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# Anthropometry of male agricultural workers of western India for the design of tools and equipments

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ABSTRACT

Agricultural workers and farmers in India perform most of the agricultural operations manually. Hence, for the design of farm equipments, hand tools and machinery involving human efforts, region specific anthropometric data is needed. A survey was conducted to collect anthropometric dimensions of male agricultural workers in the state of Maharashtra in India in the age group of 18–60 years. Almost 59 body dimensions were selected for the measurement from the recommendations by All India Coordinated Research Project (AICRP) on Human Engineering and Safety in Agriculture (HESA) and requisite by digital human manikin modeling. Total 303 male agricultural workers were selected from 23 districts of Maharashtra by convenience sampling. Repeatability of the measurements was checked by paired samples t test. From the measured dimensions, the values of minimum, maximum, mean, standard deviation (SD), standard error of mean (SEM), coefficient of variation (CV), 5th and 95th percentile values were determined. The results of the survey were compared with results of other regions of India and other countries.

*Relevance to industry:* The anthropometric data of user population is very utile for the design/improvement of farm equipments/implements for agricultural workers in order to reduce drudgery, increase efficiency, safety and comfort.



## 1. Introduction

Maharashtra is the second largest state in India both in population and geographical area. Agriculture continues to be the main occupation of the state in spite of high industrialization. Agriculture and allied activities use about 65% of the total workers in the state. 12.9% of the state's income and 9% of the country agricultural income is contributed by the agriculture and allied activities sector. Maharashtra is the major producer of Jowar and Arhar yielding 46.09 and 29.11%, respectively to the total yield of India. It is the second largest producer of Cotton (22.21%), Soybean (28.14%) in the country (Aparajit, 2013). The farm workers play an important role in the cultivation of above crops and due attention needs to be given to their capabilities and limitations during design and operation of various farm equipments so as to get higher productivity, enhanced comfort and better safety (Grandjean, 1988; Yadav et al., 2010). Manually operated equipments are extensively used in Indian agriculture for various farm operations starting from seedbed preparation to post-harvest operations. Western countries have created huge databases for anthropometric design reference (Thompson, 1972; NASA, 1978; Syed, 1993). Anthropometric data bank by Aerospace Medical Research Laboratories, Dayton, Ohio (USA) is the largest single repository of raw anthropometric data in the world. ERGODATA is another data bank located at Anthropology Laboratory of Paris University of France. However, such exhaustive data of Indian (Asian) population is not available (Yadav et al., 2010).

The efforts are being made to collect anthropometric data in India by few researchers but still there is paucity of data for many of the regions including Maharashtra (Yadav et al., 1997; Philip and Tewari, 2000; Victor et al., 2002; Tewari et al., 2007; Dewangan et al., 2005, 2008; Gite and Majumder, 2009; Yadav et al., 2010; Agrawal et al., 2010; Dewangan et al., 2010; Agrawal et al., 2011).

A little work is observed for Maharashtra (Vyavahare and Kallurkar, 2012). Aware and Powar (2008) collected 79 body dimensions and 16 strength parameters from 649 male and 377 female agricultural workers. But his work is limited to only Konkan

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region of Maharashtra. Khogare and Borkar (2011) collected anthropometric dimensions of 2500 male agricultural workers. Again his work is limited to five districts in Vidharbh region of Maharashtra state and collected data for only 19 body dimensions including age and body weight. Thus in this paper attempt is made to present anthropometric data of Maharashtra state male agricultural workers.

## 2. Methods

### 2.1. Subjects

The survey was carried out to collect anthropometric data of agricultural workers from the state of Maharashtra in India. The convenience sampling method was used to select subjects. The subjects were selected from almost all the districts of Maharashtra rather than by mere convenience so as to ensure unbiasedness. Table 1 depicts the details of subject selection from different districts of Maharashtra for the present study.

Data was collected from 303 male agricultural workers of 18–60 years age group from 23 districts of Maharashtra. Most of the data was collected at Pandharpur (Solapur district), a place of lord Vitthal, where pilgrims especially from rural parts of entire Maharashtra come to take blessings. During the pilgrimage period, places in Pandharpur such as river bed, various grounds and public places where pilgrims stay during pilgrimage were selected for the data collection. Measurements were taken in a tent or a room to ensure the privacy of the subjects. Before collection of data, subjects were given information about the survey, their role in the study and consent form that they are required to sign.

