Original Article

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Correlation between First Ray Length and Tip-to-Tip Pinch Strength among Young Adults: A Pilot Study

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ABSTRACT

Introduction: Hand anthropometry influences manual performance, yet the specific relationship between first ray length and precision pinch strength remains underexplored in Indian young adults. While hand length, forearm circumference, and Body Mass Index (BMI) have been correlated with grip strength, limited data exist on first ray anthropometry as a predictor of tip-to-tip pinch strength.

Aim: To evaluate the relationship between first ray length, including thumb and pinch strength among subjects aged 18-25 years.

Materials and Methods: This pilot cross-sectional study was conducted at Mahatma Gandhi College of Occupational Therapy, Mahatma Gandhi University of Medical Sciences and Technology, Jaipur, Rajasthan, India from July to August 2025. A total of 30 healthy university students (13 males, 17 females; mean age 19.3 years) were recruited by simple random sampling. Dominant hand tip-to-tip pinch strength was measured using a calibrated Baseline® hydraulic pinch gauge (Model 12-0200) following American Society of Hand Therapists (ASHT) positioning: seated, shoulder adducted and neutrally rotated, elbow flexed to 90°, forearm neutral, wrist 0-30° extension. Three trials with a 30-second rest were performed, and the mean was recorded in kilogram-force (kgf). Normality was assessed using the Shapiro-Wilk test. Pearson correlation coefficient (r) with 95% confidence interval, and simple linear regression were performed using Statistical Package for the Social Sciences (SPSS) version 26.0 at p-value <0.05.

Results: Mean first ray length was 13.57±1.47 cm and mean tip-to-tip pinch strength was 4.15±0.99 kgf. Data were normally distributed. A moderate positive correlation was observed between first ray length and tip-to-tip pinch strength (r=0.68, 95% CI: 0.42-0.84, p-value <0.01, R^2=0.46). Linear regression yielded: Pinch strength (kgf)=-2.08+0.46 × First ray length (cm); β=0.46, p-value <0.01.

Conclusion: A moderate positive correlation was established between first ray length and maximum pinch strength. This study supports the experimental hypothesis and helps to broaden the perspective of rehabilitation professionals, suggesting that first ray anthropometry may be a useful consideration when assessing precision pinch strength and hand function. Larger studies controlling for gender, BMI, and hand span are warranted.

Keywords: Activities of daily living, Anthropometric measurements, Hand function, Precision pinch strength

INTRODUCTION

The human hand demonstrates a high degree of specialisation in forceful grasping, precision, and manipulation. The thumb plays a pivotal role in empowering complex manoeuvres and harmonised hand activities. Approximately, 40-50% of hand function depends upon the effective action of the thumb [1,2]. Thumb length is a part of body metrics frequently measured for ergonomic, orthopaedic, and rehabilitation studies. Anthropometric studies suggest that hand dimensions, including thumb length, may influence manual performance [3-5]. However, thumb length remains clinically significant because it affects different functional activities like reaching, contact positioning, lever mechanics, holding, object manipulation, release etc. In biomechanical terms, thumb relies on stability, mobility, and muscular coordination. The thumb acts as a dynamic stabiliser during grasp and pinch activities. Position, length, and muscle attachments determine mechanical leverage and force production for doing any activity with the help of the thumb [6]. Fallahi AA and Jadidian AA, reported that handgrip strength and certain hand dimensions differ between athletes engaged in handgrip activities involving objects or opponents and non-athletes. Moreover, a significant positive correlation was observed between handgrip strength and most hand dimensions in grip athletes, suggesting their potential utility in talent identification for grip-related sports as well as in clinical assessment settings [7].

Hand morphology varies across geographical regions and ethnic groups, influencing the strength required to operate tools. For example, a study on Nigerian females demonstrated that their hands were wider and shorter compared to those of females from Hong Kong and the United Kingdom (UK). Such anthropometric differences have practical implications for ergonomic tool design and evaluation [8]. Similarly, another study identified a relationship between physiological hand shape and grip/pinch strength in children aged 5-13 years [9].

