)	Age (years)		40.17	14.96	18.00	60.00	1.293
	Height (cm)		167.97	6.07	150.70	188.50	.524
	Weight (kg)		65.85	12.698	40.40	99.10	1.096
	Waist Circumference (cm)		85.39	12.965	53.50	116.60	1.128
	Hip Circumference (cm)		91.16	7.716	70.10	108.00	.671
	Neck Circumference (cm)		34.81	2.776	28.70	42.50	.244
	BMI (kg/m^2)		23.30	4.108	14.25	34.09	.354
	WHR		.933	.091	.63	1.15	.007
	Right hand	2D (cm)	6.72	.401	5.60	8.20	.034
		4D (cm)	6.84	.409	5.70	8.10	.035
	Left hand	2D (cm)	6.74	.409	5.60	8.20	.035
		4D (cm)	6.84	.386	6.00	8.20	.033
	Right hand	2D:4D	.983	.045	.87	1.12	.003
	Left hand	2D:4D	.985	.037	.86	1.08	.003
Female (n= 171)	Age (years)		40.05	16.13	18.00	60.00	1.233
	Height (cm)		153.76	6.95	133.50	172.00	.532
	Weight (kg)		57.16	12.33	33.00	96.50	.943
	Waist Circumference (cm)		81.13	12.57	51.00	112.00	.967
	Hip Circumference (cm)		92.14	10.30	66.40	123.00	.792
	Neck Circumference (cm)		30.62	2.45	25.50	39.80	.188
	BMI (kg/m^2)		24.21	5.16	13.58	43.94	.394
	WHR		.878	.076	.70	1.12	.005
	Right hand	2D (cm)	6.22	.391	5.50	7.30	.029
		4D (cm)	6.34	.379	5.50	7.40	.029
	Left hand	2D (cm)	6.21	.389	5.20	7.20	.029
		4D (cm)	6.29	.397	5.30	7.30	.030
	Right hand	2D:4D	.980	.046	.63	1.08	.003
	Left hand	2D:4D	.988	.037	.90	1.09	.002

demonstrated a higher mean value of WHR (0.933±0.091) than females (0.878±0.076). In case of digit lengths, males have longer mean 2D and 4D than females in both hands, and particularly, mean 4D was found greater than mean 2D in both males and females. Digit ratio was higher in the left hand (male: 0.985±0.037; female: 0.988±0.037) compared to the right hand (male: 0.982±0.045; female: 0.980±0.046) among both males and females.

According to the hand pattern based on sex, the distribution of the studied population has been represented in **Table 2**. For both hands, pattern A (2D<4D) showed the highest frequency in both sexes, followed by Pattern B (2D=4D). Interestingly, on the right hand, pattern C (2D>4D) showed a slightly higher frequency in males (27.6%) than females (22.2%) and a reverse trend in the left hand (females: 32.2%; males: 25.4%). The overall result of the hand pattern demonstrated statistically non-significant differences between sexes.

Table 2. Distribution of studied population according to the hand pattern based on sex

Sex	Hand Pattern [Right hand]			χ^2	Hand Pattern [Left hand]			χ^2
	A [2D<4D]	B [2D=4D]	C [2D>4D]		A [2D<4D]	B [2D=4D]	C [2D>4D]	
Male (n = 134)	77 (57.5)	20 (14.9)	37 (27.6)	1.415^{NS}	74 (55.2)	26 (19.4)	34 (25.4)	4.157^{NS}
Female (n = 171)	109 (63.7)	24 (14.0)	38 (22.2)		96 (56.1)	20 (11.7)	55 (32.2)	

Percentages are presented in the parentheses; NS= Statistically not significant

Table 3 presented the bilateral variation in 2D, 4D length and their ratios of the study participants. Paired *t*-test revealed no significant differences between right and left hands of males in 2D (*t* = -1.012, p = .313), 4D (*t* = -0.309, p = .757), and 2D:4D (*t* = -0.341, p = .734). On the other hand, in females, except 2D (*t* = 0.444, p = .888) comparison of both 4D (*t* = 3.817, p = .000) and 2D:4D (*t* = -2.379, p = .018) between right and left hand showed statistically significant differences.

Independent sample *t*-test revealed significant differences in digit lengths of both hands; right 2D (*t* = 10.894, p = .000) and 4D (*t* = 10.941, p = .000), as well as left 2D (*t* = 11.360, p = .000), and 4D (*t* = 12.157, p = .000) between the sexes. But 2D:4D ratios of both hands were found non-significant (**Table 4**).

