Indian J Med Res 117, June 2003, pp 260-269

Hand anthropometry of Indian women

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Received October 12, 2001

***Background & objectives*: Data on the physical dimension of the hand of Indian women are scanty. This information is necessary to ascertain human-machine compatibility in the design of manual systems for the bare and gloved hand, such as design and sizing of hand tools, controls, knobs and other applications in different kinds of precision and power grips. The present study was undertaken to generate hand anthropometric data of 95 women, working in informal industries (beedi, agarbatti and garment making).**

***Methods*: Fifty one hand measurements of the right hand (lengths, breadths, circumferences, depths, spreads and clearances of hand and fingers) were taken, using anthropometric sliding and spreading calipers, measuring tape and handgrip strength dynamometer. The data were statistically analyzed to determine the normality of data and the percentile values of different hand dimensions, and simple and multiple regression analysis were done to determine better predictors of hand length and grip strength.**

***Results*: The hand breadths, circumferences and depths were approximately normally distributed, with some deviation in case of the finger lengths. Hand length was significantly correlated with the fist, wrist and finger circumferences. The fist and wrist circumferences, in combination, were better predictors of hand length. The hand lengths, breadths and depths, including finger joints of the Indian women studied were smaller than those of American, British and West Indian women. The hand circumferences of the Indian women were also smaller than the American women. Grip strengths of Indian women (20.36±3.24 kg) were less than those of American, British and West Indian women. Grip strength was found to be statistically significant with hand dimensions, such as hand height perpendicular to wrist crease (digit 5), proximal interphalangeal joint breadth (digit 3) and hand spread across wedge 1.**

***Interpretation & conclusion*: The women who are forced to frequently use cutters, strippers and other tools, which are not optimally designed to their hand dimensions and strength range, might have higher prevalence of clinical symptoms and disorders of the hand. In view of the human hand-tool interface requirements, the present data on Indian women would be useful for ergo-design applications of hand tools and devices.**

Key words Grip strength - hand and finger dimensions (length, breadth, depth, spread) - power and precision grip

The assessment of the physical dimensions of the human hand provides a metric description to ascertain human-machine compatibility[1,2] in the design of manual systems for the bare and gloved hand (*e.g.*, design of hand tools, knobs and controls, personal equipment, consumer appliances in the home and industry). Primarily adapted for reaching, grasping and manipulating, the hand functions include activities, such as pushing, adjusting objects, striking blows, and supporting the body in space.

The hand may be used as a fist, or forces may be transmitted through the fingers extended in close-packed positions. Prehensile movements of the hand have been variously described as cylinder, ball, ring, pliers and pincer grips[3] and all such grips are the variants of precision and power grips[4].

The dimensional and anatomical features of the human hand and the factors such as the size, shape, texture of object being held, *etc*., influence the functional aspects of hand uses[5-8]. The occupational disorders associated with the improper use and cumulative exertion of the wrist and hand, include osteoarthritis, dislocations or subluxations, synovitis, ligament strains and ganglia[9,10], tenosynovitis[11,12], trigger finger, intrinsic muscle strains[13] and carpal tunnel syndrome[14,15]. Generally these are referred to together as repetitive or cumulative trauma disorders (CTD) since they occur in people performing repetitive handwork. Ergonomics consideration in the design of tools and appliances, in accordance with the dimensions of the human hand, may alleviate hand disorders in the user group[16,17]. Disorders of the upper extremity are more common in women than in men[18-20]. Case studies show that women reported more symptoms of musculoskeletal disorders in the neck, thoracic back, wrists and hands than men though they performed the same types of task[21]. This may partly be attributed to the premise that women use hand tools and devices which have been primarily designed for men using the dimensions of men's hand. Data on the hand dimensions of women are scanty. The present study was therefore undertaken to generate basic hand anthropometric data (static and dynamic) of women, with reference to a sample working population from small enterprises. The measurements have been compared with the hand dimensions of women of other countries.

Material & Methods

To obtain data of hand dimensions, the women working in informal industries (*beedi* making, garment manufacturing, *agarbatti* making) in a locality at the outskirts of Ahmedabad city were selected during 1998-1999. A total of 95 women (93% of the total women workers of the locality) participated in the study. They belonged to the same ethnic group and all were right handed. None of them were apparently suffering from any disease or health impairment. The anthropometric measurements were taken in a small room adjacent to the industry premises. Fifty one hand dimensions of the right hand included lengths, breadths, circumferences, depths, spreads and clearances of hand and fingers (Fig. 1a, b, c). The instruments used for measurements were the anthropometric sliding and spreading calipers (UNA, New Delhi), measuring tape and handgrip strength dynamometer (Holtain, USA).

