Anthropological Review • Vol. 87(3), 33–45 (2024)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.87.3.03

Investigation of hand index, digit finger ratio (2D:4D), and grip strength among court sports

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Abstract: Hand index, finger ratio, and grip strength are potential indicators of proficiency in court sports. The aim of this study is to explore hand dimensions, fingers length ratio, and grip strength in court sports players, a domain in which such characteristics can significantly influence performance. Measurements, such as hand length (HL), hand breadth (HB), hand index (HI), palm length (PL), hand span (HS), index finger length (2D), ring finger length (4D), 2D to 4D ratio (2D:4D), low digit ratio (LDR), and high digit ratio (HDR) were studied in the field of hand anthropometry, along with a handgrip strength (HGS) test. Data were obtained from 135 male court sports players, including basketball, handball, and volleyball, with 45 players from each discipline. Descriptive statistics, one-way ANOVA, and an independent t-test were used to compare variables, with statistical significance set at $p < 0.05$. The ANOVA results indicated that there were no significant differences in hand variables, namely HL, HB, PL, HS, 2D, 4D, 2D:4D, LDR, HDR, and HGS, except for the HI variable. Post-hoc test results showed HI differences in basketball versus handball and volleyball. Compared to standard HI, their ranges show that all-court sports often fall into the Dolichocheri type, characterized by long fingers and a narrow, small palm. A low digit ratio may have some effect on HI in basketball and volleyball. However, it does not appear to have a significant effect on HGS across the study. In summary, the results of our study show that court athletes are similar in hand characteristics, 2D:4D, and grip strength for the nature of the game.

Key words: hand anthropometry, hand index, digit ratio (2D:4D), grip strength, court sports.

Received: 21.03.2024; Revised: 9.07.2024; Accepted: 10.07.2024

Introduction

Physical characteristics and athletic performance are crucial in court sports, such as basketball, handball, and volleyball, where skillful ball control requires having adequate hand size and grip strength (Rahman and Sharma 2023). In these sports, attributes such as hand length (HL), hand breadth (HB), hand span (HS), finger length, and handgrip strength (HGS) are vital for activities, such as shooting and dribbling in basketball, gripping and catching in handball, and spiking and blocking in volleyball. The elongated fingers of the hand, with extra skin, enhance the efficiency and comfort of gripping objects, such as a ball, by minimizing the need to spread the fingers (Nag et al. 2003). Furthermore, Visnapuu and Jürimäe (2007) suggested that individuals with broad, flat hands and longer fingers might possess a stronger grip. The hand span is used to determine the highest possible handgrip strength values (Ruiz et al. 2006), which helps to grip the ball in hand. In court players, there is a strong link between handgrip strength and general hand anthropometric measures (Apostolidis and Emmanouil 2015; Zapartidis et al. 2016; Kurtoğlu and Çiftçi 2023). The arm is composed of three segments: the upper arm, forearm, and hand (Forro et al. 2023). Hand anthropometry, which involves measuring hand size and finger lengths, especially index and ring finger length, has been correlated with athletic performance in various sports (Manning and Taylor 2001) and the ability to grip and the span of the hand were effective indicators of performance in volleyball players (Faraji et al. 2014). For instance, larger hands can enhance abilities in handling, passing, catching, and serving the ball, thereby greatly influencing individual skills and team strategies in sports where hand usage is key (Blackwell et al. 1999; Barut et al. 2008). In addition, analyzing hand dimensions can provide important insights into an individual's height, gender, and age (Aboul-Hagag et al. 2011).