Pearson correlation coefficient for the relationship between 2D:4D ratios, age, anthropometric, and derived variables was exhibited in **Table 5**. The right-hand 2D:4D ratio of females revealed a statistically significant positive correlation with height (0.205, p<0.01). Other than that, no significant relationship was found between digit ratios and age and other anthropometric variables for both Bhantu males and females. It has been observed that neck circumference was negatively correlated with the 2D:4D ratio for both males and females but in opposite hands (males: left hand; females: right hand). Except for neck circumference, other variables were found positively correlated with 2D:4D in both hands for males. For females, age and WHR were also negatively correlated with the 2D:4D ratio in both hands.

Table 3. Bilateral symmetry of 2D, 4D length and their ratios among the studied participants

Sex		2D	4D	2D:4D
Male (n = 134)	Mean	- 0.017	- 0.005	- 0.001
	SD	0.204	0.223	0.040
	t	- 1.012^{NS}	- 0.309^{NS}	- 0.341^{NS}
Female (n = 171)	Mean	0.006	0.044	- 0.008
	SD	0.191	0.152	0.044
	t	0.444^{NS}	3.817**	- 2.379*

NS= Statistically not significant; $^{**}p<0.01$, $^{*}p<0.05$

Table 4. Occurrence of sex variation in the studied population

2D		Right hand		Left hand		2D:4D	
		4D	2D	4D	Right hand	Left hand	
95% CI	Lower	0.407	0.410	0.431	0.461	-0.007	-0.120
	Upper	0.587	0.590	0.612	0.640	0.013	0.005
t		10.894*	10.941*	11.360*	12.157*	0.628^{NS}	-0.804^{NS}

NS= Statistically not significant; *p<0.05

Table 5. Pearson correlation coefficients for the relationship between 2D:4D ratios, age and anthropometric variables

Variables	Male (n= 134)		Female (n= 171)	
	Right hand	Left hand	Right hand	Left hand
	2D:4D	2D:4D	2D:4D	2D:4D
Age	.060	.059	-.085	-.093
Height	.033	.065	.205**	.059
Weight	.083	.051	.137	.079
Waist circumference	.089	.098	.030	.037
Hip circumference	.042	.028	.079	.089
Neck circumference	.032	-.073	-.115	.064
WHR	.090	.128	-.060	-.035
BMI	.068	.026	.046	.053

$^{**}p<0.01$

Discussion

The digit length and ratio are complex and multifactorial traits resulting from an intriguing combination of '*nature*' and '*nurture*', the unique reciprocal interaction between environment, genetic, etc., each contributing to the overall phenotype. In this backdrop, it is of utmost necessity to explore the distinctive biological variations reflecting both the significance and complexity of genetic heritage among the various ethnic groups living in different environmental conditions. Therefore, the present study was conducted among Bhantu adult individuals of Andaman and Nicobar Islands of India to determine intra-sexual and inter-sexual variation from digit lengths and ratios. Besides that, the association between 2D:4D with age, anthropometric, and derived variables was also explored. Many studies from India and abroad have already established differences between sexes in the absolute length of 2D and 4D [28,33,37,69,82]. Generally, males have longer 2D and 4D than females [28,33,69], and the present study also exhibits similar trends. In case of hand pattern, pattern A (2D<4D) was found dominant for both hands among the study population. The findings are similar to previous studies involving different populations from countries like Nigeria [17], China [83], Italy and Romania [74], India [69], and Malaysia [55]. Again, in India, among the females, an opposite trend (2D>4D) has also been found from the north Indian [8] and the north-west Indian population [22]. On the other hand, Setiya et al. exhibited equal digit lengths (2D=4D) among female medical college students in Madhya Pradesh [71]. However, fluctuations in 2D, 4D lengths, and ratios in females possibly due to changes in hormonal levels during the menstrual cycle was reported by Mayhew et al. [50]. On the contrary, a similar study from rural Poland failed to confirm the result and found no differences in digit lengths and ratios of both hands across the menstrual cycle [30]. Among males, the presence of longer 4D compare to 2D was in concurrence with the findings of Nayek et al. [55], Setiya et al. [71], and Sen et al. [69,70].

