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Anthropometry of Kerala female agricultural workers and design of hand tools of the region

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ABSTRACT : Women in rural India play a major role in shaping the country's economy through their active participation in agriculture. For proper design of farm equipment for women workers, it is necessary to collect anthropometric data on farm women. But not much of information is available regarding their anthropometric data. Therefore, a study was undertaken to collect anthropometric data from 120 female farm workers engaged in agriculture field activities in the age group of 19 to 65 years from Kerala, southern part of India. The mean, standard deviation, standard error of mean, coefficient of variation, relative accuracy and percentile values (5^{th}, 50^{th} and 95^{th}) of each measurement were tabulated. The means of the female measurements were compared with those obtained for the agricultural workers from other parts of the country. South Indian female workers are shorter and heavier than female workers of western and north eastern part of India. The data as obtained are intended to be used for the design/design modifications of agricultural hand tools/implements/ machinery with a view to reduce drudgery and at the same time increase efficiency, safety and comfort of operators. An attempt was also made to illustrate the relevance of these data in the design of handle of hand tools from ergonomic considerations.

KEY WORDS : Farm women, Ergonomics, Anthropometric data, Hand tools, Safety

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Kerala is located on the south-western region of India. Nowadays, agriculture in this region is modernizing very rapidly. More and more hand tools, implements and machines imported from other countries and from other regions of India are being used for various agricultural operations. This might causes improper matching between the users and designer, resulting in an inadvertent neglect of ergonomic principles in the design. This, in turn, is likely to reduce efficiency of operation and cause problems of safety and discomfort of the operator. Hence, efforts would be made to standardize these implement and to improve their design, incorporating ergonomic principles, which are expected to enhance the work output and worker's efficiency, keeping in view the operators' comfort and welfare. A thorough understanding on the various body dimensions of the expected users of these implements is a pre-requisite for the successful formulation of any such project.

The number of anthropometric surveys carried out in the country is small and the dimensions included were specific to the Indian male agricultural workers (Gite and Yadav,1989; Fernandez and Uppugonduri,1992 ;Yadav *et al.*,1997 and Dewangan *et al.*, 2008). As far as the Indian female workers are concerned available information suggests that steps have been initiated only in the recent past (Yadav *et al.*, 2000, Dewangan *et al.*, 2008). In both studies they conducted anthropometric survey of the western and north eastern (NE) regions of India. To achieve better efficiency of performance, more human comfort and to reduce musculoskeletal injury, it is necessary to design the hand tools and equipment keeping in consideration the operator's capabilities and limitations. Presently no reports are available regarding the anthropometric data of female labourers in south western region of India. This study aims, therefore, to provide female anthropometric data which can be used in design or redesign, descriptions, comparisons, and evaluation purposes. In order to illustrate the use of anthropometric data, design of hand tool is presented.

METHODOLOGY

Subjects:

The number of subjects was estimated according to the equation provided in Annex A of ISO 15535(2003) "General requirements for establishing anthropometric databases" for a 95% confidence interval for the 5th and 95th percentiles by Eqn(1)

$$n \geq = \left(3.006 \, x \, \frac{CV}{\alpha}\right)^2 \qquad (1)$$

where n is sample size, CV is the coefficient of variation, and *á* is the percentage of relative accuracy desired. In this survey, 7% relative accuracy is desired for the 5^{th} and 95^{th} percentiles and an empirical value of CV=25 is used to pre-determine the sample size. The result is 115 subjects.

The present survey was carried out in the Kerala area, south-western region of India. A preliminary survey was conducted among women agricultural labourers engaged in agriculture field activities in the region. A sample of 120 female labourers was randomly chosen from both private and government farm. The subjects were in the age group of 19 to 65 years.

Body dimensions :

Twenty eight different body dimensions that were considered important to the dimensions and positions of the functional components of implements/ tools used in various agriculture field activities have been recorded by following standard anthropometric procedure. Standard terminologies as given in the Anthropometric Source Book (NASA, 1978) have been used in the study. Due attention has been given to ISO 7250 (1996) and the recommendations of the conference on standardization of anthropometric techniques and terminologies.

