International Journal of Anatomy and Research,
Int J Anat Res 2023, Vol 11(3):8692-98. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2023.163

Original Research Article

Morphometric Analysis of Osseous Hand Arches and Its Clinical Significance

Shweta Jha *1, Ruchira Sethi 2, Raag Reeti 3.

*1 Associate Professor, Department of Anatomy, Netaji Subhas Medical College and Hospital, Bihta, Patna, Bihar, India. **ORCiD:** 0000-0001-6167-5683

2 Professor and HOD, Anatomy, UNS ASMC, JAUNPUR, U.P, India. **ORCiD:** 0000-0003-2958-2510

3 Assistant Professor, Department of Anatomy, Netaji Subhas Medical College and Hospital, Bihta, Patna, Bihar, India. **ORCiD:** 0000-0001-9946-8065

ABSTRACT

Background: The osseous hand arches are key components enabling an individual for constant, consistent day to day activity performance. The variation in the arches may occur due to usage patterns of hand or it may change with respect to gender. The anatomy of hand arches, acts as the prime component by modulating the curvature of hand to increase not only the surface area for tactile stimulation but also for a better grip and grasp strength

Objectives: To provide normative data of palmar arches height in Indian population and to define the constant anatomical landmarks to measure the palmar arch height and correlate it with grasp power in healthy individuals.

Material and Methods: Hand arch morphometry was studied for 150 hands in both genders. The measurement was taken with a standardized vernier caliper for longitudinal arch height and distal transverse arch height, and their difference was analyzed for the right and left hand and for between the genders. The association of these parameters with body mass index was also assessed.

Results: The results show gender variation for grasp strength and differences in longitudinal arch height between the right and left hand. The results of the present study add to minimalistic literature regarding arch height in hand and also attempts to provide data that may be used in defining rehabilitative exercise program.

Conclusions: Differences in hand bone structure between the dominant and non-dominant hand for LAH were observed, but not for DTAH or GP. The differences between genders is observed for grasp power and LAH for left hand only. These variations could be due to usage patterns of the hand, muscle mass differences, and hormonal differences between the genders. This study has implications during the development of hand exercises program for treating neurological deficits in an individual.

KEYWORDS: Hand, Osseous, Arches, Grasp Strength.

Corresponding Author: : Dr. Shweta Jha, Associate Professor, Department of Anatomy, Netaji Subhas Medical College and Hospital, Bihta, Patna, Bihar, India. **E-Mail:** jha350@gmail.com

Access this Article online	Journal Information
Quick Response code	**International Journal of Anatomy and Research** ISSN (E) 2321-4287 | ISSN (P) 2321-8967 **https://www.ijmhr.org/ijar.htm** **DOI-Prefix:** https://dx.doi.org/10.16965/ijar
	Article Information
DOI: 10.16965/ijar.2023.163	Received: 14 May 2023 Peer Review: 18 May 2023 Revised: 30 Jun 2023 Accepted: 06 Jul 2023 Published (O): 05 Sep 2023 Published (P): 05 Sep 2023

INTRODUCTION

The osseous hand arches provide the hand motor control, the grip, the grasp, and the strength in collaboration with the tone and movements of the thenar and the hypothenar muscles [1]. The daily activities of life and living, like cutting, lifting, pulling, holding, etc., primarily require hand and shoulder movements. The anatomy of hand arches acts as the prime component for the above-stated functions by modulating the curvature of the hand to increase the surface area for tactile stimulation and a better grip and grasp strength. Handgrip strength also determines an individual's muscular strength [2,3]. It is an important indication of general health and is regarded as one of the most reliable clinical strengths estimating methods [4,5]. The significance of osseous hand arches was further highlighted when specific hand arch training exercises were introduced in children afflicted with cerebral palsy [1]. In preschool children with neurological deficits of multiple aetiologies, hand arch training exercises provided enough development of the hand arches to make them physically less challenged towards performing daily activities and provide sufficient functional writing [6].

The arching mechanism of the hand is very similar to that of the foot, where the pillars, summit, and keystone play a significant role in adjusting the body's weight for enhanced locomotory action. In the region of the hand, the stable pillar support is extended by the little and ring finger while the dynamic component is by the index-middle finger and thumb [7-9].