In a variety of clinical settings, HGS is commonly evaluated as a gauge of general fitness and upper-limb strength (Nicolay and Walker 2005; Schlüssel et al. 2008). The simplest and most reliable measure of a person's muscular strength level is their HGS (Lee 2021; Nara et al. 2022), and it can serve as a tool for monitoring cognitive status (Kobus et al. 2021). Hand strength is extremely important in sports that require throwing, catching, and striking, making it a critical factor in the performance of court game athletes. Playing with the ball in court sports requires significant isometric hand grip strength to effectively execute their skills (Wiliński et al. 2022; Reza et al. 2023). The length of the hand has been demonstrated to exert a notable impact on hand strength and play a significant role as a reflective parameter of hand function (Hepping et al. 2015; Wichelhaus et al. 2018). Fallahi and Jadidian (2011) indicated that grip sports, such as handball, basketball, volleyball and baseball are associated with grip strength and anthropometric characteristics of their hands, indicating its potential utility in identifying sports talent. HGS and the 2D:4D ratio are negatively correlated (Zhao et al. 2012; Shen et al. 2016; Lu et al. 2017; Kociuba et al. 2019), whereas HGS shows a positive association with hand dimensions (Mahmoud et al. 2020). Therefore, in relation to hand dimensions including finger length, grip strength, with larger hands and fingers contribute to increased hand stiffness.

The 2D:4D ratio, a tentative biological marker, refers to the proportion between the lengths of the index finger (2D) and the ring finger (4D) on the same hand (Kim and Kim 2016; Fusar-Poli et al. 2021). The digit ratio, or the ratio of the lengths of different fingers, especially the 2D and 4D, is hypothesized to indicate prenatal testosterone (PT) levels, potentially influencing physical and athletic prowess (Manning 2002). Testosterone, a steroid hormone, is decisive for developing and maintaining masculine traits in the human body and is influenced by exposure in the mother's womb (Mazur and Booth 1998; Islam and Kundu 2019). Masculine characteristics might correlate with a lower ratio of the index to ring digits (2D:4D) (Islam and Kundu 2020a). The growth of the ring finger is significantly influenced by the level of PT hormone in the fetus. Higher testosterone production results in a longer ring finger, leading to a low digit ratio (LDR) (Tomkinson and Dyer 2017). A low 2D:4D ratio is associated with high PT levels and low prenatal estrogen (PE) hormone levels. Conversely, a high 2D:4D ratio indicates lower PT and higher PE levels, leading to a high digit ratio (HDR) (Manning and Fink 2018). Previous research has indicated that individuals with low 2D:4D ratios tend to exhibit superior athletic and physical performance (Kozieł et al. 2024). The 2D:4D ratio, along with other physical and physiological assessments, can play a key role in identifying young sports talent (Islam 2021). In humans, the right-hand 2D:4D is more responsive to prenatal sex hormones than the left (Manning et al. 1998), with the right-hand ratio correlating more strongly with testosterone levels and sperm count. In addition, mean digit ratios remain fairly consistent throughout one's life (Manning et al. 1998; Manning 2002). Typically, the 4D on a masculine hand (LDR) is about 1 cm longer than the 2D, while in a feminine hand (HDR), the 2D tends to be 1 cm longer than the 4D (Fig. 1.).

(A) (B)

Fig. 1. (A). Masculine hand (LDR), (B). Feminine hand (HDR)

Basketball, handball, and volleyball involve handling a ball on a court, and excelling in these games requires players to use their hands and strength to control the ball. Hand dimensions, including lengths, breadth, span, digit lengths, digit ratio, and grip strength can significantly influence players' performance. A player's hand measurements, digit finger ratios, and hand grip strength might be all considerable factors in player selection for team sports involving ball games, in addition to their level of physical fitness. In addition, lower digit-to-finger ratios are linked to more masculine hands and can be indicators of athletic success. Therefore, researchers have looked at these areas in court sports, particularly basketball, handball, and volleyball, to investigate whether there were differences in hand variables, finger length ratios, and grip strength.

Material and methods

Participants

This study involved a random selection of 135 male court game athletes, split evenly among three sports: basketball, handball, and volleyball, including 45 players in each discipline. The athletes who did not have any hand abnormalities or injuries were selected for the study. The athletes, aged 17 to 24, who had competed at least at the inter-university level in their respective sports, were selected from ten universities located around Bangladesh.