### 2.2. Body dimensions

Fifty-nine body dimensions, including body weight were included in the study from the previous studies (Dewangan et al., 2008) and digital human modeling requirements mentioned in Catia Human Measurements Editor user's guide. The standard terminologies as suggested in the Anthropometric Source Book (NASA, 1978), Dewangan et al. (2008) and CATIA V5 R17 software are used here.

### 2.3. Equipments used

Body dimensions are measured with a variety of commercially available and specially prepared equipments/instruments. A digital portable weighing scale (range: 0–150 kg, least count: 100 gm) to measure body mass, a sliding caliper (0–20 cm, 1 mm) and segmometer (0–100 cm, 1 mm) to measure hand and foot dimensions, fiber reinforced non-stretchable anthropometric tape (0–150 cm, 1 mm) and girth measurer (Baseline make, 0–150, 1 mm) to measure body circumferences, anthropometer (Galaxy make, 0–210 cm, 1 mm) to measure most of the body dimensions like, height, length, width and depth etc., a specially prepared wooden cone and plywood triangular plate to measure grip diameters and hand grip span respectively are used.

In addition to the above instruments, an anthropometric box of $50 \times 30 \times 40$ cm height is used as a reference for measuring some dimensions in sitting posture and a specially prepared platform with facility of level adjustment with spirit level is used as reference for measuring the dimensions with reference to floor.

**Table 1**
Details of subject selection from different districts of Maharashtra for the study.

| Sl. no. | District | No. of subjects | Sl. no. | District | No. of subjects |
|---|---|---|---|---|---|
| 1 | Ahmednagar | 27 | 13 | Parbhani | 21 |
| 2 | Aurangabad | 3 | 14 | Pune | 36 |
| 3 | Beed | 16 | 15 | Raigad | 2 |
| 4 | Buldhana | 3 | 16 | Ratnagiri | 4 |
| 5 | Hingoli | 5 | 17 | Sangli | 17 |
| 6 | Jalgaon | 2 | 18 | Satara | 14 |
| 7 | Jalna | 8 | 19 | Solapur | 25 |
| 8 | Kolhapur | 24 | 20 | Thane | 11 |
| 9 | Latur | 22 | 21 | Wardha | 2 |
| 10 | Nanded | 21 | 22 | Washim | 3 |
| 11 | Nashik | 8 | 23 | Yavatmal | 1 |
| 12 | Osmanabad | 28 | | | |

### 2.4. Procedure

Before taking in-field measurements, four people were initially given training so as to familiarise them with the equipments to be used, locate the body landmarks accurately and take accurate measurements. After training they were asked to take trial readings on some subjects and repeatability and accuracy in the measurement was checked. Reproduction accuracy was assessed by measuring all the anthropometric dimensions twice for 5 subjects with an interval of 2 h. These measurements were analyzed using paired-sample t-test with SPSS 20 software. Results of paired-sample t-test for 5 subjects showed that there were no significant differences ($p$ value $> 0.05$) in the dimensions between the two measurements taken at different times.

The subjects with normal health and physically sound were selected for the study. Subjects with abnormal body dimensions like dwarf or giants, musculoskeletal injury were not included in this survey. Subjects were asked to be in light cloths, empty pockets and bare footed while taking measurements to minimize errors. The subjects were asked to stand with feet closed and body erected for taking stature measurement. The subjects were told to stand on a flat surface leveled by spirit level with feet closed and body erected with shoulders, buttocks and heels touching the same vertical plane for taking measurement in standing posture. Similarly subjects were asked to sit with body vertically erected, while shoulders and head touched the same vertical plane for taking measurement in sitting postures. While taking anthropometric measurements, care was taken so that excessive compression of underlying tissues is avoided as far as possible. To achieve greater uniformity, measurements were carried out on the right hand side of subjects and data noted to the nearest millimeter. During measurements under sitting condition, the upper and lower legs of the subjects were maintained at right angle to each other (Dewangan et al., 2005). For this height adjustable stool was used.

### 2.5. Data analysis

The raw anthropometric data collected was fed in the excel sheet and excel sheet was imported into SPSS 20 software for the statistical analysis. Normality of the data was checked by using a Shapiro–Wilk's test ($p > 0.05$) (Shapiro and Wilk, 1965), skewness and kurtosis statistic, histograms and normal Q–Q plots. Levene's test ($p > 0.05$) was used to ensure equality of variances in the samples (homogeneity of variance) (Martin and Bridgmon, 2012).

