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Anthropometric Data of Farm Workers of North-Karnataka Region of India and its Practice for Better Design of Agricultural Tools and Implements

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Abstract

Agriculture provides the basic means of income for majority of Indian families. The farm workers use abundant types of tools, equipments and machinery in their day-today agricultural processes. It is thus necessary to consider the human factors in the development of these farm tools/equipments to increase the operating/working efficiencies, working comforts and thereby improving the overall productivity of the workers. To successfully meet these tasks, the body dimensions of the farm workers in a particular region has to be connected with the tools/equipments/machinery being designed and used in that region. Anthropometry is the methodical way of collecting the human body dimensions which further plays a significant role in the design of man and machine interface and hence in the design and development of products that are used by humans. Anthropometric data gives enormous amount of information to the designers and manufacturers for the development of ergonomically enhanced products which are used in a particular geographical area. Ergonomically designed equipments/products improve the human operating efficiencies and comforts during its practice. The current study is carried out to determine and examine the anthropometric data of the farm workers of northern Karnataka region of India. Twenty nine body measurements necessary for the design of farm tools/equipments/machineries were identified and the survey was conducted on 497 farm workers randomly selected (310 male and 187 female) within the age limit of 18 to 60 years from the various villages of Northern Karnataka region of India. The data thus gathered is compared with rest of Indian available data and also with other national data to evaluate the differences in the body dimensions. The information so generated can be further utilized in the better design of farm

tools, equipments and machinery for this area to improve the overall operating efficiency and comfort of the farmers.

Keywords: Ergonomics, Anthropometry, Agriculture, Farm tools, Equipments.

Introduction

Anthropometry is a Greek word, 'anthropos' means man, 'metrein' means to measure. It is an integral part of the design where human beings are involved. Anthropometry plays a vital role in the design and development of products that are used by humans [1]. Anthropometric statistics gives immense amount of information to the designers and manufacturers for the development of ergonomically improved products which are used in a particular geographical area. Ergonomically designed equipments/products improve the human operating efficiencies and comforts during its function [2,3]. Design for Human Comfort (DFHC) is the key area which needs to be tackled by every designer in today's product development situations as there is a huge amount of variations in body dimensions among individuals who are using these products [4,5].

Agriculture is the main source of livelihood in India. It is an important segment which plays a noteworthy role in the development of Indian economy. Nearly 65% of the rural people in India are engaged in the farming process and contributes roughly 17% to the GDP [6,7]. In spite of its massive involvement, agricultural sector is still considered as the most risky work place and leading to increased number of agricultural accidents [8,9]. The most common reason for this is non-involvement of ergonomics in design and utilization of traditional tools and implements for the agricultural activities thus leading to work related injuries. It is thus essential to collect

and analyze the region specific anthropometric data of agricultural workers and utilize it in the safer agricultural product development. It is also noticed that there is very little history of application of ergonomic approaches in agricultural equipment design [10]. For best possible performance in the agricultural field, a proper matching between the user-equipment is very much crucial.

Farm workers employ various types of traditional tools, equipments and machinery for their day-today farming activities. It becomes utmost necessary to consider the human factors in the design of these farm tools to boost the operating efficiencies, working comforts and thereby improving the output of the workers [11-13].

The various scrutinies made from the survey showed that, there are large differences in body dimensions between Western and Indian populations and even within Indian population, as they vary from region to region [14]. It is therefore necessary to study and analyze the body dimensions and to develop region specific anthropometric database for safe and efficient design/modification of agricultural equipments.

Anthropometric data of west, north, south and central India have been published by many surveys in the past [15-17]. Still, region detailed anthropometric statistics is not available for the implementing the ergonomics in a particular region [18]. From the literature it is also observed that, only a limited anthropometric data of this particular region of northern Karnataka is published [19-21]. The farming community in the region still uses the traditional tools that are being practiced in the other part of the country. Further it is observed that tools used in one geographic region are still being continued in other geographic region without any modifications [22]. Often these tools are designed without considering the human factors and are sometimes not suitable for the body dimensions of this region. To overcome the difficulties faced in the usage of these agricultural tools it is thus necessary to determine the anthropometric data of farmers in this particular area and utilize the same for the design and development of agricultural tools and equipments to increase the operating comforts and hence reducing the work related injuries.

Agriculture in north Karnataka

Farming is the backbone of the people in north Karnataka with wide range of crop diversification. More than %65 of the population is involved in the farming and its related processes. Jowar, wheat, paddy, maize, ground nut, sugar cane, soyabean, cotton, greengram, bengalgram and turdal are the major crops grown in majority of the areas.

Majority of the farmers have small and marginal land holdings with operating land areas from 2 to 3 hectares [23,24]. These operating areas of the land are still reducing due to increase in fragmentation of land holdings. Due to small and marginal holdings, it is uneconomical for the farmer to possess new farm machinery for their individual applications. It is also observed that there is little

mechanization happened in case of small holding farming [25]. Consequently the availability of larger machines and mechanization is benefited to only small group of farmers who are having larger farming land holdings. Hence, the farming process in small holdings in this region is usually done by utilizing animal power, manually operated tools and manually operated equipments. Further it is also observed during the survey that these traditional farm implements are usually manufactured by local manufacturer or imported from other regions without considering the application of the ergonomic principles [26]. To effectively design and manufacture the agricultural tools or machinery particularly for small holding farmers for a particular region, the anthropometric data of that region is the key parameter for its successful implementation and application.

Materials and Methods

The present study is carried out to determine the anthropometric data of the farm workers in the Dharwad district of northern Karnataka region. The statistics gives valuable information to the farm equipment designers and manufacturers to consider the ergonomics in the development of farm tools and equipments. The information is very much essential for secure, user-friendliness and efficient design of farm tools, equipments and machineries used in this particular region. Twenty nine body dimensions necessary for the design of farm equipments/machineries were recognized and the investigations were conducted on 497 farm workers randomly selected (310 male and 187 female) within the age limit of 18 to 60 years. The necessity of the records and its implementation in safer farming activity was explained to the farm workers before the data collection process. All the subjects selected were healthy and the data was collected with barefoot and wearing thin clothing.

The measurements were taken by experienced engineers ensuring that no error is included during the data collection. During standing dimension measurement, all the subjects were standing in the vertical position with face in forward direction and allowing their arms resting beside the body. Subjects were made to be seated erectly on the chair without armrests with knee at 90° and feet touching flat ground surfaces during the sitting body measurements. All the measurements of each subject were taken twice to ensure the error free measurements during the data collection process.

