



Original article

The influence of ethnic differences based on upper limb anthropometry on grip and pinch strength

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ABSTRACT

Background: Ethnic differences in upper limb anthropometry have significant variations which can influence surgical outcomes and rehabilitation. We hypothesize that there would be a significant difference in the anthropometry based on ethnicity and gender which will reflect on objective measurements.

Methods: We performed 13 anthropometric measurements of the upper limb, grip and three types of pinch strength in 210 volunteers across seven ethnicities in young adults at our university campus. We compared them statistically based on ethnic and gender differences.

Results: There was a significant correlation noted between grip, palmar and tip to tip pinch strength in 12 of the 13 anthropometric measurements. Key pinch correlated with eight parameters. Mean grip and pinch strength are noted to be more in males and from developed nations across all ethnicities.

Conclusions: This study shows that there is significant variation between the anthropometric measurements based on gender and ethnicity which correlates with differences in grip and pinch strength.

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1. Introduction

The hand represents the most sophisticated and differentiated musculoskeletal tool in the human being, demanding the largest capacity of the nervous system. Full function and adequate strength of the hand are preconditions for dealing with the demands of daily life. Many countries have been making great efforts to establish an anthropometric database for different population groups such as civilians, military personnel, students, and workers. The anthropometric measurements exhibit ethnic variations in different populations and are also affected by genetic and environmental factors, nutrition, sex, age, and physical activity.¹ Ethnicity and race are closely related, but the concept of ethnicity differs from the closely related term race in that 'race' refers to grouping based mostly upon criteria that in the past have been presumed to be biological. At the same time, 'ethnicity' also encompasses additional cultural factors.^{2,3} Ethnicity refers to a group of people whose members have an identity through a common heritage, language, and culture.³ There can be different ethnicities in each race, which are different in their geographical, cultural, nutritional, and

economic properties. Hence there have also been remarkable changes in anthropometric dimensions due to the above properties along with genetic and environmental factors.^{4–6}

Although numerous publications provide normative data for grip strength and key pinch strength, it would be helpful to predict the expected hand strength values for an individual based on easily measured factors and amongst different ethnicities. There is a paucity of reference values for upper limb anthropometry measurements and handgrip and pinch grip strength for different ethnic populations following standardized guidelines such as those recommended by the American Society of Hand Therapists.^{4–6} In South Asia, four studies on grip strength show limitations in terms of acceptable sample size, focus on a specific population, and deviation from standard protocol or type of dynamometer.^{7–10} At our institution, we have a unique opportunity in having students of various ethnicities who study or visit for electives postings. Thus, this study was undertaken to evaluate the hypothesis that hand anthropometry varies among young adults based on gender and various ethnicities, which correlates with their grip and pinch strength.

2. Methods

The institutional ethics committee approved the prospective study involving 210 students, which included 30 students from

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each ethnic community with equal gender distribution in the age group of 18–35 years. We excluded subjects who were outside the normal range for body mass index (range - 18.5–25) and with hand deformity of any etiology interfering with their ability to perform the handgrip and pinch strength. Each participant gave written consent to participate in the study following the guidelines of the Declaration of Helsinki. The ethnicities chosen were Indians, Malaysians, Chinese, Dutch, Africans, Iranians and Polish. The participants were briefed on the aims and objectives of developing a database consisting of anthropometric measurements of the upper limb and its correlation with hand grip and pinch strength. Those who agreed to participate were requested to fill a participant information sheet and a proforma containing their demographic data followed by measurements of anthropometric data, grip and pinch strength. Participants were assembled in a group of 10–20 and briefed about the procedure. Measurements of the participant's dominant upper limb were done in 10–15 min under standard protocols. A non-elastic measuring tape, JAMAR Hydraulic hand dynamometer and Hydraulic pinch gauge, Model no. 081028950, S/N:1510472 (J A Preston Corporation, New York, USA) were used following the American Society of Hand Therapists (ASHT) guidelines.² We evaluated 13 anthropometric measurements for which a standard protocol for measurement was designed along with a similar design for comparison with grip and three types of pinch strengths. Ethnic differences in anthropometry, as well as grip, key, palmar and tip to tip pinch strength, were calculated. Inter and Intra ethnic gender differences were also studied. We tabulated the maximum and minimum values across ethnicities to prepare reference values.

The comparison of various anthropometric measurements with grip strength and pinch strength was made using the analysis of variance (ANOVA) test followed by Bonferroni post hoc analysis to correlate interethnic differences. Comparison between genders within each ethnicity was made by unpaired t-test with values of $p < 0.05$ being considered significant. Intra and inter-observer comparisons were done using intraclass correlation which showed no statistical difference between the two measurements. Correlation between anthropometric measurements with grip and pinch strength was established using Carl Pearson correlation coefficient with p-value < 0.05 considered as significant and p-value < 0.01 as highly significant.