The daily activities of cutting, painting, holding, pulling, etc, require a stable and normative curvature of the hand for a comfortable, consistent, constant activity. The palmar concavity is provided with respect to three dominant arches of the hand: the proximal and distal palmar arch and one longitudinal arch. The anatomical landmarks for these arches are as under [10]:

(i) Proximal Transverse arch (PTA): with capitate bone as the keystone for this arch, it is more fixed variant which passes through the distal part of the carpus and marked on surface as the distal wrist crease.

(ii) Distal transverse arch(DTA) : In position of optimum, a concave curvature is formed at the metacarpal heads of the index, middle, ring and little ûngers.

(iii) Longitudinal arch(LA) : a carpometacarpophalangeal arch that stretches from the crease of the wrist to the tip of either the middle or the index finger.

The development of hand arches plays a key role in stabilizing little and ring fingers, keeping them curled up or outstretched, and allowing free movement of the thumb, index, and middle fingers. This also helps stabilize trunk, elbow, and wrist joints and rotation of the forearm, supporting precision motor skills like pencil grasp, which aids in smooth handwriting skills [11].

Though the significance of hand osseous arches is immense but to our knowledge, hand anthropometric studies are fewer and if there, are focussed more on the palmar width, palmar length, and finger span with very little information available for the height and configuration of osseous arches. The present study focuses on the anthropometric scale of hand arches and determines its correlation with the body mass index of an individual. A fair attempt would be made to analyze the differences between gender and dominant vs nondominant hands. This study will provide baseline data relating to the normal curvature of the hand and will correlate it with an individual's body mass index (BMI) and grasp power(GP).

METHODS

The present observational cross-sectional study was conducted after obtaining necessary ethical approval from the institutional ethical committee of Heritage Institute of medical sciences, Varanasi, Uttar Pradesh. The study was conducted at a medical school, and students in the age group of 18-25 years were selected for the study. Only students who gave consent for the study were included, and exclusion criteria were defined for non-consenting individuals with any debilitating injury of the hand resulting in deformity, subjects with musculoskeletal disorders, and/or with osteoarthritis or rheumatoid arthritis conditions. Hand anthropometry for 150 (75 subjects) hand arches was done to determine the height of the arches. An individual's height and weight were measured to assess the body mass index [12]. The grasp strength was determined, and the association of the height arch with grasp strength was done for dominant and non-dominant hands.

Position for acquiring data: Subjects were seated in a comfortable chair with the back supported and the hand resting on an adjustable plate. The arm was positioned at approximately 45-degree shoulder abduction, 90-degree elbow flexion with the forearm in pronation [13].

Measurement of longitudinal arch height (LAH): Markers were placed at the distal palmar crease and tip of the distal phalanx of the middle finger with the summit at the third metacarpophalangeal joint. Figure 1

Measurement of distal transverse arch height (DTAH): Markers were placed at second and fifth metacarpophalangeal joint as the base and height of triangle was calculated.

Proximal transverse is considered to be rigid and plays no role in Hand Object interaction. Hence was not measured.

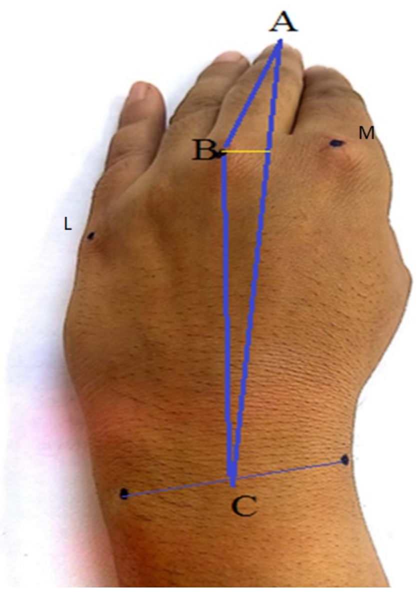

Fig. 1: Measurement of LAH : Height of triangle formed by points A,B , C .For DTAH calculation, Markers placed at points L and M as shown in the figure.

The sides of triangles formed by the marked points were measured with a standardized vernier caliper and hence were used to calculate the triangle height which otherwise depict the arch heights.