Pinch strength is a fundamental component of manual performance, reflecting the functional capacity of the thumb-finger complex. It is defined as the maximal force generated between the thumb and one or more opposing digits. Clinical evaluation of pinch strength provides valuable insights into muscle performance, hand function, rehabilitation outcomes, and recovery progression. Standardised pinch gauges or dynamometers are typically employed for measurement. Three primary forms of pinch are recognised in clinical practice: tip-to-tip, lateral, and three-jaw chuck pinches [10-12]. In the present study, only tip to tip is measured as it demands highest precision.

Alahmari KA et al., emphasised that handgrip strength shows significant correlations with hand length, BMI, forearm circumference, and grip strength itself [13]. Individuals regularly engaged in manual activities demonstrate greater pinch/grip strength and manual dexterity compared to those who do not [14]. Variations in thumb dimensions may influence hand span, leverage, and mechanical advantage during daily activities and functional tasks. Thumb morphology, therefore, has direct implications for grip and pinch strength. The strength of the thumb, index finger, and little finger is particularly relevant, as these digits define the anatomical limits

of the hand and are fundamental to prehension functions such as grasping, pinching, and object manipulation [15,16].

Previous research has established positive associations between handgrip strength and body height, weight, BMI, hand length, body surface area, arm and calf circumference, waist–hip ratio, and physical activity [17]. However, limited studies have examined the relationship between thumb length and pinch strength. This gap highlights the need for further investigation into whether first-ray length (including the thumb) can serve as a predictor of pinch force production. While the strongest correlations have been observed between hand length and pinch strength [18], the extent to which first-ray length contributes to pinch strength remains unclear, particularly in the Indian context.

Accordingly, the present study aimed to determine the correlation between first-ray length and pinch strength among subjects aged 18-25 years.

MATERIALS AND METHODS

A pilot study was conducted at Mahatma Gandhi College of Occupational Therapy, Mahatma Gandhi University of Medical Sciences and Technology, Jaipur, Rajasthan, India, from July to August 2025. Ethical approval was obtained from the Institutional Ethics Committee of MGUMST (IEC No: MGMC&H/IEC/JPR/2023/1697, dated 2023). All procedures were performed in accordance with the Declaration of Helsinki (2013). Written informed consent was obtained from all participants. Participants were assured of confidentiality and voluntary withdrawal.

Inclusion criteria: 18-25-year-old university-going healthy students of Allied health sciences, should be Indian, and only the dominant hand was used for assessment were included in the study. Fingernails were required to be trimmed so that it does not interfere with pinch strength.

Exclusion criteria: Participants with acute illness, past or present pathology of trauma to the upper extremity or cervical region, any history of upper limb injury or deformity with motor impairment, hand pain and neurological disorder involving the hand e.g. stroke or any neurodegenerative condition were excluded from the study.

Sample size: Sample size for this pilot study was based on Julious SA recommendation of a minimum of 12 participants per group for pilot studies and feasibility considerations [19]. Simple random sampling was performed using a computer generated random number table from the student enrolment list. Thirty healthy students from Occupational Therapy and Physiotherapy programs were recruited in the study.

Study Procedure

This study focused on two variables, i.e., first ray length and pinch strength. Each participant was assessed in two phases: one for first ray length measurement using a measuring scale, whereas another phase consisted of evaluation of tip-to-tip pinch strength.