Equipment :

Body dimensions were taken with a standard Anthropometer designed and developed by Indian Institute of Technology, Kharagpur, West Bengal, India. Anthropometer was calibrated periodically before use and sensitivity of the anthropometric instrument was within the recommended limit of ISO 15535 (2003). Hand and foot measurements were taken using vernier caliper with least count of 0.1 mm. A digital hand grip dynamometer (Model Baseline-12-0240)) of 100 kg capacity and a readability of 1 kg was used to take the handgrip strength. Internal grip diameter was measured using a wooden cone specially made for the purpose. In addition, a portable weighing scale (0–125 kg) was used to take the body weight.

Procedures :

The subjects were briefed about the survey beforehand demonstrating the measurement procedure, in order to ensure their full cooperation. All the dimensions were measured in a correct posture and in a precise manner. In addition, all the measurements were taken in the mornings between 7 and 12 a.m. The subjects were asked to stand on the platform of the anthropometer, its arm was adjusted according to her height and measurement was recorded from the vertical scale. The data recorded for the subjects were taken to be the mean of three readings. Measuring postures were maintained throughout the whole survey as natural as possible. To achieve a greater scientific uniformity, measurements were always carried out on the right-hand side of the subjects. To remove interobserver reliability problems, only women investigator associated with the project collected the data. Finally, descriptive statistics, including means and key percentiles used in anthropometric design, were calculated.

RESULTS AND DISCUSSION

Different statistical methods can be used in anthropometric studies. The choice of the statistical method depends to a great extent upon the nature of data and the purpose of which they are collected and presented. Table 1 shows the estimates of the range, mean, standard deviation (SD), standard error of mean (SEM), coefficient of variation (CV), relative accuracy (α) and percentile values (5^{th}, 50^{th} and 95^{th}) of anthropometric dimensions. The relative high standard deviation, in general, showed the diversity in body dimensions of the subjects. Slight variations were there between mean value and 50^{th} percentile value. For design purposes, either one of the boundary values (5^{th} or 95^{th} percentile) or the mean value was used depending upon the dimensional element.

As concerns SEM results, it can be seen that hip height, shoulder height, grip strength, eye height, stature, functional leg length, body weight and waist girth had the highest SEM values ranging 0.50–0.99 which are rather high. However, SEM of the other body dimensions are generally small (0.03-0.42). These results indicate that the spread among the mean values of hip height, shoulder height, grip strength, eye height, stature, functional leg length, body weight and waist girth is greater than the other dimensions. Therefore, the design or redesign of equipment where these dimensions are to be used should be carefully made, as generalization from the sample to the population may be difficult. However, a larger sample has to be studied, if correct judgments are to be made. As to the CV% results, it can be seen that most CVs were far lower than we had assumed (25%). However, the highest values are associated with grip strength (36%) and weight (19%). These values highly exceeded the values of all other dimensions which are generally small. In order to reduce CV% values, one has to increase the mean values or decrease the SD which could be done by adding new observations to the sample. The relative accuracy was estimated according to Eqn. (2)

$$\alpha = \frac{CV}{\sqrt{n}} \times 3.006 \qquad (2)$$

For female subjects, the relative accuracy ranged from 1.253% (stature) to 9.861% (grip strength) with a mean of 2.332%. It is widely agreed that the use of 5th, 50th or 95th percentile values is more logical in design situations. However, whether to choose the 5th, 50th or 95th percentile value is a decision, to be taken by the designer depending on his/her requirements. It is desirable to use body dimensions of 95th percentile users to establish minimum equipment dimensions involving clearances so that the smaller user group will not be adversely affected.

The mean values of 20 dimensions of the present survey and earlier surveys within the country are given in Table 2. From Table 2, it can also be seen that women workers from western (Yadav *et al.*, 2000) and north eastern (NE) regions of India (Dewangan *et al.* ,2008) are taller and lighter than from the present study. However, a large survey is desirable before drawing a conclusion in this regard.

Typical design implications :

Agricultural equipments and implements are usually designed to match the physical requirements and capacities of men and the women may have greater difficulties in operating these machines and their risk of injuries to health is enhanced. If the women have right tools for work in the fields, the work efficiency and health would be better. Particular attention should be given to the needs of the women while designing the equipment to ensure better health and safety in use of these tools. The new designs of tools should be women friendly and gender compatible, easy to maintain and safe to use.