Heron´s Formula:

Area of Triangle (R)=

$\sqrt{s(s-a)(s-b)(s-c)}$ where is s=a+b+c/2

Height= 2 R/b b=Base AB=a BC=c AC=b

Measurement of grasp power (GP): The subject held the dynamometer in the hand to be tested, with the arm at right angles and by the side of the body. When ready the subject squeezed the dynamometer with maximum isometric effort, which was maintained for about 5 seconds [14]. The average of three readings was taken for analysis (rounded off to the nearest whole number)

Statistical analysis: The descriptive statistical analysis was done for each variable using Microsoft Excel 10 and SPSS 21. The paired t-test for dependent means was used to analyze the statistical difference of significance for the dominant and non-dominant hand for both longitudinal arch height and distal transverse arch height. The paired t-test for independent means was used for statistical analysis between genders for arch height. Mann-Whitney U test was applied for BMI difference between the genders. Pearson's coefficient correlation was used to define the relationship of arch height with BMI and gender grasp power. Scatter plots show the strength of the association. Regression analysis was done to estimate the linear relationship between the independent variable of BMI with the dependent variable of longitudinal arch height. In all statistical analysis p value will be taken as p significant at $\leq$ 0.05 at 95% confidence interval.

RESULTS

A total of 75 (Male=21 and female=54) subjects consented to participate in the study. The study sample was from the age group 18-25 years with a mean age of 20.04±0.84 years. The difference in age between the genders was non-significant at $p \geq 0.05$. The mean BMI for the sample is 23.21±3.43, calculated concerning age and gender by a BMI calculator. For all the subjects, the right hand was the dominant hand.

The descriptive statistics for each variable with its significance is shown in TABLE 1.

There was no statistically significant difference for mean values of DTAH and GP for dominant and non-dominant hand. On the other hand, the difference for mean of arch height was statistically significant for LAH.(Table 1)

The gender variation between the variables is shown in Table 2. The study results show a statistically significant difference between genders for right-hand DTAH and left-hand LAH. The grasp power differences were statistically

Table 1: Descriptive statistics of variables with p value significance for dominant vs non dominant hand (NS=non-sginificant, S=significant).

Variable	Mean ±SD		T and P value
	Right Hand (Dominant)	Left Hand (Non-Dominant)	
DTAH (in mm)	8.92±3.5	9.13±5.6	t is 0.23. p is 0 .83. NS
LAH (in mm)	35.73±6.94	33.4±6.64	t is -2.32 p is 0 .024 S
GP (Kg/m2)	19.24±13.31	19.25±15.21	t is 0.01 p is .99 NS

Table 2: Gender variations between LAH, DTAH and GP(S= Significant, NS: Not significant).

		Male	Female	T and P value
DTAH (in mm)	RH	10.52±14.95	8.26±10.39	T=-2.15,p=0.036 S
	LH	8.42±14.82	9.43±38.9	T=0.58,p=0.57 NS
	T and P value	t-value is 1.49 p-value is .15 NS	t-value is -1.00 p-value is .32 NS	
LAH (in mm)	RH	36.6±49.3	35.57±48.6	T=-0.057,p=0.57 NS
	LH	37.4±47.9	31.7±34.3	T=-2.96,p=0.005 S
	T and P value	t-value is -0.30 p-value is .76 NS	t-value is 2.39 p-value is .019 S	
GP (Kg/m2)	RH	26.3±317.8	16.28±95.6)	p-value of 0.012. S
	LH	32.5±375.4	13.7±73.3	T=-4.84,p≤0.00001 S
	T and P value	t-value is -0.91 p-value is .37 NS	t-value is 1.18 p-value is .12 NS	

significant between the genders for both dominant and non-dominant hands. Only and for comparing the mean values of DTAH, LAH, and GP for male and female participants. (Table 2)

The correlation coefficient (r) is given as 0.10, which indicates a weak positive correlation between the two variables. The p-value of 0.45 suggests insufficient evidence to reject the hypothesis that no correlation between the variable and the weak positive correlation observed may be due to chance (Figure 2).