As regard the measurement landmark and positioning of the hand, it has been noted that the dimensions of a straight, flat hand are significantly longer than those of the relaxed hand[7]. In the relaxed hand there is a likely unconscious tendency to curl the hand. Comparing the anatomical landmarks of the stylion, wrist crease and proximal edge of the navicular bone of the wrist, Garrett[7] indicated that wrist crease is the best landmark for easy identification of hand measurement. Accordingly, the present measurements were taken with the hand straight and flat (unsupported), and the wrist crease as the base-line, excepting in dimensions 12, 21 to 22, 24 to 25, 32, 37 to 40 and 45 to 47 in Fig. 1.

The sample size was decided under the assumption that the tolerable error in the estimation of the mean is around 5 per cent of all the hand dimensions under study. The data were statistically analyzed by a software package, SPSS for Windows, to determine the normality of data and the percentile values of the hand dimensions. The stem-and-leaf plots and the Lilliefors test, based on a modification of the Kolmogorov-Smirnov test[22] examined the test of normality distribution of data. These tests indicated that the hand breadths, circumferences, depths and spreads were approximately normally distributed, with some deviation in case of the finger lengths. The simple and multiple regression analyses were done between hand length and other dimensions in order to find out the best set of predictors related to hand length.

Results & Discussion

The age range, body stature (height), body weight, body mass index (BMI) and arm length of the women are given in Table I. The body stature, body weight and arm length of these women were comparable to those of other Indian women sample groups[23]. The 5th percentile value of the BMI was 14.6 and the 50th percentile value was 19.9. The BMI ranged between 14 and 31.6, with over 70 per cent having BMI greater than 18.

Tables II to V present the data on hand lengths, breadths, circumferences and depths respectively,

Table I. Physical characteristics and arm length of women

	Mean±SD	Median	Range	Percentile		
				5th	50th	95th
Age (yr)	32.3±10.1	32.0	16.0-58.0	17	32	50
Body weight (kg)	45.3±8.5	43.9	29.5-69.4	33.9	43.9	64.0
Height (cm): Body stature	149.88±6.28	149.5	132.4-167.7	135.6	149.5	159.9
Body mass index (BMI)	20.2±3.73	19.9	14.0-31.6	14.6	19.9	28.0
Arm length (cm) n=95	68.55±4.20	69.1	53.9-79.0	60.8	69.1	75.3

Table II. Hand lengths of women

	Sr. no.		Mean±SD	Median	Range	Percentile		
						5th	50th	95th
Hand length (cm)	1	Wrist crease	16.96±0.94	17.0	13.5-19.0	15.4	17.0	18.4
Height: Perpendicular to wrist crease (cm)	2	Digit 1	8.21±1.12	8.1	6.2-11.2	6.5	8.1	10.4
	3	Digit 2	15.62±0.96	15.5	12.3-18.1	14.0	15.5	17.3
	4	Digit 3	16.94±0.91	16.9	14.1-19.6	15.5	17.0	18.4
	5	Digit 4	15.37±0.90	15.4	12.1-17.4	13.9	15.4	16.9
	6	Digit 5	11.39±1.20	11.5	6.5-15.7	9.8	11.5	13.0
Length: Finger to crotch level (cm)	7	Digit 1	6.41±0.63	6.5	4.4-7.4	5.3	6.6	7.2
	8	Digit 2	6.92±0.55	7.0	5.0-7.9	5.9	7.0	7.7
	9	Digit 3	7.60±0.57	7.6	5.7-8.8	6.6	7.6	8.4
	10	Digit 4	7.02±0.54	7.0	5.2-8.0	6.1	7.0	7.8
	11	Digit 5	5.63±0.54	5.7	3.9-6.6	4.6	5.7	6.4
Hand length: thumb-forefinger (cm)	12		9.35±0.79	9.3	7.1-11.1	8.0	9.3	10.6

Sr. no. of hand dimensions corresponds to the illustrations given in Figure 1.
n=95