Instruments in Measurements:

- A standard anthropometer and standardized stature meter used to measure vertical body dimensions in standing as well as in sitting positions.
- A wooden cone with carved diameters used to measure internal hand grip diameter.
- A portable weighing scale (0 to 125 kg) used for body weight measurement.
- Hand dynamometer used for the measurement of hand grip strength.

- A 0-300 mm vernier caliper (least count of 0.02 mm) was utilized to measure hand and foot dimensions.
- Standard cylindrical rods were employed during the measurement of grip reach dimensions.
- Standard measuring tape is also utilized in the measuring procedures.

Standard data sheet was prepared to note down the various anthropometric data of individual farm worker. The measuring instruments used were calibrated with the higher standards before they were used for the actual measurement.

The various body dimensions considered during the survey of

anthropometric data are illustrated in Table 1.

Results and Discussions

The anthropometric data of every parameter collected for both male and female farm workers during the survey was investigated for its mean, minimum and maximum values along with the 5th, 25th, 50th, 75th and 95th percentile values. The data thus examined is showed in Table 2 and Table 3 for male and female workers respectively. Outcomes presented in Table 2 and Table 3 provides vast data for the farm equipment designers and manufactures for the design and manufacturing of new equipment or to improve the existing apparatus to suit to the farmers of this region. The reason

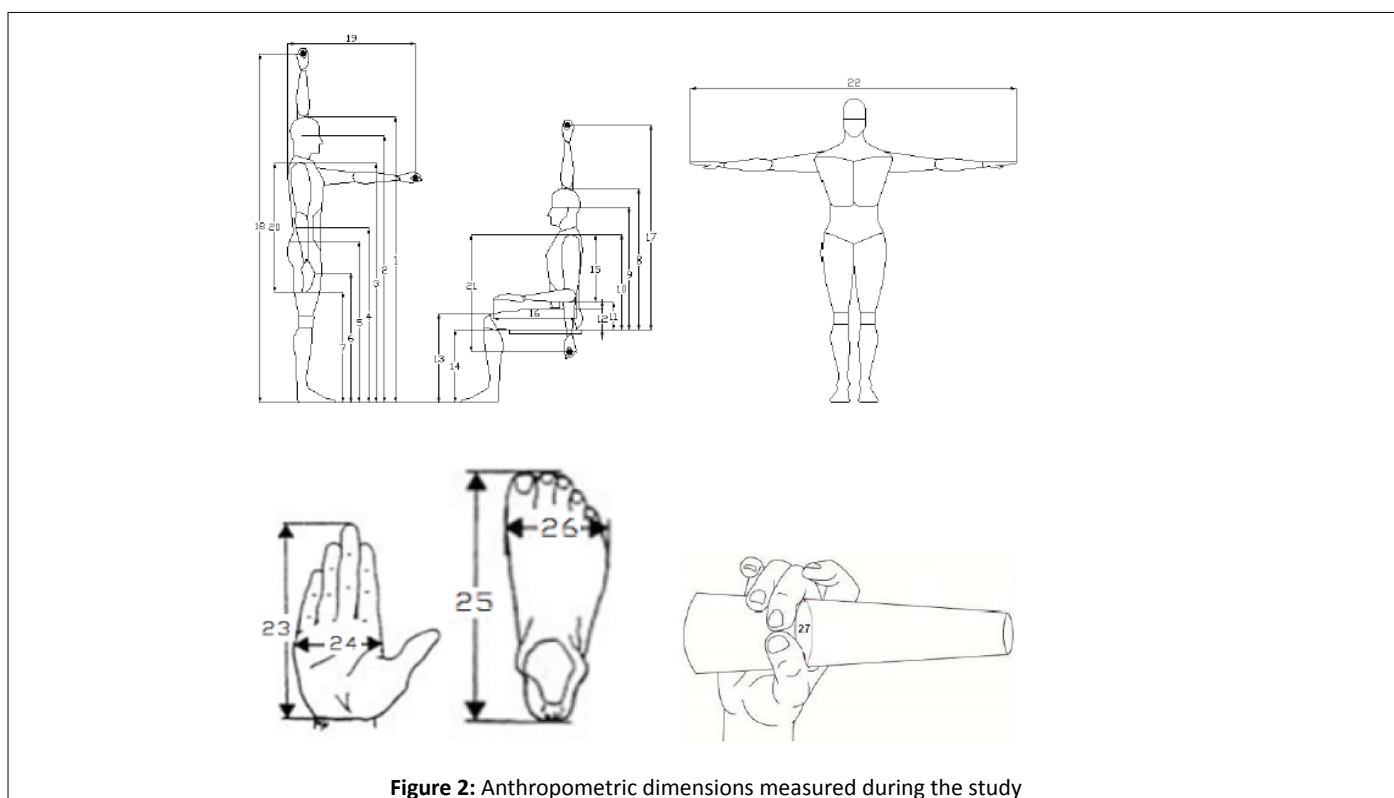
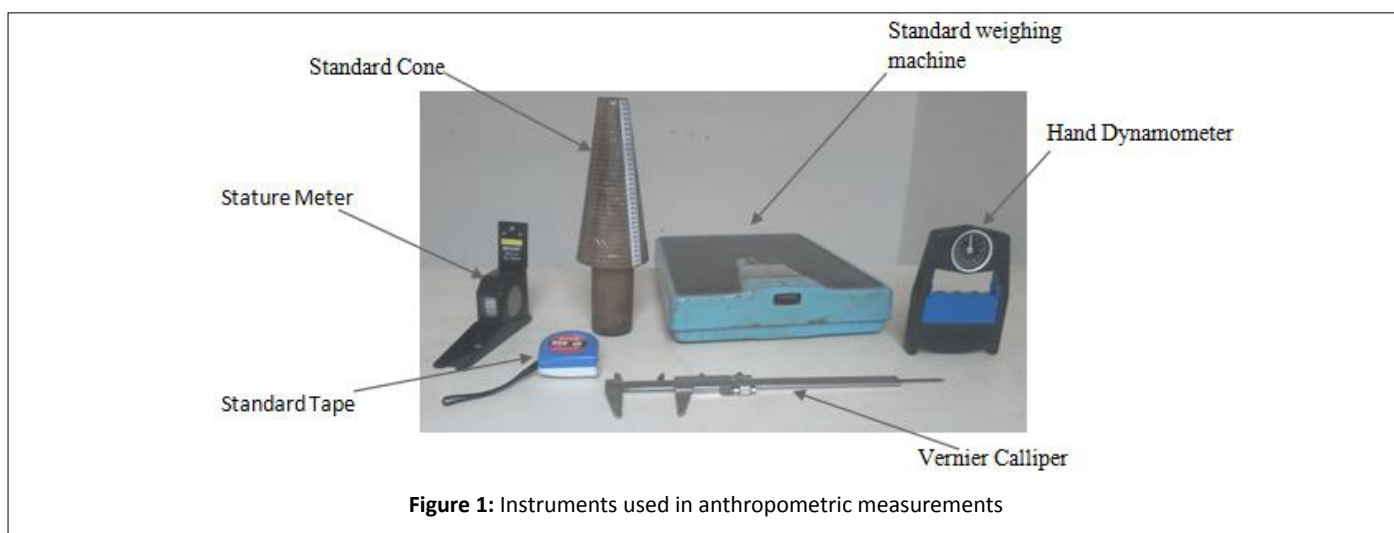