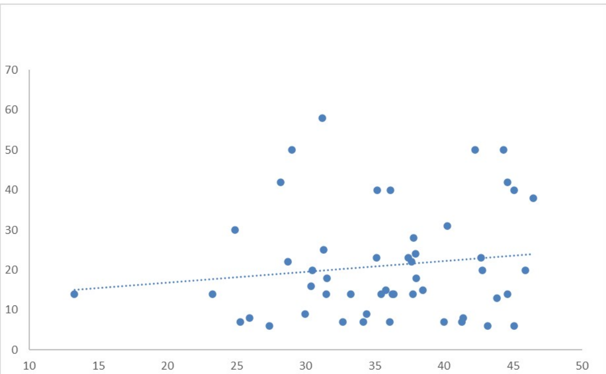

Fig. 2: Correlation between LAH and Grasp for right hand r=0.10 p=0.45

The correlation coefficient (r) is given as 0.47, which indicates a moderate positive correlation between the two variables. There is strong evidence to reject the hypothesis of no correlation between the variables, and conclude that there is a moderate positive correlation between LAH and grasp for the left hand. In other words, as LAH increases, left hand grip strength tends to increase as well.(Figure 3)

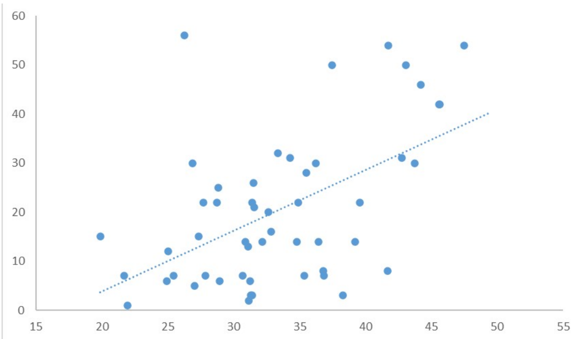

Fig. 3: Correlation between LAH and Grasp for left hand r=0.47 p=0.0004(S).

The regression analysis to define the relationship between the BMI (considered as independent variable,X) and LAH (considered as dependent variable,y). The results are shown in Figure 4 and Figure 5 for right and left hand respectively.

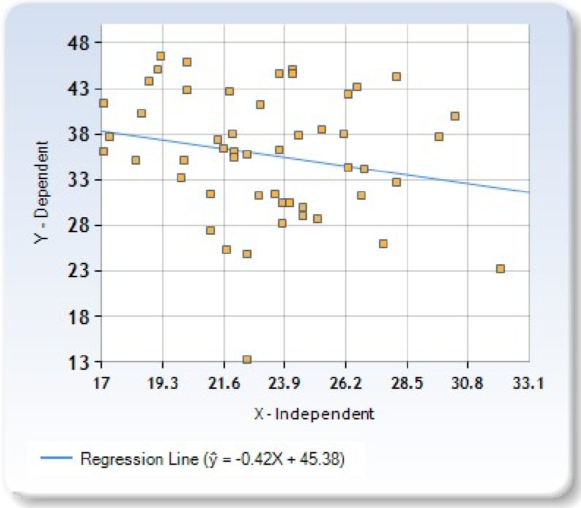

Fig. 4: Regression analysis for Right hand.

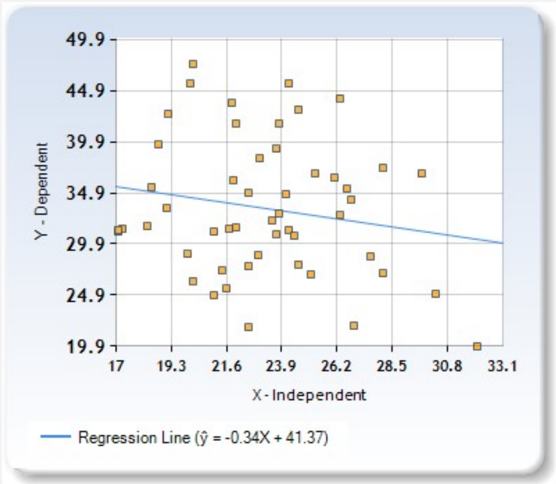

Fig. 5: Regression analysis for left hand.