A given work situation demands a particular body posture for efficient operation and maximum work output.

Table 1 : Analysis of anthropometric dimensions of women labourers (Unit: cm unless otherwise specified)

Sr. No.	Measurement	Range	Mean	SD	SEM	CV	Relative accuracy (α) %	Percentile 5th	Percentile 50th	Percentile 95th
1.	Body weight, kg	35 - 85	54.68	10.45	0.954	19.111	5.246	38.95	55.00	70.63
2.	Stature	136.5 - 173	150.92	6.89	0.629	4.565	1.253	140.00	150.00	162.00
3.	Eye Height	126.2 - 161.5	140.37	6.68	0.610	4.759	1.306	131.29	140.05	151.53
4.	Shoulder height	112.3 - 142.1	125.71	5.91	0.540	4.701	1.291	116.36	125.30	135.22
5.	Elbow height	84.3 - 110.4	96.33	4.59	0.419	4.765	1.308	89.49	95.40	104.53
6.	Hip height	76.1 - 100.2	87.02	5.48	0.500	6.297	1.729	78.48	82.30	87.50
7.	Knuckle height	51.5 - 70.3	60.42	4.29	0.392	7.100	1.949	53.98	60.50	68.20
8.	Knee height	36.2 - 52.1	42.59	3.02	0.276	7.091	1.946	38.79	42.25	49.01
9.	Shoulder grip length	54 - 73	61.83	3.45	0.315	5.580	1.532	57.00	62.00	68.00
10.	Elbow grip length	29 - 42	33.81	1.95	0.178	5.768	1.583	30.95	34.00	36.05
11.	Forward arm reach	64 - 82	72.76	3.52	0.321	4.838	1.328	66.95	73.00	79.00
12.	Grip diameter (inside)	3.8 – 5.7	4.90	0.33	0.030	6.735	1.849	4.50	4.80	5.40
13.	Grip strength, kg	2.01 - 30.9	16.62	5.97	0.545	35.921	9.861	7.69	16.75	25.87
14.	Circumference at wrist	13 - 19	15.55	0.88	0.080	5.659	1.554	14.00	15.50	17.00
15.	Circumference at elbow	19 - 29	23.48	1.85	0.169	7.879	2.163	21.00	23.00	26.53
16.	Hip breadth	30 - 50	41.92	3.60	0.329	8.588	2.358	36.00	42.00	48.00
17.	Shoulder breadth	35 - 48	39.99	3.07	0.280	7.677	2.107	36.00	40.00	46.00
18.	Shoulder elbow length	30 - 45	36.62	2.87	0.262	7.837	2.151	31.00	37.00	41.00
19.	Waist girth	39 - 120	96.43	10.93	0.998	11.335	3.112	81.95	97.00	110.20
20.	Buttocks to knee	40 - 60	51.23	3.33	0.304	6.500	1.784	45.95	51.00	56.00
21.	Hand breadth at metacarpal	4.4 - 6.9	5.77	0.58	0.053	10.052	2.759	4.90	5.90	6.60
22.	Hand breadth across thumb	6.3 - 10.3	7.78	0.78	0.071	10.026	2.752	6.60	7.60	9.00
23.	Hand length	13.6 - 17.1	15.31	0.81	0.074	5.291	1.452	14.00	15.40	16.90
24.	Palm length	6.3 - 9.2	7.96	0.58	0.053	7.268	1.995	7.00	8.00	8.91
25.	Foot length	21 - 25.6	23.01	1.23	0.112	5.346	1.468	21.00	23.00	25.40
26.	Foot breadth	6.8 - 10.5	8.53	0.67	0.061	7.855	2.156	8.10	8.50	9.90
27.	Functional leg length	81 - 105	90.03	9.34	0.853	10.374	2.848	81.00	90.00	100.10
28.	Knuckle to elbow height	24 - 47	36.20	3.24	0.296	8.950	2.457	31.77	36.30	41.20