Table 1: Anthropometric dimensions investigated during the study

| S No | Anthropometric Dimensions | Description |
|------|----------------------------------|--|
| 1 | Height | The vertical distance from the flat floor to the top of the head, when standing erectly |
| 2 | Eye height, standing | The vertical distance from the floor to the outer corner of the right eye, when standing erectly |
| 3 | Shoulder height, standing | The vertical distance from the floor to the tip of the shoulder when standing |
| 4 | Elbow height, standing | vertical distance from the floor to the lowest point of the right elbow when standing |
| 5 | Waist height, standing | The vertical distance from the flat floor to the upper margin of the iliac crest where the belt is worn |
| 6 | Knuckle height, standing | The vertical distance from the floor to the knuckle of the middle finger of the right hand when standing |
| 7 | Finger tip height, standing | The vertical distance from the floor to the tip of the inside finger of the right hand when standing |
| 8 | Sitting height | The vertical distance from the sitting surface to the top of the head when sitting erectly |
| 9 | Sitting eye height | The vertical distance from the sitting surface to the outer corner of the right eye, when sitting erectly |
| 10 | Sitting shoulder height | The vertical distance from the sitting surface to the tip of the shoulder when sitting erectly |
| 11 | Sitting elbow height | The vertical distance from the sitting surface to the lowest point of the right elbow with elbow flexed at 90 degrees |
| 12 | Sitting thigh height | The vertical distance from the sitting surface to the highest point on the top of the right thigh when sitting with knee flexed at 90 degrees |
| 13 | Sitting knee height | The vertical distance from the flat floor surface to the top of the right knee cap when sitting with knee flexed at 90 degrees |
| 14 | Popliteal height, sitting | The vertical distance from the floor to the underside of the thigh directly behind the knee when sitting knee flexed at 90 degrees |
| 15 | Shoulder elbow length | The vertical distance from the tip of the shoulder to the underside of the elbow when the elbow flexed at 90 degrees with arm hanging vertically |
| 16 | Elbow fingertip length | The distance from the back of the elbow to the tip of the middle finger when the elbow flexed at 90 degrees |
| 17 | Overhead grip reach, sitting | The vertical distance from the sitting surface to the center of the cylindrical rod firmly held in the palm of the right hand |
| 18 | Overhead grip reach, standing | The vertical distance from the standing flat surface to the center of the cylindrical rod firmly held in the palm of the right hand |
| 19 | Forward grip reach, standing | The horizontal distance from the back of the right shoulder blade to the center of the cylindrical rod firmly held in the palm of the right hand |
| 20 | Arm length, vertical | The vertical distance from the tip of the shoulder to the tip of the right middle finger with the arm hanging vertically |
| 21 | Downward grip reach | The vertical distance from the tip of the shoulder to center of the cylindrical rod firmly held in the palm of the right hand |
| 22 | Span | The distance between the tips of the middle fingers of the horizontally outstretched arms and hands |
| 23 | Hand length | The length of the right hand between the crease of the wrist and tip of the middle finger keeping the hand flat |
| 24 | Hand breadth | The breadth of the right hand across the knuckles of the four fingers |
| 25 | Foot length | The maximum length of the right foot when standing |
| 26 | Foot breadth | The maximal breadth of the right foot at right angle to the axis of the foot when standing |
| 27 | Hand grip inside diameter (Max.) | The maximum diameter formed by touching the thumb and middle finger of dominating hand by using wooden cone. |
| 28 | Hand grip strength (Kg) | The maximum amount of static force that the dominating hand can squeeze using a hand dynamometer |
| 29 | Weight (Kg) | Maximum weight of the body when standing straight on the weighing scale wearing lighter cloths |

Table 2: Anthropometric data of male farm workers

| S.No | Dimensions | Percentiles | | | | | | | Max | Mean | SD |
|------|----------------------------------|-------------|------|------|------|------|------|------|------|------|----|
| | | Min | 5th | 25th | 50th | 75th | 95th | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| 1 | Height | 1430 | 1530 | 1610 | 1649 | 1684 | 1745 | 1823 | 1649 | 65 | |
| 2 | Eye height, standing | 1320 | 1437 | 1512 | 1547 | 1582 | 1657 | 1725 | 1546 | 68 | |
| 3 | Shoulder height, standing | 1198 | 1265 | 1329 | 1402 | 1436 | 1508 | 1594 | 1386 | 73 | |
| 4 | Elbow height, standing | 798 | 923 | 982 | 1044 | 1118 | 1180 | 1384 | 1050 | 89 | |
| 5 | Waist height, standing | 808 | 880 | 916 | 967 | 1001 | 1058 | 1198 | 963 | 59 | |
| 6 | Knuckle height, standing | 598 | 648 | 692 | 710 | 733 | 800 | 867 | 714 | 42 | |
| 7 | Finger tip height, standing | 483 | 561 | 592 | 613 | 634 | 702 | 839 | 616 | 43 | |
| 8 | Sitting height | 677 | 778 | 811 | 841 | 871 | 898 | 958 | 842 | 42 | |
| 9 | Sitting eye height | 566 | 683 | 711 | 734 | 766 | 810 | 862 | 738 | 43 | |
| 10 | Sitting shoulder height | 458 | 512 | 550 | 572 | 588 | 623 | 684 | 570 | 35 | |
| 11 | Sitting elbow height | 121 | 156 | 196 | 226 | 247 | 279 | 328 | 222 | 39 | |
| 12 | Sitting thigh height | 68 | 94 | 116 | 126 | 135 | 163 | 229 | 128 | 24 | |
| 13 | Sitting knee height | 430 | 466 | 495 | 514 | 532 | 569 | 619 | 516 | 31 | |
| 14 | Sitting popliteal height | 320 | 389 | 420 | 445 | 455 | 487 | 524 | 439 | 30 | |
| 15 | Shoulder elbow length | 228 | 295 | 319 | 331 | 341 | 372 | 389 | 331 | 26 | |
| 16 | Elbow fingertip length | 404 | 420 | 440 | 453 | 465 | 491 | 511 | 453 | 21 | |
| 17 | Overhead grip reach, sitting | 996 | 1059 | 1123 | 1196 | 1253 | 1324 | 1394 | 1193 | 81 | |
| 18 | Overhead grip reach, standing | 1696 | 1820 | 1899 | 1936 | 2014 | 2179 | 2366 | 1959 | 107 | |
| 19 | Forward grip reach, standing | 612 | 637 | 695 | 737 | 774 | 792 | 848 | 731 | 50 | |
| 20 | Arm length, vertical | 631 | 690 | 728 | 756 | 779 | 802 | 805 | 751 | 36 | |
| 21 | Downward grip reach | 544 | 585 | 621 | 639 | 665 | 692 | 701 | 641 | 33 | |
| 22 | Span | 1350 | 1572 | 1674 | 1727 | 1788 | 1857 | 1972 | 1718 | 100 | |
| 23 | Hand length | 115 | 165 | 179 | 187 | 191 | 203 | 230 | 185 | 13 | |
| 24 | Hand breadth | 61 | 70 | 81 | 85 | 90 | 98 | 106 | 85 | 8 | |
| 25 | Foot length | 210 | 217 | 231 | 241 | 252 | 268 | 296 | 241 | 16 | |
| 26 | Foot breadth | 48 | 83 | 92 | 96 | 100 | 110 | 125 | 96 | 9 | |
| 27 | Hand grip inside diameter (Max.) | 40 | 46 | 50 | 52 | 54 | 56 | 66 | 52 | 4 | |
| 28 | Hand grip strength (Kg) | 13 | 35 | 54 | 65 | 75 | 80 | 99 | 62 | 15 | |
| 29 | Weight | 39 | 46 | 54 | 60 | 65 | 75 | 112 | 60 | 9 | |