The interpretation of the regression line for both the hands is that there is a negative relationship between X and y, and the slope of the line suggests that as X increases, y tends to decrease. The intercept of the line suggests that when X is equal to zero, the predicted value of y is 45.38. or 41.38 and for every one unit increase in X, y decreases by 0.42 units and 0.34 units for right and left hand respectively. (Figure 4 and 5)

DISCUSSION

The results of this study indicate that there was no significant difference between the mean values of the dominant right hand and non-dominant left hand for DTAH. This is consistent with previous studies that have also reported no significant difference between the two hands for DTAH [15,16]. However, there was a statistically significant difference between the mean values of the dominant and non-dominant hand for LAH. This finding is also consistent with previous research that has reported differences in LAH between the two hands [17].

It is possible that this difference in LAH could be due to differences in the use of the dominant and non-dominant hand for day to day activities, leading to variations in bone density and structure. The study found no significant difference between the mean values of the dominant and non-dominant hand for GP, which is also consistent with previous research [18]. An earlier study by Shweta et al suggests grasp power on right and left side showed a statistically significant difference between the two genders [19].

Overall, the results suggest that there are differences in hand bone structure between the dominant and non-dominant hand for LAH, but not for DTAH or GP. In case of grasp strength , the rule of 10% is applied which states that the dominant hand has 10% more grasp strength than the non-dominant hand [20].

In the present study, the rule applies for female genders only where dominant hand grip was more as compared to that of non-dominant hand while on the other hand, in case of males the results are reversed. It is important to observe that some individuals may have similar grip strength in both hands, this could be due to heightened physical activity or hand usage patterns. The results of this study suggest that there are significant differences in hand grip strength and hand arch measurements between male and female participants. The findings are consistent with previous research that has also shown gender differences in hand strength and grip. A study by D'Agostino et al. (2018) found that males had higher hand grip strength than females, which may be due to differences in muscle mass and hormone levels [21]. Similarly, a study by Arora et al. (2018) showed that males had higher hand arch index values compared to females [22]. Another study emphasized that grip muscle power is superior in males and in the dominant hand, the lateral dominance is more marked in females [23]. Another study by Wang et al show results consistent with the present [24]. The present study adds to the existing literature by demonstrating differences in hand grip strength and hand arch measurements between males and females, particularly in the left hand for LAH and GP measurements. These findings could have implications for rehabilitation and exercise programs that aim to improve. hand function in individuals of different gender.

CONCLUSION

Overall, the results suggest that there are differences in hand bone structure between the dominant and non-dominant hand for LAH, but not for DTAH or GP. The differences between genders is observed for grasp power and for LAH for left hand only. These variations could be due to usage patterns of the hand, muscle mass differences and hormonal differences between the genders. This study have implications during development of hand exercises program for treatment after neurological deficit in an individual.

ABBREVIATIONS

LAH: Longitudinal arch height
DTAH: Distal transverse arch height
GP: Grasp Power
PTA: Proximal Transverse Arch
DTA: Distal Transverse Arch
LA: Longitudinal Arch
BMI: Body Mass Index

Author Contributions

Dr Shweta Jha: Conceptualisation and design, data acquisition, interpretation and writing
Dr Ruchira Sethi: Conceptualisation, data interpretation and writing
Dr Raag Reeti: Data interpretation, writing and revision of manuscript

Conflicts of Interests: None

REFERENCES

[1]. Azzam AM. Effect of Hand Function Training on Improvement of Hand Grip Strength in Hemiplegic Cerebral Palsy in Children. J Nov Physiother 2012;2:116.

[2]. Ling CH, Taekema D, de Craen AJ, Gussekloo J, Westendorp RG, Maier AB. Handgrip strength and mortality in the oldest old population: the Leiden 85-plus study. CMAJ. 2010 Mar23;182(5):429-35. doi: 10.1503/cmaj.091278. Epub 2010 Feb 8. PMID: 20142372; PMCID: PMC2842834. 2010

[3]. Fool H. Influence of body composition, muscle strength, diet and physical activity on total body and forearm bone mass in Chinese adolescence girls. Br J nutr. 2007;98(6):1281–1287.

[4]. Nachon G, Rouillon Jd. Influence of the age on self-regulation of static grip forces from perceived exertion values. Neurosci lett. 2002;325:52–56.