Table 1 shows that basketball players were significantly taller (177.78 cm) and heavier (71.84 kg) compared to volleyball players (174.26 cm, 68.03 kg) and handball players (170.44 cm, 66.41 kg). In addition, compared to handball players, volleyball players were much taller. Despite these differences, their BMIs were quite similar, usually falling within the 22–23 range.

Instruments

Anthropometric measurements of hand and digit length were taken using the Digital Vernier Caliper (Mitutoyo Corporation, Japan), and HGS was measured with the Hand Grip Dynamometer (JAMAR, USA). HI was calculated by multiplying the HL by hundred, divided by the HB, and the 2D:4D ratio was the length of 2D divided by 4D.

Procedures

This study's hand measurements and grip strength data were limited to the right hand only. For hand measurements, all study participants were instructed to place their right hands flat on the table, palms up with fingers extended, except for HB, where the palm downward, fingers together, and thumb stretched out. All measurements of the right hand were taken using a Digital Vernier Caliper. Furthermore, a Hand Grip Dynamometer was used to assess HGS.

Table 1. General anthropometric characteristic of the subjects (mean±SD)

Groups	N	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Basketball	45	22.04±1.21	177.78±6.75	71.84±6.75	22.72±1.65
Handball	45	21.69±1.68	170.44±6.37	66.41±7.87	22.82±1.92
Volleyball	45	21.82±1.85	174.26±7.08	68.03±8.66	22.38±2.35
Sig. level		0.57	0.00	0.00	0.56

Measurements of hand dimensions

HL was gauged from the Mid-stylion (a wrist point) to the Dactylion (middle finger's tip); ensuring fingers were extended but not overstretched, to determine the hand's length from wrist to middle fingertip. HB involved measuring from the second metacarpal's outermost point (index finger base) to the fifth metacarpal's innermost point (little finger base). Palm length (PL) measurement extended from the wrist's farthest central crease to the middle finger's base crease. HS referred to the span between the tips of the thumb and little finger when the hand is perfectly stretched. The 2D and 4D lengths were taken from the basal crease to the fingertip along the medial line of a fully extended hand. All measurements of the hand were recorded using a digital caliper, with the results noted in millimeters (mm).

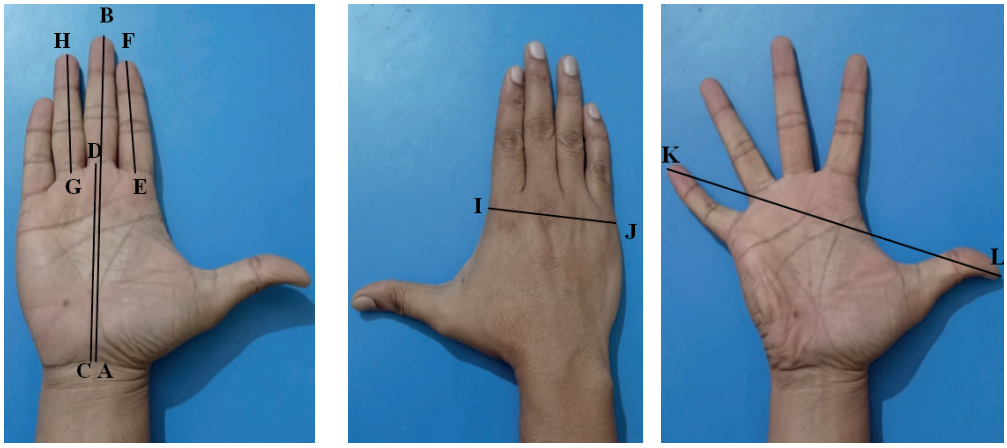

Fig. 2. Hand measuring landmarks: HL (A-B), PL (C-D), 2D (E-F), 4D (G-H), HB (I-J), and HS (K-L)

Hand Index (HI)

The HI was determined by dividing the HB by the HL and then multiplying the resulting score by hundred. The HI scores were compared using the standard HI and five distinct categories: Hyperdolichocheir, Dolichocheir, Mesocheir, Brachycheir, and Hyperbrachycheir, as defined by Martin and Saller (1957). In this study, the mean HI values of 42.50 for basketball, 43.59 for handball, and 43.50 for volleyball players, often fell into the Dolichocheri type. This type is characterized by long fingers and a narrow, small palm.