3. Results

The overall anthropometric measurements have been tabulated with maximum and minimum values across all ethnicities in Table 1. A total of 210 subjects (105 males and females each) volunteered with a mean age of 18–35 years. None of them had a background of any heavy professional sports or labour intensive work. 30 volunteers each from the seven ethnic communities were selected with 15 men and women each being evaluated. Our study gives the normative data of 13 upper limb measurements in seven ethnicities.

The comparison of various anthropometric measurements with grip strength and pinch strength which was made using analysis of variance (ANOVA) test followed by Bonferroni post hoc analysis to correlate interethnic differences shows good correlation for all the 13 parameters (Table 2).

There were marked differences observed among the various ethnic groups when the evaluation was done concerning the anthropometric values, grip and the three types of pinch strengths ($p = 0.000$) (Tables 1 and 2). These differences were maintained concerning gender as well with higher values being recorded for men. Overall grip strength was maximum in Dutch males and Malay females. Overall tip to tip, key and palmar pinch were maximum in Iranian, Dutch and Polish men respectively and Chinese, Iranian and Indian ladies respectively (Table 1).

Correlation between anthropometric measurements with grip and pinch strength was established using the Carl Pearson correlation coefficient. Out of the 13 anthropometric measurements, 12 parameters correlated with grip strength except for arm circumference which showed no correlation ($p = 0.295$) (Table 3). The palmar and tip to tip pinch strength positively correlated with 12 each which also included a weak negative correlation with arm circumference (r -value = -0.283) and forearm circumference (r value = -0.327) respectively. The key pinch strength positively correlated with eight anthropometric measurements but failed with forearm length and circumference, five finger span, digit 4 and 5 lengths respectively (Table 3).

Intraobserver and interobserver comparisons between genders within each ethnicity were done using the intraclass correlation coefficient showed no statistical difference between the two measurements.

Table 1
Overall maximum and minimum measurements across ethnicities.

Measurement	Maximum		Minimum	
	Male	Female	Male	Female
Arm length	Polish 40.5 cm	Malay 36.8 cm	Indian 27.9 cm	Malay 24.6 cm
Forearm length	Indian 31.3 cm	Malay 27.6 cm	Indian 20.7 cm	Malay 18.4 cm
Arm circumference	Chinese 34.0 cm	Iranian 31 cm	Indian 22.5	Iranian 24.0 cm
Forearm circumference	Dutch 25.8 cm	Indian 22.9 cm	Dutch 19.8 cm	Iranian 18.22 cm
Wrist circumference	Polish 17.4 cm	Chinese 16.2 cm	Polish 14.9 cm	Iranian 13.7 cm
Hand length	African 20.9 cm	Malay 18.6 cm	Iranian 16 cm	Malay 13.0 cm
Hand circumference	African 21.7 cm	Malay 20.6 cm	Polish 16.8 cm	Malay 12.8 cm
Maximum five finger span	Polish 22.2 cm	Malay 21.3 cm	Iranian 17.7 cm	Malay 16.2 cm
Digit one length	Iranian 8 cm	African 6.9 cm	Polish 6.4 cm	Indian 6.2 cm
Digit two length	Polish 8.5 cm	Malay 7.6 cm	Polish 6.5 cm	Malay 6.6 cm
Digit three length	Polish 10.4 cm	Iranian 9 cm	African 8.5 cm	Chinese 7.9 cm
Digit four length	Polish 10 cm	Malay 8.3 cm	African 6.5 cm	Malay 6.3 cm
Digit five length	Iranian 8.8 cm	Malay 7.3 cm	Polish 5.8 cm	Malay 5.4 cm
Grip strength	Dutch 50.0 kg	Malay 33.9 kg	Indian 38.3 kg	African 24.4 kg
Tip to tip strength	Iranian 11.4 kg	Chinese 10.1 kg	Iranian 7.4 kg	African 4.6 kg
Key pinch strength	Dutch 16.9 kg	Iranian 12.2 kg	Polish 8.2 kg	Chinese 7.5 kg
Palmar pinch strength	Polish 18.4 kg	Chinese 15.27 kg	Indian 10.4 kg	Chinese 7.5 kg

Table 2
Showing the mean values for the seven ethnic groups in total (including both men and women).