[5]. Hager-Ross C, Schieber MH. Quantifying the independence of human finger movments: comparisions of digits, hands and movement frequencies. Neurosci. 2000;20:8542–8550.

[6]. Li-Tsang, Cecilia & Cecilia, W & Li-Tsang, Ph & Phil, M. The Hand Function of Children with and Without Neurological Motor Disorders. The British Journal of Developmental Disabilities 2003;49: 99-110.

[7]. Barnes MJ, Johnson GS. Upper Motor Neurone Syndrome and Spasticity. Arch Phys Med Rehabil 2001;23: 453-460.

[8]. McDonnell MN, Hillier SL, Ridding MC, Miles TS. Impairments in precision grip correlate with functional measures in adult hemiplegia. Clin Neurophysiol. 2006;117: 1474-1480.

[9]. Guo CB, Zhang W, Ma DQ, Zhang KH, Huang JQ. Hand grip strength: an indicator of nutritional state and the mix of postoperative complications in patients with oral and maxillofacial cancers. Br J Oral Maxillofac Surg 1996;34:325-327.

[10]. Sangole, A.P., Levin, M.F. A new perspective in the understanding of hand dysfunction following neurological injury. Topics in Stroke Rehabilitation2007;14(3):80–94.

[11]. Therapy skill builders. Forearm, hand and finger control. A division of communication skill builders. 1991;602-323-7500.

[12]. Nuttall, F. Q. Body mass index: Obesity, BMI, and health: A critical review. Nutrition Today 2015; 50(3):117-128.

[13]. Archana P. Sangolea, Mindy F. Levin. Arches of the hand in reach to grasp. Journal of Biomechanics 2008;41:829–837.

[14]. Nicola M Massy-Westropp, Tiffany K Gill, Anne W Taylor, Richard W Bohannon and Catherine L Hill. Hand Grip Strength: age and gender stratified normative data in a population-based study. BMC Research Notes 2011;4:127.

[15]. Haward BM, Griffin MJ. Repeatability of grip strength and dexterity tests and the effects of age and gender. Int Arch Occup Environ Health. 2002 Jan;75(1-2):111-9.

[16]. De Smet, L., Van Glabbeek, F., & Thys, L. Grip strength in right-handers and left-handers. Ergonomics 1982;25(9):785-791.

[17]. Tsai, L. C., & Yu, B. The difference of hand arch index between right and left hands. Work 2015;51(2):237-243.

[18]. De Smet, L., Van Glabbeek, F., & Thys, L. Grip strength in right-handers and left-handers. Ergonomics 1982;25(9):785-791.

[19]. Shweta Jha, Ruchira Sethi. Correlative study between handgrasp power with handwriting speed and legibility among medical students. Int. J. Heal. Clin. Res. [Internet]. 2021;4(13):88-91.

[20]. Petersen P, Petrick M, Connor H, Conklin D. Grip strength and hand dominance: challenging the 10% rule. Am J Occup Ther. 1989 Jul;43(7):444-7.

[21]. D'Agostino, J., Bo, M., Dean, E., & Luo, J. Gender differences in hand grip strength and rate of fatigue in the dominant and non-dominant hand. Work 2018; 60(1):95-101.

[22]. Arora, K., Gauba, V., & Gupta, N. A study of hand arch index in Indian population and its comparison between the sexes. Indian Journal of Orthopaedics 2018; 52(1): 76-80

[23]. Aoki, H. & Demura, Svetlana. The effect of gender and lateral dominance on gripping muscle power in young adults. Sport Sciences for Health 2008; 3: 1-6.

[24]. Wang YC, Bohannon RW, Kapellusch J, Washburn D, Li X, Yen SC, Rahman MH. Between-side differences in hand-grip strength across the age span: Findings from 2011-2014 NHANES and 2011 NIH Toolbox studies. Laterality. 2019 Nov; 24(6):697-706.

How to cite this article:

Shweta Jha, Ruchira Sethi, Raag Reeti. Morphometric Analysis of Osseous Hand Arches and Its Clinical Significance. Int J Anat Res 2023;11(3):8692-8698. **DOI:** 10.16965/ijar.2023.163