Table 3: Anthropometric data of female farm workers

| S.No | Dimensions | Percentiles | | | | | | | Max | Mean | SD |
|------|---------------------------|-------------|------|------|------|------|------|------|------|------|----|
| | | Min | 5th | 25th | 50th | 75th | 95th | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| 1 | Height | 1370 | 1414 | 1462 | 1509 | 1541 | 1632 | 1678 | 1511 | 66 | |
| 2 | Eye height, standing | 1308 | 1325 | 1375 | 1425 | 1456 | 1530 | 1602 | 1420 | 63 | |
| 3 | Shoulder height, standing | 1140 | 1168 | 1232 | 1273 | 1326 | 1361 | 1405 | 1276 | 60 | |
| 4 | Elbow height, standing | 832 | 869 | 928 | 966 | 996 | 1040 | 1169 | 964 | 60 | |
| 5 | Waist height, standing | 732 | 833 | 902 | 943 | 984 | 1022 | 1032 | 941 | 61 | |
| 6 | Knuckle height, standing | 622 | 634 | 661 | 695 | 728 | 783 | 810 | 697 | 43 | |

| | | | | | | | | | | |
|----|----------------------------------|------|------|------|------|------|------|------|------|----|
| 7 | Finger tip height, standing | 504 | 521 | 550 | 581 | 604 | 642 | 759 | 583 | 45 |
| 8 | Sitting height | 661 | 711 | 743 | 773 | 807 | 835 | 855 | 775 | 43 |
| 9 | Sitting eye height | 524 | 571 | 630 | 653 | 685 | 735 | 767 | 657 | 49 |
| 10 | Sitting shoulder height | 415 | 469 | 510 | 533 | 546 | 590 | 650 | 529 | 40 |
| 11 | Sitting elbow height | 110 | 125 | 168 | 195 | 221 | 264 | 281 | 196 | 43 |
| 12 | Sitting thigh height | 70 | 89 | 102 | 108 | 129 | 150 | 205 | 115 | 23 |
| 13 | Sitting knee height | 419 | 442 | 466 | 492 | 510 | 528 | 568 | 489 | 27 |
| 14 | Sitting popliteal height | 316 | 363 | 383 | 402 | 418 | 443 | 459 | 400 | 27 |
| 15 | Shoulder elbow length | 212 | 273 | 306 | 322 | 336 | 349 | 360 | 319 | 24 |
| 16 | Elbow fingertip length | 373 | 394 | 429 | 436 | 442 | 461 | 492 | 433 | 20 |
| 17 | Overhead grip reach, sitting | 915 | 952 | 1002 | 1051 | 1094 | 1162 | 1204 | 1053 | 77 |
| 18 | Overhead grip reach, standing | 1571 | 1624 | 1697 | 1775 | 1861 | 1940 | 2056 | 1777 | 98 |
| 19 | Forward grip reach, standing | 562 | 581 | 605 | 639 | 674 | 718 | 761 | 641 | 44 |
| 20 | Arm length, vertical | 615 | 646 | 690 | 728 | 743 | 763 | 789 | 718 | 36 |
| 21 | Downward grip reach | 497 | 523 | 569 | 598 | 620 | 640 | 672 | 596 | 35 |
| 22 | Span | 1421 | 1436 | 1518 | 1543 | 1612 | 1686 | 1764 | 1558 | 76 |
| 23 | Hand length | 144 | 151 | 161 | 173 | 180 | 188 | 190 | 171 | 12 |
| 24 | Hand breadth | 60 | 67 | 71 | 74 | 79 | 85 | 90 | 75 | 6 |
| 25 | Foot length | 175 | 198 | 226 | 231 | 236 | 248 | 287 | 230 | 16 |
| 26 | Foot breadth | 52 | 73 | 84 | 89 | 92 | 102 | 109 | 88 | 9 |
| 27 | Hand grip inside diameter (Max.) | 43 | 45 | 48 | 50 | 52 | 54 | 56 | 50 | 3 |
| 28 | Hand grip strength (Kg) | 20 | 28 | 36 | 43 | 48 | 55 | 66 | 42 | 9 |
| 29 | Weight | 35 | 41 | 48 | 54 | 59 | 68 | 81 | 54 | 9 |