SD ,standard deviation; SEM, standard error of mean, CV, coefficient of variation

Table 2 : Comparison of mean values of some dimensions from earlier surveys within the country with those of present survey

Sr. No:	Body dimension	Yadav *et al.* (2000)	Dewangan *et al.* (2008)	Present study
1.	Body Weight, Kg	49.5	48.01	54.68
2.	Stature	154.6	153.25	150.92
3.	Eye height	145.3	141.76	140.37
4.	Shoulder height	127.5	127.09	125.71
5.	Elbow height	97.3	96.18	96.33
6.	Knuckle height	64.5	66.38	60.42
7.	Knee height	46.5	41.21	42.59
8.	Shoulder grip length	66.7	66.64	61.83
9.	Elbow grip length	38.5	32.83	33.81
10.	Forward arm reach	76.4	73.12	72.76
11.	Grip diameter (Inside)	3.8	4.35	4.90
12.	Grip strength, kg	24.3	5.93	16.62
13.	Hip breadth	36.4	31.12	41.92
14.	Shoulder breadth	40.5	33.49	39.99
15.	Functional leg length	91.8	90.02	90.03
16.	Waist girth	88.3	75.48	96.43
17.	Buttocks to knee	50.4	50.51	51.23
18.	Hand breadth across thumb	7.8	8.78	7.78
19.	Hand length	16.5	16.53	15.31
20.	Foot length	25.6	22.7	23.01

Unit: cm unless otherwise specified

Poor working postures could lead to postural stress, fatigue and pain, which may in turn force the worker to stop work until the muscles recover. Typical examples of such work situations could be those of involved in paddy production system *viz*., transplanting, weeding and harvesting. In these operations the workers (usually female in most of the developing countries) have to bend over work surfaces for targets which are too low. It may be suggested that pain rather than capacity may often be the limiting factor in such task situations. In view of this the posture assumed in a task is solely depended on the size and dimensions of the device or the equipment being used for performing the task. As a result, a good equipment or machine design will have a great bearing on the anthropometry of the worker.

For manually operated implements, the handle is one of the most important components with which the operator controls and guides the implement properly during field operations. The elbow height (standing) data are helpful for designing proper handle height. Elbow height (standing) for the 5th percentile female Indians is 96.33 cm in the present study. In rice cultivation rotary weeder is commonly used by the female labourers in study region. It works by the push pull action and the weeds were uprooted and buried in the field itself. The handle of the weeder should be designed such that during operation the operator stands erect as far as possible to reduce musculoskeletal discomfort (Dewangan *et al.*, 2008). Grandjean, 1988 suggested that the elbow flexion angle should be in the range of 85–110° for maximum work efficiency. An angle in the range of 50–60° has been suggested between ground and handle (Pradhan, *et al*., 1987). Taking the elbow flexion value of 100^0, inclination of weeder handle with the horizontal as 55^0 and 5th and 95th percentile values of elbow height as 89.49 and 104.53 cm, respectively, and elbow grip length for 5th and 95th percentile population as 30.95 and 36.05 cm, respectively, the optimum length of the handle can be found out from the geometry adopted by the operator (Dewangan *et al.* ,2008). The optimum length of the handle for the population under study ranged 102.73–120.00 cm. Hence, the existing handle of the weeder was modified as telescopic handle. This illustration amply shows that use of anthropometric data can be very helpful in the design of farm equipment.

Conclusion :

Anthropometric data from 120 female farm workers engaged in agriculture field activities in the age group of 19 to 65 years from Kerala, southern part of India were selected as subjects. The pertinent anthropometric dimensions of women labourers were identified. Twenty eight different body dimensions with reference to the dimensions and positions of the functional components of implements/ tools used in various agriculture field activities have been recorded by following standard anthropometric procedure. The results indicate that the spread among the mean values of hip height, shoulder height, grip strength, eye height, stature, functional leg length, body weight and waist girth is greater than the other dimensions. It can also be seen that women workers from western and north eastern (NE) part of India are taller and lighter than from the south part of India. The equipment will have to be designed keeping in view the anthropometric data of women workers in consideration. It will help to make the equipment women friendly and safe for operation.

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