2D:4D, LDR, and HDR

To calculate the 2D:4D ratio, the length of 2D is divided by 4D. All court players (N=135) were categorized into LDR and HDR groups based on their 2D:4D ratios, using the quartile deviation method. Those with a digit ratio of 0.951 and below (25% and below) were categorized into the LDR group, while those with 0.987 and above (75% and above) were categorized into the HDR group. Analysis of the quartile deviation revealed distinct groups among basketball, handball, and volleyball players. In basketball (N=24), 9 players were in the LDR

and 15 in the HDR group. In handball (N=21), there were 12 LDR and 9 HDR players. Finally, in volleyball (N=26), the distribution was 14 LDR and 12 HDR players.

HGS

The handgrip strength of each subject was assessed using the JAMAR hydraulic hand dynamometer. While taking the measurements study participants sat upright and gripped the dynamometer in a comfortable sitting position while keeping their shoulder and elbow at 0° and 90°, respectively. The maximum HGS was automatically recorded in kilograms (kg) by a peak-hold needle. The average score from the three attempts was used as the final score.

Statistical analysis

Descriptive statistics, an independent t-test, and a one-way ANOVA were employed to compare variables used in this study. Levene's test showed equal variances, indicating a normal distribution of data. All statistical procedures were conducted using the IBM's SPSS version 22 for Windows (George and Mallery 2019). Results were considered significant at the $p<0.05$ level (two-sided).

Results

Table 2 indicates that there were no significant differences between the hand variables, namely HL ($F = 1.38$, $p = 0.26$); HB ($F = 0.36$, $p = 0.70$); PL ($F = 0.07$, $p = 0.93$); HS ($F = 0.17$, $p = 0.85$); 2D ($F = 0.94$, $p = 0.39$); 4D ($F = 0.51$, $p = 0.60$); 2D:4D ($F = 0.89$, $p = 0.42$; LDR ($F = 0.65$, $p = 0.53$); HDR ($F = 0.53$, $p = 0.59$); and HGS ($F = 0.50$, $p = 0.61$). However, a significant difference was noted among the groups for the variable HI ($F = 3.31$, $p = 0.047$). The result shows that there were no significant differences in various hand measurements and handgrip strength among the groups, except for the HI variable, where a significant difference was found.

Table 2. Comparison of hand dimensions, finger length ratios, and grip strength among court sports athletes

Variables	Groups	N	Mean	Std. Deviation	F-value	p level
HL (mm)	Basketball	45	193.29	8.76	1.38	n.s.
	Handball	45	190.38	10.28		
	Volleyball	45	190.10	11.12		
HB (mm)	Basketball	45	82.08	4.81	0.36	n.s.
	Handball	45	82.93	5.20		
	Volleyball	45	82.54	4.21		
HI (mm)	Basketball	45	42.50	2.37	3.13	<0.05
	Handball	45	43.59	2.14		
	Volleyball	45	43.50	2.38		
PL (mm)	Basketball	45	109.80	5.06	0.07	n.s.
	Handball	45	109.62	6.21		
	Volleyball	45	109.35	6.31		
HS (mm)	Basketball	45	215.81	11.28	0.17	n.s.
	Handball	45	214.67	12.92		
	Volleyball	45	216.06	12.23		

