Anthropometric survey of farm workers of Ladakh region of India and its application in equipment design

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Abstract: The environment and resultant discomfort has severe impact on overall working efficiency of human and machine while using farm tools and machinery in hills. The Ladakh region of Jammu and Kashmir State of India is predominantly hilly. Anthropometric data of agricultural workers is very essential for the safe and efficient design of farm machinery. In the present studies, an anthropometric survey was carried out for agricultural workers of Ladakh region, wherein 90 male and female agricultural workers were selected and 79 body dimensions were precisely measured and recorded from each subject, thereafter analysed statistically. For making the data comprehensive and more useful, a set of 23 body dimensions, which are having direct implications on agricultural tool/implement design were selected, and compared with data of different regions of India and also with those of Egyptian, Japanese, British, Thailand, Mexican and Chinese workers. There were significant differences in stature and other body dimensions among the populations. From these data, it appears that values of body dimensions of Ladakh workers were lesser than those of five other regions of India and six other countries as mentioned above. In stature, Ladakhi men were shorter by 5.08 cm as compared to North-eastern Indian male workers. Similarly, Ladakhi women were shorter by 12.65 cm as compared to British women. The Ratio of sitting height to stature (RSH) of Indian women (present study) was found lower (0.46) as compared to those of Egyptian (0.52), Japanese (0.53), British (0.53), Thailand (0.53) and Chinese (0.54). The obtained results indicate that Indian women are short legged. These results suggest that it is essential to generate the necessary anthropometric data of different regions of the country through extensive surveys for designing region specific farm machineries to properly exploit the working potential of farm workers. Application of this data on tool design is illustrated through some examples.

Keywords: anthropometric survey, body dimensions, agricultural workers, tool design

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1 Introduction

The present need for the use of agricultural machineries/ equipments for agricultural mechanization require a good knowledge and proper design of agricultural equipment with special consideration to efficiency, safety and comfort of people while using them. Ladakh division of the Jammu and Kashmir state comprises of Leh and Kargil districts. It is inhabited by different ethnic groups residing in remote, inaccessible, resource-poor high altitude zone in western Himalayas. This region has witnessed little change or advancement in the operative economic and technological level over the centuries. The region represents about 44% of the total area of Jammu and Kashmir State, and is one of the most elevated regions on earth (Bhasin and Nag, 2002). The

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region varies considerably with factor such as race from the rest of the country and state. The people of the region belong mainly to the mongoloid ethnic while in rest of India; people are of Aryan ethnic group except in north-eastern states. Mostly animate power source is utilized for performing agricultural operations due to inherited constraints like difficult terrain, wide variation in slopes and altitudes, land tenure systems and cultivation practices. Due to lack of fabrication facility in the region, the variety of equipment, including hand tools developed for Jammu and Kashmir division are generally used. Apparently the body dimensions of these farm workers are shorter than that of Jammu and Kashmir region. Mismatches between human anthropometric dimensions and equipment dimensions are known to be a contributing factor in decreased productivity, discomfort, accidents, biomechanical stresses, fatigue, injuries and cumulative traumas.

Anthropometric dimensions are one of the essential factors in designing machines and devices (Mebarki and Davies, 1990). The design and dimensions of agricultural tools and implements have a great bearing on the body dimensions and physical built of the users, requiring compatibility essentially between machine devices and worker body dimensions. The only way to fulfil this objective is to create database of anthropometric dimensions of the user population. Majority of the earlier studies involving anthropometric data survey are case studies and generally, considering male workers only (Gite and Yadav, 1989; Dewangan et al., 2005). In India, it is estimated that 88% of rural women working population is engaged in agricultural sector, which is nearly 50.2% of the total agricultural labour force (Reddy et al., 1994). Most of the anthropometric data is limited to male agricultural workers of India (Sen, 1964; Gupta et al., 1983; Gite and Yadav, 1989; Dewangan et al., 2005). In the recent past some step have been taken up to collect anthropometric data of female workers in India (Tewari and Ailavadi, 2002; Dewangan et al., 2008, Dixit and Namgial, 2012). Due to paucity of female anthropometric data, anthropometric data of male workers are extrapolated to define women at work whenever necessary. Such an approach is likely to be inaccurate due to obvious anthropometric, physiological and biomechanical differences between male and female subjects (Cox et al., 1984). The body dimensions vary with age, sex, ethnic groups (Sanders and McCormick, 1992). There is considerable difference between the anthropometric data of Indian and Western population emphasizing the need of generating anthropometric database for agricultural workers (Gite and Singh, 1997, Dixit and Namgial, 2012) as it is not feasible practically to design equipments for an individual sex (male or female).

In view of the above discussion, the present study was conducted to generate anthropometric data of male and female agricultural workers of Ladakh region. The data so collected will be the first of its kind in the Ladakh region. These data can be compared with those of other regions of the country as well as with other countries, for the consideration of ergonomic design of agricultural equipment and machines.