Ethnicity	Mean															
	Grip strength - kg	Tip to tip pinch - kg	Key pinch - kg	Palmar pinch - kg	Arm length - cm	Forearm length - cm	Forearm circ. - cm	Wrist circ. - cm	Hand length - cm	Hand circ. - cm	5 finger span - cm	Digit 1 length - cm	Digit 2 length - cm	Digit 3 length - cm	Digit 4 length - cm	Digit 5 length - cm
African	34.0	6.8	8.9	11.9	35.0	28.0	22.5	15.5	19.5	19.6	18.7	6.4	7.8	8.9	8.4	6.4
Iranian	40.0	10.8	8.4	9.1	30.8	27.4	22.6	14.9	19.5	18.9	21.3	7.2	7.2	8.4	8.5	7.3
Chinese	32.0	6.5	9.0	8.2	26.9	20.4	23.6	14.8	18.3	18.1	17.2	6.8	7.2	8.5	7.4	6.3
Dutch	38.0	6.4	14.0	10.0	32.7	21.9	24.3	15.8	18.4	19.5	16.9	6.7	7.3	8.5	7.7	6.1
Polish	40.0	8.8	12.6	14.8	37.4	28.7	20.0	16.8	19.1	21.1	20.8	7.3	8.0	9.5	8.9	7.7
Indian	38.0	7.3	11.6	16.4	38.4	29.5	19.0	16.0	18.1	19.4	18.2	6.6	7.6	8.6	7.7	5.8
Malays	36.0	8.2	11.3	9.8	26.0	19.5	20.3	14.9	14.5	14.8	16.2	7.0	6.5	8.8	6.4	5.6
Anova P-	.000															
value																

^a Circ. Circumference.

4. Discussion

Ethnic differences in anthropometric data have been observed for years. In our study, eight upper limb anthropometric measurements of young adults have been compiled in a single study which has not been done previously although each measurement has been done individually in different studies. Yap et al. found that upper body segment lengths differ significantly among adult Chinese, Malays and Indians in descending order.¹ Khadem and Islam conducted a comprehensive anthropometric study of Bangladeshi men and found significant differences between the body dimensions in comparison to similar samples of Portuguese, Dutch, Indians, Sri Lankan and Singapore men.¹¹ Furthermore, anthropometric differences are not only found among different countries, but also different ethnicities within countries. Davies et al. compared hand dimensions between Blacks, Indians and Caucasians residing in West Indies and concluded that Blacks had larger hand dimensions compared to both Caucasians and Indians who incidentally had similar measurements.¹² Courtney concluded that Hong Kong Chinese ladies had overall smaller hands than British and Americans but larger than the Japanese population in their.¹³ The anthropometric data of young adults (aged 18–35years) from seven ethnic communities are compiled into a unique database through this study. We have also observed significant differences in the anthropometric measurements between different ethnicities as seen in our results (Tables 1 and 2).

The upper limb anthropometric dimensions are larger for men in all ethnicities when compared to women as seen in our study and correlate with other studies.^{14,15} Our findings suggest larger anthropometric dimensions within a range of 10–15% for men which is similar as shown by other workers) indicating that gender influences the variation in anthropometric dimensions which was studied in young adults compared to older studies in the elderly population.^{16,17} In a comparison of our study to those in certain ethnic groups, it was seen that overall differences in the measurements were significant in many ethnic groups such as an Indian male had the maximum forearm length of 31.3 cm and females had a maximum forearm circumference of 22.9 cm when compared to Malay males of 27.6 cm and Iranian females of 18.22 cm who had the minimum forearm length and forearm circumference respectively. The previous study done in Iranian young adults show a mean arm length of 34.9 cm, forearm length of 20.6 cm, hand circumference of 16.6 cm and hand length of 18.3 cm.¹⁸ This was comparatively different (30.8 cm, 27.4 cm, 18.3 cm and 19.5 cm respectively) in our study. Their study was done only in the 15–18yrs age group and standard anthropometric reference points were not used which incidentally was done in our study. Considering that there are differences in anthropometric data in different decades, updating the database is crucial. Hand length when compared to previous studies had similar average measurements as in our study.^{19–22} Anthropometric measurements like arm circumference, forearm circumference and five finger span in ladies could not be compared across different ethnicities with other studies due to lack of available data and standard measuring techniques which can be taken from our study for future references.

Reference values are essential if informed decisions are to be made about the normality of an individual's status relative to the population. Such values are particularly important when it comes to handgrip dynamometry. It includes grip and pinch strength which is not only used to describe the status of the hand but also to characterize overall upper extremity strength. Measurement of handgrip strength is commonly performed to measure baseline deficiency in hand muscle power, monitor progress during rehabilitation, and document outcomes after rehabilitation. The handgrip and pinch grip strength have long been used as a surrogate

Table 3
Showing the Pearson's correlation values for each of the 13 variables of anthropometric measurements in comparison to the grip and three types of pinch strength.