Furthermore, statistically significant bilateral variation was found in the 4D length and 2D:4D ratio among females corroborating with the earlier studies [8,32,50]. However, males did not show any bilateral variationsin the digit lengths and ratio in this study, similar to the study of Paul et al. [58], Gillam et al. [64], and Robertson et al. [65]. In contrast, others have evidence of significant bilateral variation among males [62,76].

Typically, it has been seen that the 2D:4D ratio is lower in males than females [42,45,82]. The probable reason behind this phenomenon is the relationship between digit ratio and prenatal androgen exposure, specifically, a lower 2D:4D is correlated with the presence of a high level of testosterone, a characteristic feature of males, while a higher 2D:4D ratio correlates with a low level of testosterone, a distinctive feature of female [22,42]. While the exact reason is unclear, it was argued that Hox gene might influence the differences in both the digits and genitals in mammals [16,38,42]. Several hormones like estradiol, progesterone, testosterone, etc., and their cognate receptors have been seen to regulate Hox gene expression [36,61]. Nevertheless, no significant sexual dimorphism was observed in 2D:4D ratios in this study which contradicts many previous studies. Similar findings were also observed among the Zulus [45], Dutch [64], Austrians [79], Hadza hunter-gatherers [2], and Yali of Papua [47]. A probable reason behind no sexual differences in digit ratio among these populations may be due to the harsh environmental conditions that lead to more competition irrespective of sexes [47]. Even other studies at the molecular level did not support the hypothesis that digit ratio is related to prenatal androgen exposure [18,52] or adult testosterone levels [19,31]. Thus, there is scope for future studies focussing on comprehensive historical perspective as well as gene-environment interaction in studying digit ratios.

Additionally, the present study also investigated the relationships between digit ratios and anthropometric variables in the studied population. Only right-hand 2D:4D of females have shown a positively significant (0.205, $p<0.01$) correlation with height among all the anthropometric and derived variables. This finding is similar to the work of Lippa where a positive significant correlation was observed between height and digit ratio in both hands of females, not males [37]. Previous literature showed variations in results, where no significant correlation of height with 2D:4D has also been reported by many researchers [13,21,42,54]. While some other researchers reported a significant negative association between height and digit ratios [3,73]. Except for height, there was no significant correlation between digit ratio and other anthropometric variables in the present study. In accordance with the findings of Barut et al. [3], Muller et al. [54], and Jacob et al. [21], it was found that the 2D:4D ratio had no relationship with weight. Again, in this study, waist and hip circumferences were found non significantly associated with 2D:4D for both males and females, same as the findings of Muller et al. [54]. On the other hand, Fink et al. found a negative association between 2D:4D (both hands) and waist and hip circumferences in females [13]. However, other studies also produced similar trends in males [9,12]. Previous studies showed inconsistent results for BMI, where no significant association between digit ratio and BMI has been reported like the present study [21,25,41,54]. However, Fink et al. noted a significant positive relationship between BMI and digit ratio in the left hand of males [13]. In accord with the study of Jeevanandam and Prathibha [25], neck circumference did not reveal any statistically significant correlation with digit ratio. This was contradictory to previous works where a significant positive correlation was found between the digit ratio and neck circumference of males only [1,12]. In case of WHR, earlier works [13,41] did not show any significant relation with digit ratio, as in the present study. As studies revealed an independent association of WHR and neck circumference with obesity and risk of heart disease so the use of digit ratio may be indicative for being overweight in females and suggests a predisposition toward cardiovascular disease [1,57,59].

Conclusion

The present study was unique as it was probably the first presentation of information on sexual dimorphism, intraindividual variation from digit length, and their ratio of both sexes in Bhantus of Andaman. Sexual dimorphism was only seen in digit lengths, not in the digit ratio, indicating no consensus on the intra-sexual and inter-sexual variations in digit ratios and traits across various ethnic groups. Nevertheless, significant bilateral variation was observed for the 4D and 2D:4D ratio in the case of females only. Among different anthropometric variables, only height was found significantly correlated with the right-hand 2D:4D ratio of females. Further research is required on large samples considering the ethnic and sex differences for exploring the meaningful associations between digit ratios, hormonal influence, and behavioural traits.

Acknowledgements: The authors gratefully acknowledge all the participants for their cooperation and help during data collection. Furthermore, special thanks to the Director, Anthropological Survey of India, Ministry of Culture, Government of India, for providing all sorts of logistic support for the successful accomplishment of this research work.

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