Some outliers were eliminated, which may be the result of mistake while recording data. In built functions in excel along with some custom formulae were used to calculate values of minimum, maximum, mean, SD, standard error of mean (SEM), CV, 5th and 95th percentile. The maximum margin of error for any dimension was found to be less than 0.9.

## 3. Results

The values of minimum, maximum, mean, SD, SEM, CV, 5th and 95th percentile for various body dimensions are presented in Table 2. The anthropometric dimensions of Maharashtra are compared with other regions of India, i.e., central, eastern, northern, southern and existing western India (WI) region (Table 4).

From SEM results it can be seen that weight, stature, eye height,

**Table 2**
Anthropometric body dimensions of male agricultural workers in the state of Maharashtra in India.

| Sl. no. | Dimensions | Min. | Max. | Mean | SD | SEM | CV (%) | Percentile | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 5th | 50th | 95th |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Standing measurements | | | | | | | | | | |
| 1 | Weight (Kg) | 38.7 | 77.5 | 57.9 | 7.2 | 0.41 | 12.44 | 46.5 | 58.1 | 69.9 |
| 2 | Stature | 147.5 | 180.5 | 164.7 | 6.0 | 0.34 | 3.64 | 154.6 | 165.0 | 174.6 |
| 3 | Eye height | 138.0 | 169.9 | 154.7 | 6.0 | 0.34 | 3.88 | 144.5 | 155.1 | 164.3 |
| 4 | Acromial height | 123.2 | 152.7 | 137.6 | 5.5 | 0.32 | 4.00 | 128.4 | 138.0 | 147.0 |
| 5 | Axilla height | 109.3 | 139.5 | 125.2 | 5.2 | 0.30 | 4.15 | 116.6 | 125.3 | 133.3 |
| 6 | Chest height | 107.3 | 138.7 | 122.2 | 5.2 | 0.30 | 4.26 | 114.0 | 122.3 | 130.4 |
| 7 | Tenth rib height | 90.7 | 122.7 | 107.0 | 5.2 | 0.30 | 4.86 | 97.4 | 107.1 | 114.2 |
| 8 | Iliocrystale height | 85.3 | 112.5 | 97.9 | 4.7 | 0.27 | 4.80 | 90.3 | 97.8 | 105.5 |
| 9 | Waist height, omphalion | 84.2 | 113.7 | 99.6 | 4.9 | 0.28 | 4.92 | 91.7 | 99.9 | 107.4 |
| 10 | Olecranon height | 88.2 | 114.5 | 102.5 | 4.5 | 0.26 | 4.39 | 94.7 | 102.5 | 109.0 |
| 11 | Elbow height | 91.4 | 117.5 | 104.3 | 4.4 | 0.25 | 4.22 | 96.6 | 104.4 | 111.4 |
| 12 | Crotch height | 60.0 | 88.0 | 76.6 | 4.8 | 0.28 | 6.27 | 70.0 | 76.5 | 84.5 |
| 13 | Knee height, midpatella | 40.2 | 54.0 | 48.5 | 2.7 | 0.16 | 5.57 | 43.5 | 48.7 | 52.5 |
| 14 | Wrist-wall length | 56.6 | 86.0 | 64.8 | 3.5 | 0.20 | 5.40 | 59.3 | 65.0 | 70.0 |
| 15 | Wrist-wall length, extended | 58.3 | 77.2 | 67.6 | 3.3 | 0.19 | 4.88 | 62.2 | 67.7 | 72.8 |
| 16 | Acromion-radiale length | 23.3 | 39.1 | 31.6 | 2.6 | 0.15 | 8.23 | 26.5 | 32.0 | 35.1 |
| 17 | Radiale-stylion length | 20.9 | 34.5 | 26.5 | 2.3 | 0.13 | 8.68 | 23.0 | 26.5 | 31.0 |
| 18 | Shoulder-elbow length | 23.3 | 43.5 | 37.0 | 2.6 | 0.15 | 7.03 | 33.3 | 37.0 | 41.0 |
| 19 | Forearm hand length | 23.9 | 51.4 | 45.4 | 2.9 | 0.17 | 6.39 | 41.0 | 45.5 | 49.5 |
| 20 | Forearm centre of grip length | 28.5 | 44.6 | 33.7 | 1.9 | 0.11 | 5.64 | 30.5 | 33.5 | 36.5 |
| 21 | Chest breadth | 22.0 | 39.4 | 26.2 | 2.1 | 0.12 | 8.02 | 23.7 | 26.0 | 29.5 |
| 22 | Waist breadth, omphalion | 18.2 | 33.0 | 25.2 | 2.3 | 0.13 | 9.13 | 21.3 | 25.5 | 28.6 |
| 23 | Hip breadth | 25.0 | 35.2 | 29.3 | 1.7 | 0.10 | 5.80 | 26.6 | 29.3 | 32.0 |
| 24 | Bispinous breadth | 19.0 | 31.5 | 25.2 | 2.1 | 0.12 | 8.33 | 21.5 | 25.2 | 28.7 |