Variables	Groups	N	Mean	Std. Deviation	F-value	p level
2D (mm)	Basketball	45	75.45	4.08	0.94	n.s.
	Handball	45	74.26	4.59		
	Volleyball	45	74.33	5.14		
4D (mm)	Basketball	45	77.50	4.22	0.51	n.s.
	Handball	45	76.88	5.04		
	Volleyball	45	76.50	5.02		
2D:4D	Basketball	45	0.974	0.02	0.89	n.s.
	Handball	45	0.967	0.03		
	Volleyball	45	0.972	0.03		
LDR	Basketball	09	0.940	0.02	0.65	n.s.
	Handball	12	0.934	0.02		
	Volleyball	14	0.940	0.01		
HDR	Basketball	15	1.000	0.01	0.53	n.s.
	Handball	09	1.003	0.01		
	Volleyball	12	1.006	0.02		
HGS (kg)	Basketball	45	48.40	8.12	0.50	n.s.
	Handball	45	49.42	7.22		
	Volleyball	45	47.89	6.74		

The LSD post-hoc test (Fig. 3) showed that there was a statistically significant difference in the HI between basketball and handball and between basketball and volleyball; however, no significant difference was found between handball and volleyball.

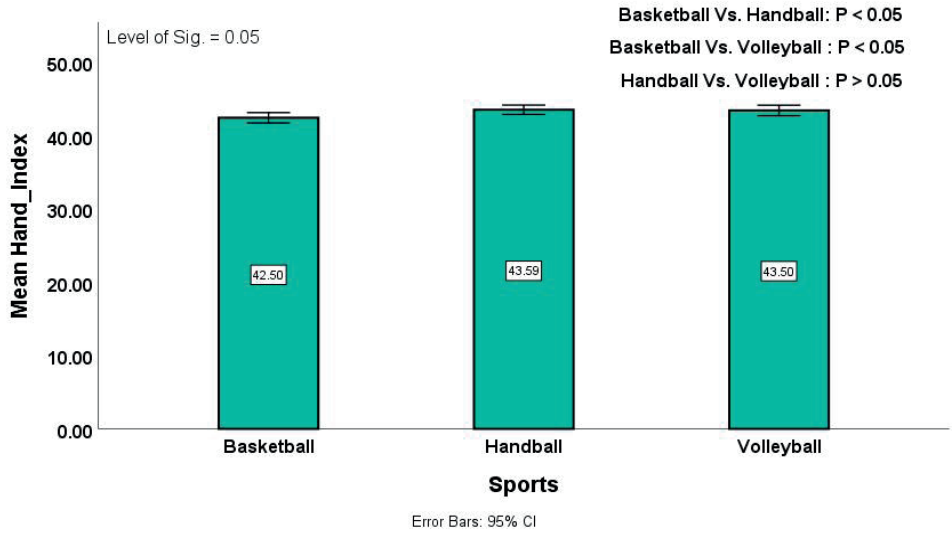

Fig. 3. The difference in the mean value of HI between the three groups

Table 3. HI and HGS between the LDR and HDR (2D:4D)

Groups	Variables	Digit Ratio	N	Mean	Std. Dev.	t	df	p (2-tailed)
Basketball	HI	LDR	9	43.37	1.57	2.36	22	<0.05
		HDR	15	41.45	2.41			
	HGS	LDR	9	49.74	6.96	0.16	22	n.s.
		HDR	15	49.11	11.90			
Handball	HI	LDR	12	43.47	2.12	0.09	19	n.s.
		HDR	9	43.55	1.60			
	HGS	LDR	12	50.47	5.12	1.51	16	n.s.
		HDR	9	46.70	6.01			
Volleyball	HI	LDR	14	44.29	3.25	2.10	22	<0.05
		HDR	12	42.09	2.03			
	HGS	LDR	14	48.26	3.67	0.07	19	n.s.
		HDR	12	48.39	5.37			