2 Materials and methods

2.1 Equipment used

An integrated composite anthropometer (ICA) designed and developed at the Indian Institute of Technology (IIT), Kharagpur, India was used to measure the anthropometric dimensions (Figure 1). It facilitates the measurement of vertical, transverse and circumferential body dimensions in standing as well as in sitting posture. It consists of base platform, backrest, seat pan, telescopic supports, rope and pulley arrangement and arrangement for force measurement. The base platform forms reference surface for vertical dimensions. The lower part of long backrest is separate and can be converted to seat pan by folding it at an angle of 90° to the backrest and the seat pan is supported by a telescopic square cross section pipe. A pin arrangement is provided to adjust the height of the seat pan, which becomes the reference frame for measuring body dimensions in seated posture. Vertical measurements are measured on a steel tape. One end of the tape is fixed at an appropriate location on the base platform while the body of the tape is hinged at top of square pipe attached to frame of a long backrest. A transverse scale with a pointer running on vertical scale is provided to observe the data accurately and precisely. This scale is used to measure the dimensions in the horizontal plane. The seat pan and long backrest are adjustable by means of a rope and pulley arrangement for different body dimensions. A wooden cone was used to measure internal grip diameter and a steel hole template of 12 different sizes (13-24 mm) was used to measure the diameter of index finger. A portable weighing scale (0-125 kg) was used for body weight. Skin fold calliper was used for measuring of skin dimensions. Vernier calliper was used to measure the hand and foot dimensions with a sensitivity of 0.1 mm.

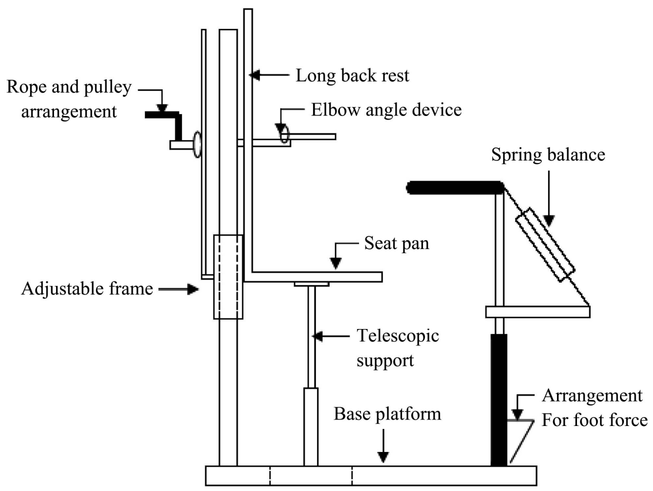

Figure 1 Integrated Composite Anthropometer used in the study (Tewari et al., 2007)

2.2 Subjects

An anthropometric survey was carried out in all the districts of the Ladakh region (Leh and Kargil) of Jammu and Kashmir State of India. From each district, two to three villages were selected. The subjects were selected among farmers and agricultural labours. As per recommendation of AICRP on ESA, a total of 90 subjects (60 males + 30 females) in the age group of 18-60 years of age were randomly chosen from two districts. All the subjects were paid for their time and participation.

2.3 Body dimensions

Seventy-nine body dimensions as recommended by the AICRP on ESA, India (Gite and Chatterjee, 1999) were included for this study. Due attention has been given to basic human body measurements for technological design (Anonymous, 1996) and the recommendations of the conference on standardization of anthropometric techniques and terminologies (Hertzberg, 1968). Standard terminologies as given in the Anthropometric Source Book (Anonymous, 1978) have been used in the present studies. In the standing posture, there are 49 measurements including 16 vertical dimensions, 9 transverse dimensions, 5 circumferential dimensions, 18 fore limb measurement and 1 weight. In the sitting posture, there are 16 measurements namely 8 heights and 8 transverse measurements. In sitting/ standing posture the number are 14, namely 7 hind limbs, 3 head dimensions and 4 skin fold dimensions.

2.4 Procedure

The standard proforma developed by AICRP on ESA, Bhopal, India was used for collecting data. Prior to collecting anthropometric data, survey team was given adequate training on the identification of the landmarks and measurement procedure as recommended by ICA for accurate and precise measurement of identified body dimensions. The trained staff members collected anthropometric dimensions of the selected subjects in each village. The subjects were informed with the objectives of the study, body dimensions, measurement procedures and clothing requirement. The data of female workers was collected by the well trained women investigators.

For measuring body dimensions in standing posture, subjects were asked to stand on base platform of ICA with their feet closed and their body vertically erected, while heels, buttocks and shoulders touched the same vertical plane. ICA was adjusted for height of the subject. Similarly, in the sitting posture, subjects were asked to sit with their body vertically erect, while their shoulders and head touched the same vertical plane. In sitting posture, feet of the subject completely touched the base platform. Subjects were bare footed with light clothes during measurement to minimize errors. During the measurement of body dimensions, care was taken to avoid any excessive compression of underlying tissues and to avoid incorrect measurement. The sequence of measurement was from standing to sitting postures.