| 25 | Bideltoid breadth | 31.8 | 46.4 | 39.4 | 2.2 | 0.13 | 5.58 | 35.6 | 39.5 | 42.8 |
| 26 | Biacromial breadth | 27.4 | 40.0 | 32.9 | 1.9 | 0.11 | 5.78 | 29.7 | 32.7 | 35.9 |
| 27 | Waist depth, omphalion | 14.1 | 25.2 | 19.2 | 1.8 | 0.10 | 9.38 | 16.0 | 19.1 | 22.4 |
| 28 | Sleeve length, outseam | 48.0 | 69.0 | 59.5 | 3.3 | 0.19 | 5.55 | 54.0 | 60.0 | 65.0 |
| 29 | Wrist circumference | 13.0 | 19.0 | 15.5 | 0.8 | 0.05 | 5.16 | 14.2 | 15.5 | 17.0 |
| 30 | Elbow circumference, straight | 18.0 | 27.0 | 23.1 | 1.5 | 0.09 | 6.49 | 20.5 | 23.0 | 25.2 |
| 31 | Knee circumference | 22.0 | 40.0 | 32.8 | 2.5 | 0.14 | 7.62 | 29.0 | 33.0 | 36.2 |
| 32 | Waist circumference, omphalion | 63.5 | 100.3 | 77.9 | 7.3 | 0.42 | 9.37 | 67.0 | 78.3 | 89.9 |
| 33 | Buttock circumference | 73.4 | 101.0 | 86.5 | 5.0 | 0.29 | 5.78 | 79.0 | 86.2 | 94.0 |
| 34 | Acromion-wall length | 7.3 | 13.0 | 10.2 | 0.8 | 0.05 | 7.84 | 9.0 | 10.1 | 11.6 |
| Sitting measurements | | | | | | | | | | |
| 35 | Height | 71.0 | 93.1 | 83.6 | 3.3 | 0.19 | 3.95 | 78.1 | 83.9 | 89.0 |
| 36 | Eye height | 63.1 | 85.7 | 74.0 | 3.2 | 0.18 | 4.32 | 68.6 | 74.1 | 78.8 |
| 37 | Acromial height | 46.2 | 64.4 | 56.6 | 3.0 | 0.17 | 5.30 | 51.7 | 56.8 | 61.6 |
| 38 | Elbow rest height | 15.7 | 27.4 | 20.8 | 2.0 | 0.11 | 9.62 | 18.0 | 20.4 | 24.5 |
| 39 | Thigh clearance height | 9.7 | 17.6 | 13.8 | 1.3 | 0.07 | 9.42 | 11.8 | 13.8 | 16.1 |
| 40 | Knee height | 43.0 | 56.5 | 50.3 | 2.6 | 0.15 | 5.17 | 45.6 | 50.3 | 54.7 |
| 41 | Popliteal height | 38.4 | 53.8 | 44.3 | 2.2 | 0.13 | 4.97 | 41.0 | 44.2 | 47.8 |
| 42 | Hip breadth | 26.2 | 37.0 | 30.9 | 1.9 | 0.11 | 6.15 | 28.0 | 30.8 | 33.5 |
| 43 | Elbow–elbow breadth | 29.6 | 47.0 | 38.6 | 3.0 | 0.17 | 7.77 | 33.7 | 38.7 | 43.2 |
| 44 | Buttock knee length | 46.4 | 66.0 | 56.0 | 3.1 | 0.18 | 5.54 | 51.0 | 56.0 | 60.8 |
| 45 | Buttock popliteal length | 38.2 | 57.4 | 47.1 | 3.2 | 0.18 | 6.79 | 41.4 | 47.2 | 52.2 |
| 46 | Coronoid fossa to hand length | 33.9 | 48.5 | 39.9 | 2.3 | 0.13 | 5.76 | 36.0 | 40.0 | 43.5 |
| Sitting/standing measurements | | | | | | | | | | |
| 47 | Foot length | 21.5 | 29.0 | 24.5 | 1.2 | 0.07 | 4.90 | 22.7 | 24.5 | 26.6 |
| 48 | Instep length | 15.5 | 28.5 | 18.2 | 1.3 | 0.07 | 7.14 | 16.5 | 18.0 | 20.0 |
| 49 | Foot breadth | 7.3 | 11.0 | 9.1 | 0.7 | 0.04 | 7.69 | 8.0 | 9.2 | 10.2 |
| 50 | Bimalleolar breadth | 5.5 | 10.4 | 6.8 | 0.5 | 0.03 | 7.35 | 6.1 | 6.8 | 7.7 |
| 51 | Hand length | 15.9 | 25.6 | 18.0 | 0.9 | 0.05 | 5.00 | 16.5 | 18.0 | 19.4 |
| 52 | Wrist-index finger length | 14.7 | 18.9 | 16.7 | 0.9 | 0.05 | 5.39 | 15.2 | 16.7 | 18.2 |
| 53 | Palm length | 8.1 | 12.2 | 10.2 | 0.6 | 0.03 | 5.88 | 9.1 | 10.2 | 11.1 |
| 54 | Hand breadth at metacarpal-III | 6.2 | 9.7 | 8.1 | 0.4 | 0.02 | 4.94 | 7.4 | 8.1 | 8.8 |
| 55 | Hand breadth across thumb | 7.7 | 11.2 | 9.8 | 0.5 | 0.03 | 5.10 | 9.0 | 9.9 | 10.7 |
| 56 | Grip diameter (inside) | 3.6 | 6.0 | 4.7 | 0.4 | 0.02 | 8.51 | 4.0 | 4.7 | 5.4 |
| 57 | Grip diameter (outside) | 5.8 | 9.7 | 8.1 | 0.5 | 0.03 | 6.17 | 7.2 | 8.1 | 9.0 |
| 58 | Middle finger palm grip diameter | 2.0 | 4.0 | 3.1 | 0.3 | 0.02 | 9.68 | 2.7 | 3.1 | 3.6 |
| 59 | Grip span | 5.8 | 11.0 | 8.5 | 0.8 | 0.05 | 9.41 | 7.5 | 8.5 | 9.8 |