Phase 1: Tip-to-Tip Pinch Strength Measurement

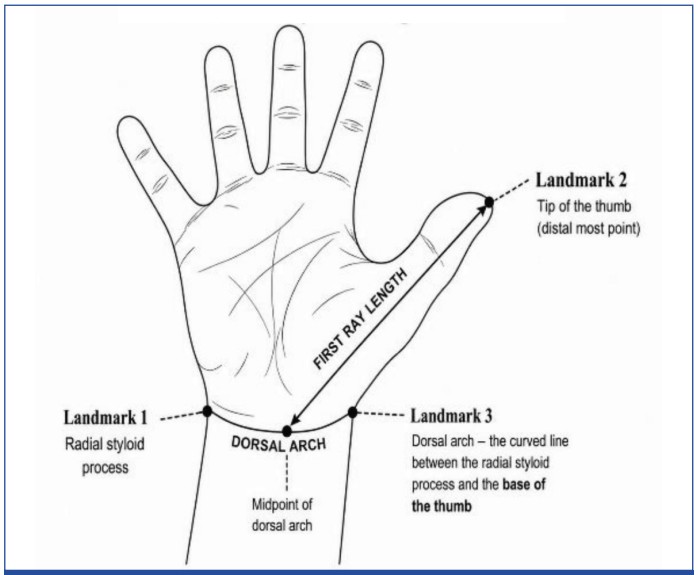
Instrument: Baseline® Hydraulic Pinch Gauge, Model 12-0200 (Fabrication Enterprises Inc., USA). The instrument has reported excellent inter-rater reliability (ICC=0.98) [16] and intra-rater reliability (ICC=0.97) [20].

Participants were seated comfortably on a chair without armrests, feet flat on the floor, shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position, wrist in 0-30° extension and 0-15° ulnar deviation [21]. The pinch gauge was held by the assessor. Participants were instructed to pinch the gauge between the pulps of the thumb and index finger with maximal effort for three seconds. Three trials were performed with 30-second rest intervals. The mean of three trials was considered for analysis. All measurements were taken for the dominant hand only, between 10:00 AM and 1:00 PM to avoid diurnal variation.

Phase 2: First Ray Length Measurement

Landmark definition: First ray length was defined as the linear distance from the midpoint of the dorsal crease over the first metacarpophalangeal joint (dorsal arch) to the most distal point of the thumb pulp tip.

Each participant's dominant hand was placed palmar side down on A4 paper with fingers extended and thumb abducted. The hand outline was traced using a fine-tip pencil held perpendicular to the paper. The dorsal MCP joint crease was identified and its midpoint marked. A line was drawn from this point to the thumb tip of the tracing [7]. This distance was then measured using a digital vernier caliper (Mitutoyo, least count 0.01 mm, accuracy ±0.02 mm). Two measurements were taken by the same assessor and averaged. The assessor was blinded to pinch strength values during anthropometric measurement [Table/Fig-1].



[Table/Fig-1]: Measurement of first ray length.
Note: This method measures first ray functional length including metacarpal contribution, not isolated anatomical thumb length, and therefore values are higher than pure thumb length norms; This is explicitly acknowledged as a study limitation.

STATISTICAL ANALYSIS

Data were entered in Microsoft Excel 2019 and analysed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY). Descriptive statistics: mean, Standard Deviation (SD), frequency, and percentage. Normality was tested using the Shapiro-Wilk test. Pearson correlation coefficient (r) was calculated to assess correlation between first ray length and pinch strength, with a 95% confidence interval (CI). Simple linear regression was performed to examine the predictive relationship. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 30 healthy participants were included. The sample comprised 13 males (43.3%) and 17 females (56.7%). The mean age was 19.3±1.2 years (males: 19.7±1.3 years; females: 19.0±1.0 years). All participants were right-hand dominant. The mean first ray length of the participants was 13.57±1.47 cm, indicating moderate variability among subjects. Pinch strength recorded was 4.15±0.99 kgf, suggesting some variation in pinch strength performance across the sample [Table/Fig-2].

Gender	n (%)	Percentage	Mean ± standard deviation pinch strength (kgf)	Mean±Standard deviation Thumb length (cm)
Males	13 (43.3)		4.65±0.89	14.5±1.29
Female	17 (56.7)		3.77±0.91	12.85±1.18
Total	30 (100)		4.15±0.99	13.57±1.47*