Table 4: Correlation coefficient between different anthropometric body dimensions of male farm workers in standing posture

| Body Dimensions | Height | Weight | Eye Height | Shoulder Height | Elbow Height | Hip Height | Knuckle Height | Finger tip Height |
|-------------------|--------|--------|------------|-----------------|--------------|------------|----------------|-------------------|
| Height | 1 | 0.45 | 0.91 | 0.85 | 0.65 | 0.60 | 0.65 | 0.58 |
| Weight | | 1 | 0.46(ns) | 0.45(ns) | 0.23(ns) | 0.16(ns) | 0.30(ns) | 0.28(ns) |
| Eye Height | | | 1 | 0.85 | 0.69 | 0.62 | 0.65 | 0.61 |
| Shoulder Height | | | | 1 | 0.61 | 0.58 | 0.60 | 0.55 |
| Elbow Height | | | | | 1 | 0.63 | 0.56 | 0.54 |
| Hip Height | | | | | | 1 | 0.57 | 0.55 |
| Knuckle Height | | | | | | | 1 | 0.69 |
| Finger tip Height | | | | | | | | 1 |

ns- Not significant

Table 5: Correlation coefficient between different anthropometric body dimensions of male farm workers in sitting posture

| Body Dimensions | Sitting Height | Sitting Eye Height | Sitting shoulder Height | Sitting elbow Height | Sitting thigh height | Sitting knee Height | Sitting Popliteal Height |
|-------------------------|----------------|--------------------|-------------------------|----------------------|----------------------|---------------------|--------------------------|
| Sitting Height | 1 | 0.73 | 0.69 | 0.52 | 0.27(ns) | 0.52 | 0.50 |
| Sitting Eye Height | | 1 | 0.60 | 0.58 | 0.30(ns) | 0.52 | 0.50 |
| Sitting shoulder Height | | | 1 | 0.55 | 0.30(ns) | 0.57 | 0.56 |
| Sitting elbow Height | | | | 1 | 0.28(ns) | 0.56 | 0.57 |

| | | | | | | | |
|--------------------------|--|--|--|--|---|----------|----------|
| Sitting thigh height | | | | | 1 | 0.08(ns) | 0.22(ns) |
| Sitting knee Height | | | | | | 1 | 0.62 |
| Sitting Popliteal Height | | | | | | | 1 |

Table 6: Correlation coefficient between anthropometric body dimensions of male farm workers in standing posture

| Body Dimensions | StandingHeight | Hand Length | Hand Breadth | Foot Length | Foot Breadth | Span | Forward Grip reach | Overhead Grip reach |
|-----------------|----------------|-------------|--------------|-------------|--------------|------|--------------------|---------------------|
| Standing Height | 1 | 0.45 | 0.40 | 0.52 | 0.35 | 0.60 | 0.60 | 0.60 |

Table 7: Correlation coefficient between different anthropometric body dimensions of female farm workers in standing posture

| Body Dimensions | Height | Weight | Eye Height | Shoulder Height | Elbow Height | Hip Height | Knuckle Height | Finger tip Height |
|-------------------|--------|--------|------------|-----------------|--------------|------------|----------------|-------------------|
| Height | 1 | 0.42 | 0.81 | 0.70 | 0.62 | 0.53 | 0.55 | 0.56 |
| Weight | | 1 | -0.1(ns) | 0.18(ns) | 0.21(ns) | 0.25(ns) | 0.32(ns) | 0.10(ns) |
| Eye Height | | | 1 | 0.85 | 0.69 | 0.62 | 0.65 | 0.61 |
| Shoulder Height | | | | 1 | 0.71 | 0.67 | 0.60 | 0.55 |
| Elbow Height | | | | | 1 | 0.53 | 0.56 | 0.50 |
| Hip Height | | | | | | 1 | 0.61 | 0.59 |
| Knuckle Height | | | | | | | 1 | 0.69 |
| Finger tip Height | | | | | | | | 1 |

Table 8: Correlation coefficient between different anthropometric body dimensions of female farm workers in sitting posture

| Body Dimensions | Sitting Height | Sitting Eye Height | Sitting shoulder Height | Sitting elbow Height | Sitting thigh height | Sitting knee Height | Sitting Popliteal Height |
|--------------------------|----------------|--------------------|-------------------------|----------------------|----------------------|---------------------|--------------------------|
| Sitting Height | 1 | 0.61 | 0.59 | 0.53 | 0.15(ns) | 0.55 | 0.51 |
| Sitting Eye Height | | 1 | 0.54 | 0.55 | -0.15(ns) | 0.56 | 0.54 |
| Sitting shoulder Height | | | 1 | 0.58 | -0.15(ns) | 0.55 | 0.52 |
| Sitting elbow Height | | | | 1 | 0.09(ns) | 0.58 | 0.52 |
| Sitting thigh height | | | | | 1 | 0.28(ns) | 0.32(ns) |
| Sitting knee Height | | | | | | 1 | 0.50 |
| Sitting Popliteal Height | | | | | | | 1 |

ns- Not significant

Table 9: Correlation coefficient between anthropometric body dimensions of female farm workers in standing posture

| Body Dimensions | Standing Height | Hand Length | Hand Breadth | Foot Length | Foot Breadth | Span | Forward Grip reach | Overhead Grip reach |
|-----------------|-----------------|-------------|--------------|-------------|--------------|------|--------------------|---------------------|
| Standing Height | 1 | 0.42 | 0.50 | 0.59 | 0.58 | 0.55 | 0.62 | 0.60 |

Table 10: Comparison of mean anthropometric data of male farmers of North Karnataka from different regions of India

| S.No | Dimensions | North Karnataka region α | Kashmir region $\psi, @$ | Northeastern region Υ, ϵ | West Bengal region ϵ | Maharashtra region $\delta, \#$ | Uttar Pradesh region Ω |
|------|---------------------------|---------------------------------|--------------------------|--|-------------------------------|---------------------------------|-------------------------------|
| 1 | Height | 1649 | 1657 | 1614 | 1627 | 1651 | 1637 |
| 2 | Eye height, standing | 1546 | 1543 | 1535 | NA | 1553 | 1530 |
| 3 | Shoulder height, standing | 1386 | 1370 | 1327 | NA | 1379 | 1380 |
| 4 | Elbow height, standing | 1050 | 1043 | 1014 | NA | 1047 | 1026 |