Measurements are in cm, until otherwise specified.
Min = minimum, Max = maximum, SEM = standard error of mean.

**Table 3**
BMI distribution of the sample population.

| Category | BMI value (kg/m$^2$) | No. of subjects | Percentage of sample population |
|---|---|---|---|
| Underweight | <18.5 | 47 | 15.51 |
| Normal weight | 18.5 to 24.9 | 226 | 74.59 |
| Overweight | 25 to 29.9 | 28 | 9.24 |
| Obesity | >=30 | 2 | 0.66 |

**Table 4**
The mean (SD) values of anthropometric data for male agricultural workers of Maharashtra and other regions in India.

| Body dimension | Central India[a] (n = 39,y = 15 −60) | Eastern India[b] (n = 134,y = ns) | Northern India[c] (n = 40, y = ns) | North eastern India[d] (n = 280,y = 20−30) | North eastern India[e] (n = 200,y = ns) | Southern India[f] (n = 128,y = 18 −35) | Western India[g] (n = 40, y = ns) | Western India[h] (n = 303, y = 18 −60) |
|---|---|---|---|---|---|---|---|---|
| Stature | 162.00(4.95) | 162.10(5.80) | 168.50(6.84) | 164.87(4.54) | 162.7(6.50) | 160.70(6.00) | 164.40 | 164.7(6.00) |
| Eye height | 151.00(5.22) | 150.80(5.10) | – | 153.55(5.00) | – | 149.70(6.10) | – | 154.7 (6.00) |
| Shoulder height | 134.60(4.87) | 131.20(4.80) | – | 134.47(4.30) | – | 130.10(4.60) | – | 137.6(5.50) |
| Sitting height | 83.80(2.52) | 80.90(2.20) | – | 84.70(2.88) | 84.2(3.80) | 79.10(4.00) | 86.20 | 83.6(3.30) |
| Sitting eye height | 73.90(2.62) | 71.40(2.00) | – | 73.38(3.17) | 73.1(4.40) | 70.10(4.60) | – | 74.0(3.20) |
| Sitting shoulder height | 55.70(2.08) | 53.40(2.12) | – | 54.30(2.74) | 56.1(3.10) | 52.90(3.90) | – | 56.6(3.00) |
| Popliteal height | 41.60(2.07) | 42.00(1.74) | – | 41.25(2.56) | 40.2(2.20) | 47.10(3.50) | 42.00 | 44.3(2.20) |
| Buttock popliteal length | 46.60(1.75) | 46.20(2.28) | – | 44.52(2.45) | 41.4(3.20) | 44.70(2.30) | 45.60 | 47.1(3.20) |
| Fore arm hand length | 45.90(2.00) | 44.60(1.96) | – | 43.20(1.97) | 44.3(2.60) | 40.10(2.50) | – | 45.4(2.90) |
| Hand length | 18.30(0.84) | 17.80(1.61) | – | 17.95(0.56) | 17.6(1.00) | 16.40(1.40) | 19.10 | 18(0.90) |