Table III. Hand breadths of women

Breadths (cm)	Sr. no.	Mean±SD	Median	Range	Percentile		
					5th	50th	95th
Hand breadth - metacarpal	13	6.8±0.51	6.8	4.7-8.0	6.0	6.8	7.6
Interphalangeal joint: Digit 1	14	1.47±0.21	1.5	1.0-2.4	1.1	1.5	1.8
Distal interphalangeal joint : Digit 2	15	1.04±0.16	1.1	0.6-1.4	0.7	1.1	1.2
Proximal interphalangeal joint: Digit 2	16	1.3±0.17	1.3	0.8-1.7	1.0	1.3	1.5
Distal interphalangeal joint: Digit 3	17	1.04±0.15	1.1	0.6-1.5	0.8	1.1	1.2
Proximal interphalangeal joint: Digit 3	18	1.33±0.15	1.3	0.75-1.7	1.0	1.3	1.6
Wrist breadth	19	4.61±0.48	4.5	3.6-6.2	4.1	4.5	6.0
Hand breadth - metacarpal (minimum)	20	6.42±0.71	6.3	4.7-9.6	5.4	6.3	7.1
Grip breadth (inside)	21	4.43±0.56	4.5	3.1-6.0	3.5	4.5	5.2
Grip breadth (outside)	22	8.35±0.67	8.4	6.3-9.6	6.9	8.4	9.4

Sr. no. of hand dimensions corresponds to the illustrations given in Figure 1.
n=95

Table IV. Hand circumferences of women

Circumference (cm)	Sr. no.	Mean±SD	Median	Range	Percentile		
					5th	50th	95th
Metacarpal	23	17.23±1.06	17.5	13.8-19.5	15.0	17.5	18.6
Fingertips even	24	18.25±2.16	18.0	10.5-23.5	15.3	18.0	22.5
Fist	25	23.51±1.23	23.5	20.3-26.7	21.5	23.5	25.5
Wrist	26	14.36±0.69	14.3	12.7-16.3	13.2	14.3	15.5
Interphalangeal joint: Digit 1	27	6.06±0.30	6.0	5.2-7.0	5.6	6.0	6.5
Distal interphalangeal joint : Digit 2	28	4.80±0.42	4.8	3.3-7.3	4.2	4.8	5.1
Proximal interphalangeal joint : Digit 2	29	5.70±0.31	5.7	4.8-6.5	5.2	5.7	6.2
Distal interphalangeal joint Digit : 3	30	4.91±0.25	4.9	4.2-5.7	4.5	4.9	5.4
Proximal interphalangeal joint : Digit 3	31	5.92±0.36	5.9	5.2-7.8	5.3	5.9	6.4
Hand circumference thumb-forefinger	32	22.53±1.62	22.5	19-29.7	20.0	22.5	25.0
Hand circumference metacarpal (minimum)	33	18.86±1.02	19.0	15.7-21.6	17.3	19.0	21.0

Sr. no. of hand dimensions corresponds to the illustrations given in Figure 1.
n=95