	Pearson Correlation matrix	Arm length	Forearm length	Arm circ.	Forearm circ.	Wrist circ.	Hand length	Hand circ.	5 Finger span	Digit 1 length	Digit 2 length	Digit 3 length	Digit 4 length	Digit 5 length
Grip strength	r value	.439 ^(a)	.450 ^(a)	.078	.301 ^(a)	.588 ^(a)	.650 ^(a)	.630 ^(a)	.516 ^(a)	.644 ^(a)	.433 ^(a)	.514 ^(a)	.594 ^(a)	.413 ^(a)
	p	.000	.000	.295	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Tip to tip pinch	r value	.230 ^(a)	.525 ^(a)	-.283 ^(b)	.140	.314 ^(a)	.623 ^(a)	.482 ^(a)	.793 ^(a)	.539 ^(a)	.279 ^(a)	.268 ^(a)	.541 ^(a)	.583 ^(a)
	p	.002	.000	.000	.061	.000	.000	.000	.000	.000	.000	.000	.000	.000
Palmar pinch	r value	.862 ^(a)	.706 ^(a)	.375 ^(a)	-.327 ^(b)	.563 ^(a)	.236 ^(a)	.519 ^(a)	.344 ^(a)	.214 ^(a)	.571 ^(a)	.503 ^(a)	.424 ^(a)	.137
	p	.000	.000	.000	.000	.000	.001	.000	.000	.004	.000	.000	.000	.068
Key pinch	r value	.489 ^(a)	.118	.318 ^(a)	.162 ^(b)	.571 ^(a)	.276 ^(a)	.589 ^(a)	.063	.348 ^(a)	.350 ^(a)	.393 ^(a)	.165 ^(b)	.053
	p	.000	.114	.000	.030	.000	.000	.000	.398	.000	.000	.000	.027	.481

^a Correlation is significant at the 0.001 level (2- tailed).

^b Correlation is significant at 0.005 level (2-tailed).

measure of total body strength. Poor grip has been shown in several studies to predict functional limitations and disability.^{19–22} Reliable and valid evaluation of hand strength is of importance in determining the effectiveness of different treatment strategies or effects of different procedures. The handgrip and pinch grip strength can also be used in the clinical setting, such as rehabilitation, to determine the extent of an injury or disease process and the potential for and the progress of the individual in rehabilitation. Grip and pinch strength measurements provide an objective index of the functional integrity of the upper extremity. In addition to its predictive value grip strength and key pinch, strength is considered to be “objective” outcome parameters and are used to quantify outcome after orthopedic interventions.^{19–22} Nicolay et al. studied the relation of hand anthropometric measurements to grip strength in participants aged 18–33 years along with effects of gender and hand dominance and concluded that forearm length, circumference and hand measurements correlated strongly with maximum grip strength, except finger length, which produced a significant but weakly positive correlation but this study used electric apparatus to measure grip strength compared to the standard Jamar dynamometer in our study.¹⁹ Koley et al. did an Indian study for changes in grip strength in the age group of 6–25 yrs which was done with a digital dynamometer in standing position with elbow extension resulting in mean grip strength of 29.70 kg and 19.13 kg in males and females in that age group.⁹ In regards to hand dominance, it was concluded that after prolonged periods of work the initial differences in strength between the dominant and non-dominant hand lessens. Günther et al. studied grip strength in healthy Caucasian adults and concluded that hand dominance showed only a partial positive correlation or no correlation with grip strength whereas hand size, forearm length and circumference, did show a direct correlation with grip strength.²⁰ Mean strength was more in men than in women. Interestingly our study showed no or a weak negative correlation with forearm circumference for the pinch strength values although the correlation was seen for grip strength. The handgrip and pinch strength data of young adults were collected in this study based on the dominant hand. It is found that the mean handgrip strength of young adult males and females is 47 and 31 kg, respectively. A similar result was obtained by Mathiowetz et al., who showed that the handgrip strength of young men and ladies was 46.2 kg and 30.3 kg respectively.²¹ Hence, it can be deduced that the handgrip strength of young adults is within 30 kg and 50 kg for both genders. The results obtained in this study agree well with those of the previous study which revealed that the people in developed countries like Dutch and Malay have higher hand grip and pinch strength compared to those in developing countries in Africa and South Asia.

Our limitations are that we could not compare the grip and pinch strength measurements to many of the previous studies as they were done with different methodology and age groups.

Nevertheless, it did show that the average grip and pinch strength were comparatively similar in some ethnicities like Iranians, Malays although being different in Africans, Chinese, and Indians.^{1,7,9,13–15,19} Ethnicities like Polish and Dutch did not have normative data for young adults to compare and the same has been presented for future reference in our study. The limited sample size prevented us from a more rigorous statistical evaluation with wider parameters like Body Mass Index which would have helped in the evaluation of weaker correlation of some of the anthropometric measures with pinch strength values.

Our observation suggests a significant correlation of the anthropometric measurements influenced by ethnicity and gender which can have a measurable bearing on the evaluation of grip and pinch strength values.

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Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Manipal Academy of Higher Education (Date: 15-11-2017/No.706/2017).

Informed Consent

Informed consent was taken from all the participants who took part in the study.

Declaration of competing interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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