| | | | | | | | |
|----|----------------------------------|------|-----|------|-----|------|------|
| 5 | Waist height, standing | 963 | NA | 931 | 942 | 1007 | 1029 |
| 6 | Knuckle height, standing | 714 | NA | 691 | NA | NA | NA |
| 7 | Finger tip height, standing | 616 | NA | NA | NA | NA | NA |
| 8 | Sitting height | 842 | 838 | 848 | 842 | 838 | 785 |
| 9 | Sitting eye height | 738 | 732 | 733 | 731 | 741 | 691 |
| 10 | Sitting shoulder height | 570 | NA | 588 | 561 | 568 | 580 |
| 11 | Sitting elbow height | 222 | NA | 246 | NA | 221 | 196 |
| 12 | Sitting thigh height | 128 | NA | 136 | NA | 131 | NA |
| 13 | Sitting knee height | 516 | NA | 495 | NA | 503 | 511 |
| 14 | Sitting popliteal height | 439 | 420 | 417 | 402 | 443 | 421 |
| 15 | Shoulder elbow length | 331 | NA | NA | NA | 386 | 336 |
| 16 | Elbow fingertip length | 453 | 445 | 432 | NA | 457 | NA |
| 17 | Overhead grip reach, sitting | 1193 | NA | NA | NA | NA | NA |
| 18 | Overhead grip reach, standing | 1959 | NA | 1958 | NA | NA | NA |
| 19 | Forward grip reach, standing | 731 | NA | 752 | NA | 710 | NA |
| 20 | Arm length, vertical | 751 | 786 | NA | NA | NA | NA |
| 21 | Downward grip reach | 641 | NA | NA | NA | NA | NA |
| 22 | Span | 1718 | NA | 1670 | NA | NA | NA |
| 23 | Hand length | 185 | 191 | 169 | 176 | 182 | 188 |
| 24 | Hand breadth | 85 | 86 | 78 | 77 | 83 | 80 |
| 25 | Foot length | 241 | NA | 240 | NA | 248 | 251 |
| 26 | Foot breadth | 96 | NA | 98 | NA | 91 | 96 |
| 27 | Hand grip inside diameter (Max.) | 52 | 49 | 48 | 44 | 51 | 51 |
| 28 | Hand grip strength (Kg) | 62 | 31 | NA | NA | 29 | NA |
| 29 | Weight | 60 | 60 | 54 | 52 | 57 | 58 |

Note: α - Present study; ¥ -K.N. Dewangan et al. [27]; € -K. N. Agrawal et al. [4]; £ -V. K. Tewari et al. [28];
 ψ -Jagvir Dixit et al. [29]; @- Jagvir Dixit et al. [30]; δ -S.H. More et al. [3]; # - Pravin K. Bhuse et al. [31];
 Ω- A.M. Abood et al. [32]

Table 11: Comparison of mean anthropometric data of male farmers of North Karnataka with other national population

| S.No | Dimensions | North Karnataka region α | Chinese a, g | Japanese b, f | German c | British d | American e |
|------|-----------------------------|--------------------------|--------------|---------------|----------|-----------|------------|
| 1 | Height | 1649 | 1688 | 1658 | 1745 | 1738 | 1755 |
| 2 | Eye height, standing | 1546 | 1585 | 1566 | 1603 | NA | 1643 |
| 3 | Shoulder height, standing | 1386 | 1421 | 1345 | 1464 | NA | 1435 |
| 4 | Elbow height, standing | 1050 | 1054 | 1064 | NA | NA | 1072 |
| 5 | Waist height, standing | 963 | 998 | NA | NA | NA | NA |
| 6 | Knuckle height, standing | 714 | NA | 740 | NA | NA | NA |
| 7 | Finger tip height, standing | 616 | NA | NA | NA | NA | NA |
| 8 | Sitting height | 842 | 896 | 904 | 921 | 919 | 913 |
| 9 | Sitting eye height | 738 | 794 | 785 | 802 | 803 | 800 |
| 10 | Sitting shoulder height | 570 | 604 | NA | 623 | NA | 598 |
| 11 | Sitting elbow height | 222 | 254 | NA | 243 | NA | 232 |
| 12 | Sitting thigh height | 128 | 125 | NA | 146 | 145 | NA |
| 13 | Sitting knee height | 516 | 484 | 493 | 530 | NA | 558 |

| | | | | | | | |
|----|----------------------------------|------|-----|-----|-----|-----|------|
| 14 | Sitting popliteal height | 439 | 401 | 402 | 454 | NA | 431 |
| 15 | Shoulder elbow length | 331 | NA | NA | 346 | NA | NA |
| 16 | Elbow fingertip length | 453 | NA | NA | NA | NA | NA |
| 17 | Overhead grip reach, sitting | 1193 | NA | NA | NA | NA | 1309 |
| 18 | Overhead grip reach, standing | 1959 | NA | NA | NA | NA | 2106 |
| 19 | Forward grip reach, standing | 731 | NA | NA | NA | NA | 750 |
| 20 | Arm length, vertical | 751 | NA | NA | NA | NA | NA |
| 21 | Downward grip reach | 641 | NA | NA | NA | NA | 665 |
| 22 | Span | 1718 | NA | NA | NA | NA | 1831 |
| 23 | Hand length | 185 | 183 | 182 | 182 | 180 | 194 |
| 24 | Hand breadth | 85 | NA | NA | 81 | 80 | 90 |
| 25 | Foot length | 241 | NA | NA | 255 | NA | NA |
| 26 | Foot breadth | 96 | NA | NA | NA | NA | NA |
| 27 | Hand grip inside diameter (Max.) | 52 | NA | NA | NA | NA | NA |
| 28 | Hand grip strength (Kg) | 62 | NA | NA | NA | NA | NA |
| 29 | Weight | 60 | 59 | 65 | NA | NA | NA |

Note: **α** -Present study; **a** -Shao and Zhou [33]; **b** -Yokohori [34]; **c** -Jurgens et al. [35]; **d** -Haslegrave [36]; **e**-Gordon, Claire C. et. al [37]; **f**-Yu-Cheng Lin et al. [38]; **g**- HaitaoHu et.al [39]