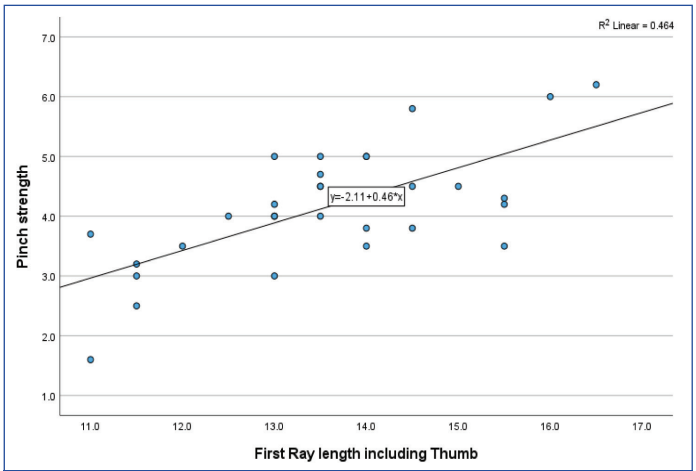
[Table/Fig-2]: Gender-wise descriptive statistics for first ray length and tip-to-tip pinch strength.
*First ray length of 13.57±1.47 reflects hand tracing up to dorsal Arch rather than palmar margin

A moderate positive correlation was established for all subjects between first ray length and pinch strength [Table/Fig-3].

Gender	N	Correlation coefficient	Significance (p-value)
Male	13	0.645	0.017*
Female	17	0.527	0.030*
Total	30	0.682	<0.001**

[Table/Fig-3]: Pearson correlation coefficient was established with significance level. *Correlation is significant at 0.05 level (2 tailed); ** Correlation is significant at 0.01 level (2 tailed)

The positive regression coefficient (β=0.46) indicates that first ray length was positively associated with pinch strength [Table/Fig-4].



[Table/Fig-4]: Scatter plot showing positive linear relationship between first ray length (cm) and tip-to-tip pinch strength (kgf).

DISCUSSION

The present study established a significant moderate positive correlation between first-ray length and pinch strength. These findings are consistent with those of Francis TG and Anandhi S, who reported that thumb length was positively correlated with grip strength and work-related musculoskeletal disorders, while negatively correlated with unilateral hand finger dexterity among dental professionals. Their results emphasised that thumb length may serve as a more reliable predictor of hand grip strength and susceptibility to work-related musculoskeletal disorders [21].

Similarly, Li YX et al., investigated the respective roles of the thumb and index finger in tip-pinch force perception across different force levels in males and females. In their study of 42 healthy participants (21 males and 21 females), sex-related differences were observed: females demonstrated greater reliance on the thumb, whereas males depended more heavily on the index finger for accurate pinch force control. These findings highlight the digit-specific contributions to precision pinch tasks and underscore the importance of considering sex differences in hand function research [22].

Bardo A et al., explored the relationship between pinch strength and manual dexterity in healthy individuals, demonstrating that variations in hand strength influenced the ability to perform precise, coordinated movements required for everyday tasks. Importantly, their study revealed that stronger pinch force does not necessarily translate into superior fine motor performance. This underscores the need to assess both pinch strength and manual dexterity when evaluating hand performance, particularly in clinical, rehabilitation, and ergonomic contexts [14].

The current study's demonstration of a moderate correlation suggests that thumb-specific anthropometry exerts a more direct influence on precision pinch tasks than generalised hand measurements. Supporting evidence is also provided by Prasanna KJ and Shivani S, who investigated the relationship between fingernail length and pinch strength among 100 college females [17]. Fingernail length, measured with a vernier calliper, showed a significant negative correlation with pinch strength across all pinch types. Longer nails were associated with reduced pinch strength, with tip pinch being the weakest and lateral pinch the strongest. These results further emphasise the role of thumb-related morphology in determining pinch performance [23].

Limitation(s)

The pilot nature of the study and its relatively small sample size (n=30), drawn from a single centre, may limit the generalisability of the findings to broader and more diverse populations. Taken together, the findings reinforce the importance of thumb-specific anthropometric parameters in evaluating pinch strength and precision tasks. Future research should incorporate broader physiological variables and standardised anatomical measurements to clarify the predictive value of first-ray length in diverse populations.

CONCLUSION(S)

This pilot study demonstrated a moderate positive correlation between first ray functional length and tip-to-tip pinch strength in young adults aged 18-25 years. First ray length accounted for 46% of the variance in pinch strength. While preliminary, these findings suggest that first ray anthropometry may be a useful adjunct parameter in hand function assessment and ergonomic evaluation. Larger, adequately powered studies with rigorous anthropometric methods are warranted to confirm these findings.

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