All dimensions are in cm, n = number of subjects, y = age group range in years, ns = not specified.
[a] Gite and Yadav (1989).
[b] Yadav et al. (1997).
[c] Gupta et al. (1983).
[d] Dewangan et al.(2005).
[e] Tewari et al.(2007).
[f] Fernandez and Uppugonduri (1992).
[g] Sen (1964).
[h] Present study.

acromial height, axilla height, chest height, tenth rib height, iliocrystale height, waist height at omphalion, olecranon height, crotch height, waist circumference at omphalion and buttock circumference have higher SEM values ranging 0.26–0.40. However, SEM of other body dimensions is generally small. The CV% of few body dimensions, like weight, waist depth at omphalion, elbow rest height, thigh clearance height, middle finger palm grip diameter, grip span are relatively high. The Body mass index (BMI)distribution of the population is shown in the Table 3.

## 4. Discussion

It has been well accepted that equipments/tools designed without conceiving body dimensions of user population will result into musculoskeletal disorders, discomfort and low efficiency. Anthropometric data presented in Table 2 assists the designer to design new farm equipments or improve existing equipments for the user population. Table 2 shows that the spread among the mean values of some standing posture dimensions such as stature, eye height, acrominal height, Axilla height, chest height, tenth rib height, Iliocrystale height, Waist height, Crotch height, waist circumference and buttock circumference is greater than the other dimensions. It may also be noted that body dimensions in the present study are taken in static posture. Therefore, the anthropometric data presented in Table 2 should not be used as it is for design and/or modification of the tools, equipment and work places. For this purpose, functional body dimensions are required. In order to use the data for design of the equipment in the dynamic conditions, a guideline provided be used. Functional body dimensions are best suited for dynamic conditions and are determined from the static body dimensions (Kroemer, 1983).

Table 4 presents comparison of anthropometric data of Maharashtra region with other regions in India. It can be observed that WI males are taller than central, eastern, north eastern and southern India males but shorter than northern India males. Also, stature is nearly same as that in study by Sen (1964) for the same region–Eye, shoulder, sitting eye and sitting shoulder heights as well as buttock popliteal length for WI males are greater than the other regions in India. Northern India males are taller than those of any other region of the India in the Table 4. Southern India males are shorter in stature, eye height, shoulder height, sitting height, sitting eye height, sitting shoulder height and forearm hand length than those of other regions. BMI distribution shows that about 75% of the population is having normal weight (Table 3).

Table 5 presents a comparison of male anthropometric data of Maharashtra state with that of other countries. It has been observed that stature, bideltoid breadth, sitting height, Sitting acromial height, hand length and foot length of Maharashtra male workers are smaller than that of other countries in the table. Algerian males have higher stature, acromial height, elbow height, sitting acromial

**Table 5**
The mean (SD) values of anthropometric data for male agricultural workers of Maharashtra and other nationals.