Table 12: Comparison of mean anthropometric data of female farmers of North Karnataka from different regions of India

| S.No | Dimensions | North Karnataka region α | Kashmir region @ | Northeastern region ¥ | West Bengal region £ | Hydrabad Karnataka region δ | Kerala region Ω | Gujarat region Δ |
|------|-------------------------------|--------------------------|------------------|-----------------------|----------------------|-----------------------------|-----------------|------------------|
| 1 | Height | 1509 | 1498 | 1532 | 1499 | 1531 | 1509 | 1506 |
| 2 | Eye height, standing | 1425 | 1424 | 1418 | NA | 1420 | 1404 | 1382 |
| 3 | Shoulder height, standing | 1273 | 1278 | 1271 | NA | 1297 | 1257 | 1244 |
| 4 | Elbow height, standing | 966 | 981 | 962 | NA | 975 | 963 | 911 |
| 5 | Waist height, standing | 943 | NA | NA | NA | 948 | 870 | NA |
| 6 | Knuckle height, standing | 695 | 648 | 664 | NA | NA | 604 | NA |
| 7 | Finger tip height, standing | 581 | NA | NA | NA | NA | NA | NA |
| 8 | Sitting height | 773 | 695 | 803 | 764 | 781 | NA | NA |
| 9 | Sitting eye height | 653 | 603 | 687 | 657 | 677 | NA | 592 |
| 10 | Sitting shoulder height | 533 | 479 | 546 | NA | NA | NA | NA |
| 11 | Sitting elbow height | 195 | 152 | 234 | 211 | 206 | NA | NA |
| 12 | Sitting thigh height | 108 | NA | 143 | NA | NA | NA | NA |
| 13 | Sitting knee height | 492 | 492 | 453 | NA | 449 | 426 | 389 |
| 14 | Sitting popliteal height | 402 | 336 | 353 | 384 | 412 | NA | 356 |
| 15 | Shoulder elbow length | 322 | NA | NA | NA | NA | 366 | NA |
| 16 | Elbow fingertip length | 436 | NA | NA | NA | NA | NA | NA |
| 17 | Overhead grip reach, sitting | 1051 | NA | 1110 | NA | NA | NA | NA |
| 18 | Overhead grip reach, standing | 1775 | NA | 1844 | NA | NA | NA | 1824 |
| 19 | Forward grip reach, standing | 639 | NA | NA | NA | NA | NA | 674 |
| 20 | Arm length, vertical | 728 | NA | NA | NA | NA | NA | NA |

| | | | | | | | | |
|----|----------------------------------|------|-----|------|-----|------|-----|-----|
| 21 | Downward grip reach | 598 | NA | NA | NA | NA | NA | NA |
| 22 | Span | 1543 | NA | 1531 | NA | 1551 | NA | NA |
| 23 | Hand length | 173 | 157 | 165 | 162 | 170 | 153 | NA |
| 24 | Hand breadth | 74 | NA | 65 | 69 | 85 | 58 | 75 |
| 25 | Foot length | 231 | NA | 227 | NA | NA | 230 | 229 |
| 26 | Foot breadth | 89 | NA | 89 | NA | NA | 85 | 93 |
| 27 | Hand grip inside diameter (Max.) | 50 | 37 | 44 | 42 | 45 | 49 | NA |
| 28 | Hand grip strength (Kg) | 43 | NA | NA | NA | NA | NA | NA |
| 29 | Weight | 54 | 46 | 48 | 43 | 47 | 55 | NA |

¥- K.N. Dewangan et.al [27]; £-V-Tewari et.al. [28]; @- Jagvir Dixit [29]; δ- Premkumar et al. [19]; Ω- Bini Sam [40](2013); Δ- Surabhi Sing et al. [41]

Table 13: Comparison of mean anthropometric data of female farmers of North Karnataka with other national population

| S.No | Dimensions | North Karnataka region α | Chinese a | Japanese b | Malaysia c | British d | American e |
|------|----------------------------------|--------------------------|-----------|------------|------------|-----------|------------|
| 1 | Height | 1509 | 1586 | 1569 | 1560 | 1515 | 1570 |
| 2 | Eye height, standing | 1425 | 1473 | 1448 | 1448 | 1420 | 1451 |
| 3 | Shoulder height, standing | 1273 | 1303 | 1270 | 1293 | 1240 | 1271 |
| 4 | Elbow height, standing | 966 | 1002 | 984 | 982 | 945 | 984 |
| 5 | Waist height, standing | 943 | NA | 967 | NA | NA | 967 |
| 6 | Knuckle height, standing | 695 | NA | NA | NA | NA | NA |
| 7 | Finger tip height, standing | 581 | NA | 611 | NA | NA | NA |
| 8 | Sitting height | 773 | 767 | 850 | 783 | 785 | 848 |
| 9 | Sitting eye height | 653 | 665 | 732 | 677 | 685 | 738 |
| 10 | Sitting shoulder height | 533 | 517 | NA | 523 | 515 | NA |
| 11 | Sitting elbow height | 195 | 186 | 253 | 193 | 205 | 250 |
| 12 | Sitting thigh height | 108 | 130 | 129 | .136 | 140 | 129 |
| 13 | Sitting knee height | 492 | NA | 412 | NA | NA | 456 |
| 14 | Sitting popliteal height | 402 | 399 | 362 | 393 | 380 | 383 |
| 15 | Shoulder elbow length | 322 | NA | NA | NA | NA | 358 |
| 16 | Elbow fingertip length | 436 | NA | NA | NA | 405 | NA |
| 17 | Overhead grip reach, sitting | 1051 | NA | NA | NA | NA | 1221 |
| 18 | Overhead grip reach, standing | 1775 | 1883 | NA | 1843 | NA | 2024 |
| 19 | Forward grip reach, standing | 639 | 663 | NA | 683 | NA | 716 |
| 20 | Arm length, vertical | 728 | NA | NA | NA | NA | NA |
| 21 | Downward grip reach | 598 | NA | NA | NA | NA | NA |
| 22 | Span | 1543 | NA | NA | NA | NA | NA |
| 23 | Hand length | 173 | 173 | 168 | 166 | 165 | 172 |
| 24 | Hand breadth | 74 | 68 | 78 | 73 | 70 | 78 |
| 25 | Foot length | 231 | 235 | NA | 228 | 229 | 247 |
| 26 | Foot breadth | 89 | 87 | NA | 85 | 93 | 94 |
| 27 | Hand grip inside diameter (Max.) | 50 | NA | NA | NA | NA | NA |
| 28 | Hand grip strength (Kg) | 43 | NA | NA | NA | NA | NA |
| 29 | Weight | 54 | 55 | 52 | 55 | NA | 62 |

a- K. Karmegam et al. [42]; b- Yu-Cheng Lin et al. [38]; c- Karmegam et al, [43]; d- BS4467, British Standard [44]; e- NASA data ; Mandy Stirling; S.A. Lavendera[45,46]