Table V. Hand depths of women

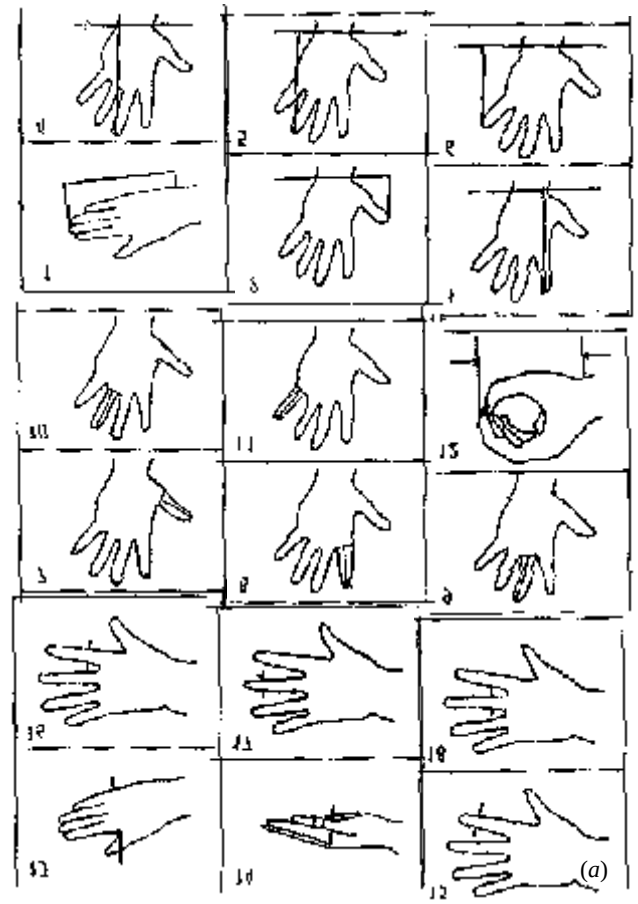
Depth (cm)	Sr. no.	Mean ±SD	Median	Range	Percentile 5th	Percentile 50th	Percentile 95th
Hand depth: Metacarpal 3	34	2.22 ±0.24	2.2	1.6-2.8	1.8	2.2	2.6
Hand depth: Thenar Pad	35	3.42 ±0.52	3.4	1.7-4.8	2.6	3.4	4.4
Interphalangeal joint depth: Digit 1	36	1.15 ±0.16	1.2	0.7-1.5	0.9	1.2	1.4
Interphalangeal joint depth Digit 2	37	0.78 ±0.15	0.8	0.4-1.5	0.6	0.8	1.0
Proximal interphalangeal joint depth: Digit 2	38	1.13 ±0.15	1.1	0.7-1.7	0.9	1.1	1.4
Distal interphalangeal joint depth: Digit 3	39	0.79 ± 0.13	0.8	0.5-1.1	0.6	0.8	1.0
Proximal interphalangeal joint depth : Digit 3	40	1.19 ±0.13	1.2	0.8-1.5	1.0	1.2	1.4

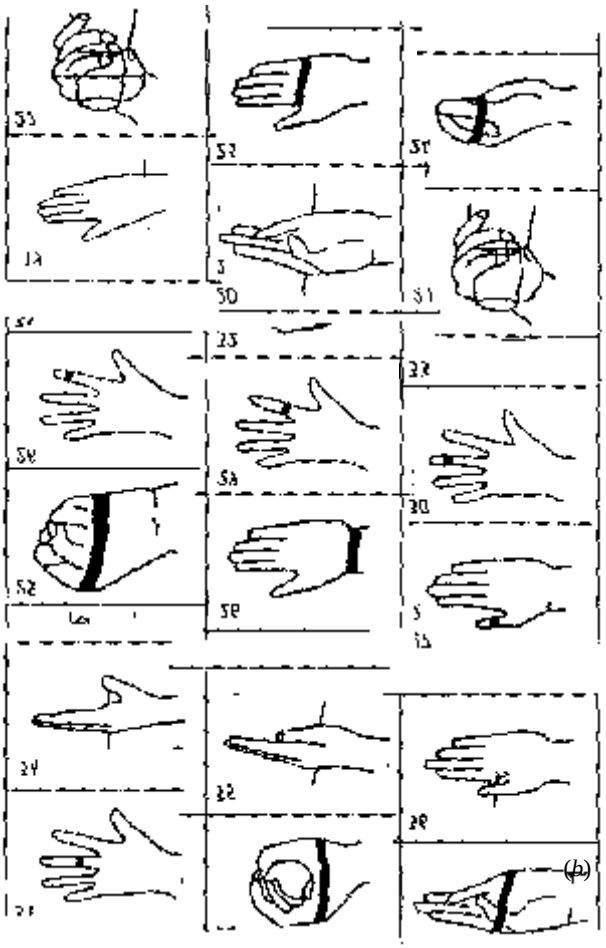
Sr. no. of hand dimensions corresponds to the illustrations given in Figure 1.
n=95

corresponding to the illustrations given in the Figure. Data on hand spreads and clearances are given in Table VI. Damon *et al*[24] noted that for grips and knobs, thumb-forefinger overlap is better than a wider grip separating the two. For whole-hand grasping, the fingers should be placed around the main shaft and the heel of the hand used to close the movable part. Also, force application can be better for small knob controls that match to the thumb and forefinger dimension. However, no comparative data of the hand dimensions of Indians (both men and women) are available. With the limitation of the small sample size in the present study, the hand dimensions of the Indian women studied were compared with other groups of American[7], British[5] and West Indian[6] women (Table VII). The sample sizes in the British[5] and West Indian[6] groups were 51 and 20 respectively, and for the American[6] group the size of the sample was not available. The average hand lengths, breadths and depths, including finger joints of the Indian women were smaller than those of American, British and West Indian women. The hand circumferences (dimensions 23 to 26) of the present women were also smaller than those of the American[7] women.