| Body dimension | Algerian[a] (n = 514) | Chinese[b] (n = 146) | Filipino[c] (n = 843) | Korean[d] (n = 909) | Indian[e] (n = 303) | Singaporean[f] (n = 832) | Taiwanese[g] (n = 1200) | Thai[h] (n = 100) |
|---|---|---|---|---|---|---|---|---|
| Stature | 172.6(7.6) | 170.3(5.6) | 167.0(8.0) | 170.2(5.0) | 164.7(6.0) | 168.5(5.3) | 168.7(6.0) | 171.9(5.2) |
| Eye height | 159.7(6.6) | – | 155.0(6.9) | – | 154.7 (6.0) | – | 156.9(5.9) | 160.2(5.0) |
| Acromial height | 144.6(6.7) | 140.6(5.4) | 137.5(6.1) | – | 137.6(5.5) | – | 138.3(5.3) | 140.7(11.7) |
| Elbow height | 109.9(5.3) | – | 104.1(6.7) | – | 104.3(4.4) | – | 104.9(4.2) | 109.2(8.8) |
| Bideltoid breadth | – | – | – | – | 39.4(2.2) | – | – | 43.2(2.3) |
| Sitting height | 87.0(3.5) | – | 84.8(5.8) | 92.1(2.9) | 83.6(3.3) | 89.4(3.2) | 90.3(3.2) | 90.2(3.4) |
| Sitting eye height | 74.4(3.9) | – | 73.4(3.8) | – | 74.0(3.2) | – | 78.5(3.1) | 78.0(3.4) |
| Sitting acromial height | 60.9(3.7 | – | – | 60.1(2.7) | 56.6(3.0) | – | – | 60.6(2.7) |
| Sitting knee height | – | 47.2(4.4) | 50.0(4.0) | – | 50.3(2.6) | – | 51.6(2.8) | 52.8(2.3) |
| Buttock knee length | 57.4(3.8) | – | 54.8(5.2) | – | 56.0(3.1) | 57.3(2.6) | 55.2(3.2) | 58.5(2.5) |
| Popliteal height | 42.2(3.0) | – | 43.3(2.6) | – | 44.3(2.2) | – | 40.4(2.0) | 43.0(1.6) |
| Buttock popliteal length | 47.5(2.9) | – | 46.4(3.7) | – | 47.1(3.2) | – | 44.9(2.9) | 48.2(4.0) |
| Sitting hip breadth | 33.7(2.6) | – | 35.6(4.1) | 34.4(1.9) | 30.9(1.9) | 30.9(1.5) | – | 34.3(5.5) |
| Thigh clearance height | – | – | 13.5(4.5) | – | 13.8(1.3) | – | 22.3(1.8) | 14.2(1.5) |
| Elbow–elbow breadth | 43.0(3.8) | – | 30.6(2.1) | – | 38.6(3.0) | – | – | – |
| Fore arm hand length | – | – | 44.1(4.1) | – | 45.4(2.9) | – | – | 47.1(1.6) |
| Hand length | 19.4(1.4) | – | 19.8(7.8) | – | 18.0(0.9) | – | – | 19.0(0.7) |
| Foot length | 25.4(1.5) | – | 25.4(1.7) | – | 24.5(1.2) | – | – | 25.4(1.0) |
| Foot breadth | 9.5(0.8) | – | 10.5(6.4) | – | 9.1(0.7) | – | – | 9.8(0.5) |

Measurements are in cm, n = number of subjects.
[a] Mokdad (2002).
[b] Xiao et al. (2005).
[c] Prado-Lu (2007).
[d] Park et al. (2000).
[e] Present study.
[f] Singh et al. (1995).
[g] Wang et al. (1999).
[h] Klamklaya et al. (2008).

height and elbow–elbow breadth than those of other nations in the Table 5. Korean males have highest sitting height whereas Thai males have highest sitting knee height, buttock knee length, buttock popliteal length and fore arm hand length in males of all other countries in the Table 5.

It is desirable that designer should design the equipments or tools for 90% population i.e. for population within 5th and 95th percentile anthropometric data values. But this may vary as per the strategy of the designer and company.

## 5. Conclusions

In this survey, 59 body dimensions including weight were measured from 303 subjects with age group of 18–60 years from the Maharashtra state of India. The results of present study were compared with the results of similar studies conducted in other regions of India and other countries. From the data it appears that stature is greater than other region male workers except northern India. Also, eye height and shoulder height are greater than that of the other regions in India.

In comparison to Algerian, Chinese, Filipino, Korean, Singaporean, Taiwanese and Thai male workers it is noticed that Indian male population is shorter in stature, sitting height, hand length and foot length. Thus, agricultural equipments designed for other regions of India and other countries are not ergonomically suitable for WI region population. Thus, there is a need of modifying or redesigning of existing equipments for the WI region based on scientific application of anthropometric data of workers. Moreover, there is need to consider anthropometric differences while buying agricultural equipments for WI region.

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