Discussion

The findings in Table 2 suggest that there was not a notable variation in hand measurements and handgrip strength across the groups, except for the HI variable, which exhibited a significant difference. Our study involved court sports players using a cross-sectional design. Findings indicated no notable variations in the width, length, and palm length of the right hand, as well as grip strength. However, significant statistical differences were observed in the hand index values among male basketball, volleyball, and handball athletes (Barut 2008). Basketball players had greater values in right hand length and span compared to volleyball players; however, no significant differences were observed between the two groups (Gaurav et al. 2015). Athletes from different sports, including handball, basketball, and football, exhibit similar levels of hand grip strength (Karakoç et al. 2015). The grip strength of ball game athletes was found to be almost identical (Rahman and Sharma 2023). The grip strength of the dominant hand in males exhibited a tendency to be influenced by hand shape, although the impact was not statistically significant (Bardo et al. 2021). 2D:4D ratios in right hands were compared among non-athletes, volleyball, and soccer players, showing no significant differences (Tomaszewska and Lubońska 2022). Koziel et al. (2016), reported significant differences in mean 2D:4D values among the three distinct male sporting groups on the right hand. The study identified a significant difference in the right 2D:4D ratio between the three groups tested (Kociuba et al. 2022). The present study HI shows that basketball players exhibit differences between handball and volleyball players. In addition, the mean values of court players often fall within the Dolichocheri type, characterized by long fingers and a narrow, short palm. A cross-sectional study of 100 university students, aged 17–26, found that the most common hand index was like that (Sarkodie et al. 2023). The average index for the right hand was 42.83 mm (Cha-

nana and Bandapalle 2022), 43.08 mm (Dey and Kapoor 2017), showing that the hand morphology of male individuals is predominantly categorized as Dolichocheir type (Chia and Anyanwu 2020).

Table 3 revealed significant differences in HI between basketball and volleyball players, while for HGS, no significant differences were found between low and high digit ratios across sports, with the 2D:4D ratio (Table 2) nearly identical in basketball (0.974), handball (0.967), and volleyball (0.972). Ball players with a lower digit ratio have better anthropometric measurements of body composition compared to those exhibiting a higher digit ratio, although the difference is not significant (Islam 2020). Participants in team sports such as soccer (0.965), volleyball (0.969), basketball (0.972), and handball (0.978) generally had higher digit ratios, with the 2D:4D being nearly the same (Malik and Singh 2014). Among ball players, the right-hand 2D:4D ratio showed no significant difference between opposition and cooperative ball players (Ramos et al. 2022). The digit ratio of 108 participants was classified into high (0.973 and above, top 25%, n=28) and low (0.942 and below, bottom 25%, n=28) groups based on quartile deviation (Islam and Kundu 2020b). A low digit ratio is associated with improved endurance and handgrip strength (Ranson et al. 2015; Koziel et al. 2017).

In summary, anthropometric hand measurements, including size, shape, and length, play a crucial role in the strength and precision of hand movements, thereby significantly influencing performance in court games. Because basketball, handball, and volleyball games involve handling a ball, hand anthropometry and grip strength are paramount. Consequently, no notable differences in hand length, digit length, or grip strength were observed among players in the three court games in the present study. This finding aligns with the results reported by numerous previous researchers.

The limitation of the study is that hand measurements and grip strength data were only taken from the right hand. However, expanding the variety of court sports and increasing the sample size both contribute to achieving more accurate results and improved precision by including more measurements. Further research is needed to determine the extent to which these variables relate to performance.

Conclusions

In summary, all court sports athletes were found to exhibit similar hand dimensions, 2D:4D, and HGS, except for the HI. According to HI, basketball players differ between handball and volleyball, and all HI's were characterized by long fingers and a narrow, short palm. The 4D was significantly higher than the 2D, and the LDR exhibited higher HI values in basketball and volleyball. Regarding HGS, no significant differences were found between low and high digit ratios across sports. Court athletes were similar in hand features and grip strength for the nature of play.

Acknowledgment

The authors express their gratitude to all participants who contributed to the study.

Conflicts of interests

The authors declare no conflicts of interest.

Authors' contribution

MHR – conceived the idea of the study, collected and analyzed the data, prepared the tables and figures, drafted the manuscript, and revised and finalized the manuscript. JPS – planned and supervised the research, set the goals, provided substantive supervision, and finalized the manuscript.

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