The correlations, and simple and multiple linear regression analysis between hand length and other hand dimensions were undertaken and the statistically significant correlation coefficients are given in Table VIII. The values of the correlation coefficients >0.200 are significant at 5 per cent level and the values >0.267 are significant at 1 per cent level, indicating that the hand length was significantly correlated with the fist, wrist and finger circumferences. Metacarpal circumference (No. 23) showed highest correlation coefficient (r=0.549, $P<0.01$) with hand length. The smaller lengths and circumferences indicated smaller size of the hand. The multiple regression equations showed that the fist and wrist circumferences, in combination, were better predictors (r= 407; $P<0.01$) of hand length.

It is important to note that the functionality of a tool handle or a grasping object depends on the hand dimensions. A grasping object that requires an





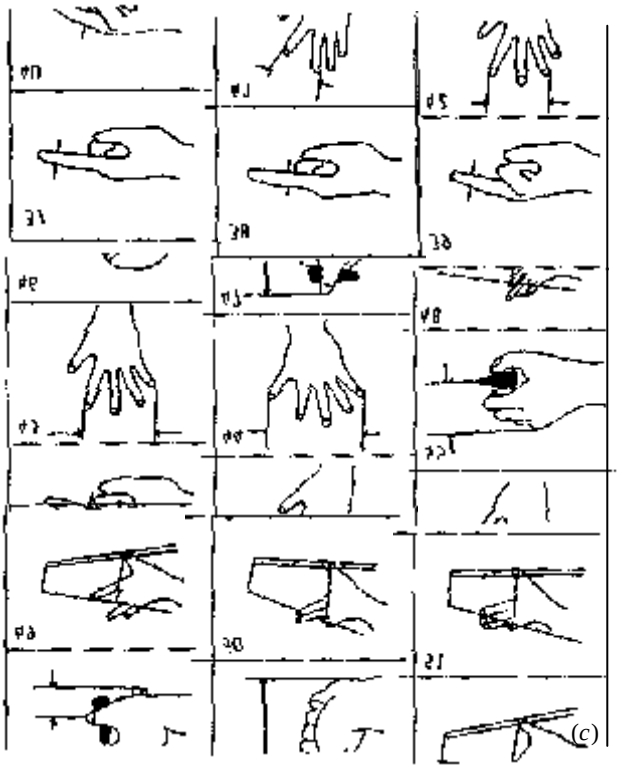


Fig.1a, b, c. Selected hand dimensions of women.

Table VI. Hand spreads and clearances of women

Spread/clearance (cm)	Sr. no.	Mean ±SD	Median	Range	Percentile		
					5th	50th	95th
Finger tip spread: Digit 2-3	41	8.54 ±1.46	8.6	5.1-12.0	5.9	8.6	10.7
Finger tip spread: Digit 2-4	42	10.58 ± 1.26	10.5	6.3-13.3	8.9	10.4	13.0
Finger tip spread: Digit 2-5	43	13.74 ± 1.36	13.8	10.1-17.0	11.2	13.8	16.3
Hand spread maximum	44	17.26 ± 1.46	17.3	13.4-20.2	15.0	17.3	19.3
Hand clearance: around knob	45	6.89 ±0.92	7.1	4.0-8.8	5.2	7.1	8.0
Hand clearance: palmar	46	2.41 ±0.47	2.4	1.5-4.5	1.6	2.4	3.2
Hand clearance: supinated hand	47	10.4 ± 1.07	10.6	7.6-12.8	8.4	10.6	11.9
Hand spread across wedge 1	48	10.78 ± 0.87	11.2	8.5-12.5	9.4	11.2	12.5
Hand spread across wedge 2	49	12.53 ± 0.96	13.0	10.2-14.4	10.5	13.0	14.0
Hand spread across wedge 3	50	12.92 ±0.91	13.0	10.8-14.5	11.2	13.0	14.4
Hand spread across wedge 4	51	12.69 ± 0.95	13.0	9.7-14.4	11.1	13.0	14.0
Grip strength (kg), supinated		20.36 ±3.24	20.0	12.5-30.0	15.0	20.0	25.0

Sr. no. of hand dimensions corresponds to the illustrations given in Figure l.