Table 14: Application of anthropometric data in different agricultural situations

| S.No | Anthropometric Dimensions | Usefulness and applications in agriculture |
|------|----------------------------------|---|
| 1 | Height | <ul style="list-style-type: none"> To design proper handle height. It should be designed ensuring that the operator is standing erect while operating. Design of controls, display positions of equipments. Handle height for animal driven plough. Handle of manual, semi-automatic or fully automatic weeder. Handle of seed sowing equipment. Design of Lever operated knapsack (LOK) sprayer. Design of power operated thresher, feeding chute height. Lift studies and analysis in force applications. |
| 2 | Eye height, standing | |
| 3 | Shoulder height, standing | |
| 4 | Elbow height, standing | |
| 5 | Waist height, standing | |
| 6 | Knuckle height, standing | |
| 7 | Finger tip height, standing | |
| 8 | Sitting height | <ul style="list-style-type: none"> Design of seating system for tractors, power tiller, planter. Work place layout design, working area space designs. Design of lever, push-pull buttons, control panels, display devices from the sitting position. Design of display systems, visual observation systems. Clearance between seat and steering system or inner portion of working table. Design of sitting mechanisms for thresher, cutter, harvester, plant feeder. Steering wheel position and orientation. |
| 9 | Sitting eye height | |
| 10 | Sitting shoulder height | |
| 11 | Sitting elbow height | |
| 12 | Sitting thigh height | |
| 13 | Sitting knee height | |
| 14 | Sitting popliteal height | |
| 15 | Shoulder elbow length | |
| 16 | Elbow fingertip length | <ul style="list-style-type: none"> Control buttons, levers position to be designed within the operator's reach. Workplace, working space design and design of controls. Lift, pick-up studies, workplace layout designs Design of gear levers, position control levers, various pull type control levers. |
| 17 | Overhead grip reach, sitting | |
| 18 | Overhead grip reach, standing | |
| 19 | Forward grip reach, standing | |
| 20 | Arm length, vertical | |
| 21 | Downward grip reach | |
| 22 | Span | <ul style="list-style-type: none"> To design Handle grip diameter for Hand Tools and Manually Operated Equipment To design Handle length for Hand Tools and Manually Operated Equipments To design hand operating buttons, emergency knobs diameters for push-pull operations. Design of hand gloves. To design foot operated pedals, knobs, buttons or levers. Design of safety shoes. Design of hand operated levers, braking system, clutch mechanisms, sprayer triggers. |
| 23 | Hand length | |
| 24 | Hand breadth | |
| 25 | Foot length | |
| 26 | Foot breadth | |
| 27 | Hand grip inside diameter (Max.) | |
| 28 | Hand grip strength (Kg) | <ul style="list-style-type: none"> Strength analysis of various elements where full body weight is acting like on seat, platform for thresher, harvester, plough etc. Load carrying capacity of individual farm worker. Push-pull strength for operating an equipments, Foot/leg strength for operating a pedal or lever. Cranking torque and steering strength for cutters, steering wheels and manual crusher. |
| 29 | Weight | |

and importance of each data in the agricultural sector is discussed in Table 14.

The mean data value is compared with the other Indian regional data and with the data of the rest of the world as presented in Table 10, 11, 12 and 13. From the analysis it found that there is a considerable difference in the body dimensions when compared with the other ethnic population of the world. However, as compared with Indian population of different regions there is a slight variation in dimensions were observed.

The body height is an important dimension to be considered first when designing any agricultural tool, equipment or machinery because of its significance in influential to several other body dimensions. The 5th, 25th, 50th, 75th and 95th percentile values of stature for male agricultural workers were found to be 1430mm, 1530mm, 1610mm, 1646mm, 1684mm and 1745mm respectively. However, their female counterpart's values are 1370mm, 1414mm, 1462mm, 1509mm, 1541mm and 1632mm. The design parameter of any agriculture tools or equipments should not exceed from the data obtained from the study, otherwise the tools or equipments will be awkward for the users in their daily usage.

Further investigation on the data obtained showed that the mean eye height standing, shoulder height standing, elbow height standing, waist height standing, knuckle height standing and finger tip height standing of female workers were found to be 90%-97% of corresponding body dimensions of male farm workers. The sitting anthropometric data like sitting height, sitting eye height, sitting shoulder height, sitting elbow height, sitting thigh height, sitting knee height and sitting popliteal height of female farm workers range from 85%-95% of the male counterparts. Except for hand grip strength, all other anthropometric data of female workers range from 86%-96% of the male data. The mean hand grip strength of female worker was found to be 66% of the male hand grip strength.

Handle is the most important part of the agricultural tool, equipment and machinery. The height of the handle for Weeder, Sowing Equipment or animal driven Plough depends upon the elbow height of the user. The mean standing elbow height of male and female farm workers was found to be 1044 mm and 966 mm respectively. However, to suit the handle height to the remaining population, some height adjusting mechanisms must be incorporated in the equipment of machinery. The handle diameter should be designed based on the 5th percentile of hand grip inside diameter which is 46 mm for male and 45 mm for female. The length of the handle is to be designed for the 95th percentile of hand breadth data, which is 106 mm for male and 90 mm for female. After adding a clearance of 5 mm on each side of the handle, the recommended handle length is 116 mm.

A correlation coefficient was produced to measure the correlation between the different anthropometric data with other relative parameters. These correlations help us in determining the degree of relationship between variables. A correlation between variables indicates that as one variable changes in value, the other variable tends to change in a specific direction.

Three category of data: standing body linear measurements, sitting body linear measurements and standing with other remaining measurements were prepared separately for male and female workers as presented in Table 4, 5, 6, 7, 8, and 9. It is seen from the result that, correlation coefficients which are higher than 0.115 are significant at 5% level. The correlation table reveals that all parameters are correlated with each other. The maximum correlation is found between the eye height and the body height, which is 0.91 for male and 0.81 for female farm workers.

Conclusion

The current work presents the study related to the anthropometric data of farm workers in northern Karnataka region of India. The body dimensions and muscular strength of male farm workers is greater than the female workers. The mean stature and body weight of male farm worker are 1649 mm and 60 kg and 1509 mm and 54 kg for female workers. The mean dominating hand strength values are 65 kg for male workers and 43 kg for female workers.

The anthropometric data presented in Table 2 and 3 of male and female farm workers of northern Karnataka region respectively indicates that the body dimensions are smaller than the data of the other ethnic population from China, Japan, Germany, British and America. However, slight differences in the body dimensions are observed from the anthropometric data of other part of the country. From the correlation coefficient study it is seen that, most of the data are correlated positively and significantly with its other related data. The maximum correlation is found between the eye height and the stature, which is 0.91 for male and 0.81 for female farm workers.

Ergonomic approach in designing farm tools, implements and machinery is seldom practiced in developing countries like India due to lack of availability of anthropometric database of the user group in various regions of the country. The data will help the designers and manufacturers in developing improved farm tools, implements and machinery for a particular area. The data thus generated can also be utilized in improving the currently being used farm tools, implements and machinery from other parts of the country. This can reduce work related injuries and occupational health problems in Indian agricultural scenario.

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