n=95

excessive wrist pronation/supination or widely spread fingers is less efficient and more fatiguing than the one, which conforms to neutral positions[25,26]. The hand position influences how much muscle force must be exerted[27,28] to hold an object. Biomechanical analysis suggests that the primary line of transmission of force is along the middle finger, through a large central carpal bone and along the radius to the humerus. Forces through the other fingers and thumb are also transmitted to the radius. With the excessive deviation of the wrist, or excessive spreading of the fingers, the lines of transmission of force are distorted. For example, excessive ulnar and radial deviations of the wrist are associated with tenosynovitis at the base of the thumb or De Quervains disease[29].

Table VII. Comparison of selected hand dimensions

Population	Sr.no.	Present study	American[7]	British[5]	West Indian[6]
Sample size		95	-	5.1	20
Hand length	1	16.96	17.90	17.43	18.4
Digit 2 length: Finger tip to crotch level	8	6.92	6.91	7.83	-
Digit 3 length: Finger tip to crotch level	9	7.60	7.80	7.70	8.01
Digit 4 length: Finger tip to crotch level	10	7.02	7.32	8.62	-
Digit 5 length: Finger tip to crotch level	11	5.63	5.46	5.67	5.71
Hand breadth - metacarpal	13	6.80	7.70	7.72	7.97
Distal interphalangeal joint breadth - Digit 3	17	1.04	1.52	1.49	1.61
Proximal interphalangeal joint breadth - Digit 3	18	1.33	1.83	1.75	1.84
Wrist breadth	19	4.61	5.82	5.16	-
Hand depth - metacarpal 3	34	2.22	2.77	2.57	2.79
Hand depth - Thenar pad	35	3.42	5.16	3.94	4.45
Distal interphalangeal joint depth - Digit 3	39	0.79	1.32	1.24	1.35
Proximal interphalangeal joint depth - Digit 3	40	1.19	1.68	1.66	1.78
Grip strength (kg)		20.36	-	27.9	33.4

Superscript numbers represent reference numbers

Table VIII. Simple and multiple regression analysis between selected hand measurements of women

Dependent variables	Simple and Multiple Regression equations (Dimention no.)	Correlation coefficient (r)
Hand length (cm)	2.15 × Proximal interphalangeal joint breadth, Digit 3 (18) + 14.09	0.342**
	0.49 × Metacarpal circumference (23) + 8.52	0.549**
	0.11 × Fingertips even circumference (24) + 14.91	0.258*
	0.27 × Fist circumference (25) +10.66	0.351**
	0.50 × Wrist circumference (26) +9.82	0.363**
	0.55 × Distal interphalangeal joint circumference, Digit 2 (28) + 14.34	0.242*
	1.38 × Distal interphalangeal joint circumference, Digit 3 (30) +10.18	0.360**
	1.45 × Proximal interphalangeal joint depth, Digit 3 (40) + 15.24	0.202*
	0.2 × Fist circumference (25) + 0.34 × Wrist circumference (26) + 8.2	0.407**
	0.1 × Hand spread, max (44) + 0.5 × Hand clearance palmer (46) + 8.4	0.394**
	0.9 × Hand depth, metacarpal 3 (34) - 0.1 × Hand circumference, thumb-forefinger (32) + 16.4	0.226*
Grip strength (kg)	26.79 - 0.57 × Hand height, perpendicular to wrist crease, Digit 5 (6)	- 0.202*
	5.24 × Proximal interphalangeal Joint breadth, Digit 3 (18) + 13.34	0.240*
	0.91 × Hand spread across wedge 1 (48) + 10.51	0.241*

n= 95; *P** <0.05, **<0.01

The handgrip strengths of the present women were much less (20.36±3.24 kg) than those of the American[7], British[5] and West Indian[6] women. Grip strength was found to be significantly correlated with three hand dimensions (6, 18, 48) (Table VIII). The women who are forced to frequently use cutters, strippers and other tools, which are not optimally designed for the female strength range, might have a higher prevalence of clinical symptoms and disorders of the hand. In a study of 1400 women with US air force, Ducharme[30] observed that soldering tools, pliers and wire strippers caused frequent complaints in women workers, due to dimensional incompatibility and improper usage of tools. In view of the human hand-tool interface requirements, the present data on Indian women may be useful for ergo-design application of hand tools and devices.

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