The collected data were used to compute minimum, maximum, mean, standard deviation, 5^{th} and 95^{th} percentile values of each anthropometric measures using

Microsoft excel (USA) software package and results are presented in Table 1. Data of mean of 8 selected body dimensions of Ladakh male agricultural workers were compared with those of other regions of India (i.e. Southern, Eastern, North eastern, central and western India) and are presented in Table 2. Similarly, data on mean selected body dimensions of Indian female agricultural workers surveyed were compared with those of Egyptian, Japanese, Mexican, Thailand, British and Taiwanese (Table 3).

Table 1 Anthropometric dimensions of male and (female) agricultural workers of Ladakh region of India

Sl. No	Dimensions	Range (Min. – Max.)	Mean	Standard deviation	5th percentile	95th percentile
1	Weight (kg)	45.0 (43.0) -70.0 (77.0)	56.8 (49.4)	6.5 (3.4)	46.9 (43.8)	66.7 (55.0)
2	Stature	151.9 (140.1) -166.8 (155.0)	157.7 (149.8)	4.2 (3.1)	153.3(144.8)	166.2 (154.8)
3	Elbow rest height	15.1 (11.3)- 20.4 (17.3)	20.4 (15.2)	1.2 (1.3)	16.0 (13.1)	20.0 (17.4)
4	Iliocrystale height	85.6 (87.4) -99.4 (95.5)	93.3 (91.8)	4.0 (1.8)	86.7 (88.8)	99.9 (94.8)
5	Metacarpal-III height	54.3 (52.1)- 69.5 (68.9)	69.5 (61.0)	4.1 (5.2)	56.1 (52.3)	69.4 (69.6)
6	Waist circumference	69.3 (64.3) – 86.3 (82.3)	75.0 (76.4)	3.7 (3.4)	68.9 (70.8)	81.1 (82.1)
7	Arm reach from the wall	70.6 (60.0) – 84.3 (76.3)	78.6 (70.4)	3.9 (3.5)	72.1 (64.6)	85.0 (76.2)
8	Scapula to waist back length	42.9 (37.8) – 53.3 (50.6)	48.5 (45.0)	2.6 (3.3)	44.2 (39.7)	52.7 (50.4)
9	Sitting height	72.4 (54.1) – 86.4 (83.1)	80.5 (69.5)	4.0 (5.9)	73.9 (59.7)	87.0 (79.2)
10	Sitting eye height	62.3 (46.3) - 76.1(72.9)	71.0 (60.3)	3.8 (5.6)	64.8 (51.1)	77.2 (69.5)
11	Sitting acromion height	48.5 (35.2) – 63.4 (55.9)	55.4 (47.9)	3.7 (4.3)	49.3 (40.9)	61.4 (54.9)
12	Popliteal height sitting	31.8 (22.3) - 43.8 (42.4)	37.7 (33.6)	3.0 (4.3)	32.7 (26.5)	42.6 (40.7)
13	Buttock knee length	46.0 (40.9) – 55.1 (54.8)	50.1 (49.2)	2.2 (3.0)	46.4 (44.3)	53.8 (54.0)
14	Buttock popliteal length	38.4 (32.9) – 49.9 (47.6)	43.0 (40.8)	2.8 (3.4)	38.5 (35.1)	47.6 (46.4)
15	Forearm hand length	36.4 (30.2) – 45.9 (39.4)	41.4 (34.6)	2.7 (2.3)	37.0 (30.8)	45.8 (38.4)
16	Elbow grip length	29.9 (22.4) – 41.5 (31.8)	34.0 (25.9)	2.5(2.5)	29.9(21.8)	38.1(30.0)
17	Grip span	5.0 (2.9) – 6.2 (6.9)	5.6 (4.9)	0.3 (0.6)	5.1(4.3)	6.3 (6.3)
18	Hand breadth at metacarpal-III	7.6 (5.4) – 9.3 (9.4)	8.3 (7.5)	0.4 (0.7)	7.6 (6.4)	8.7 (9.0)
19	Hip breadth sitting	30.1(30.1) – 34.5 (36.9)	32.07 (34.1)	1.0 (1.6)	31.1 (31.4)	34.3 (36.7)
20	Grip diameter (inside)	4.0 (2.7) – 5.0 (4.7)	4.5 (3.7)	0.3 (0.5)	4.0 (3.0)	5.0 (4.5)
21	Middle finger palm grip dia.	2.5 (2.0) – 3.5 (3.8)	3.1 (2.7)	0.3 (0.4)	2.6 (2.1)	3.6 (3.4)
22	Hand length	17.4 (13.7) –20.3(17.7)	19.1 (15.7)	0.7 (0.9)	17.9 (14.1)	20.3 (17.2)
23	Age (years)	27.0 (22.0) – 49.0 (40.0)	36.3(32.9)	5.8 (5.1)	26.7 (24.5)	45.8 (41.3)

Note: All the dimensions are in cm until otherwise specified.

Table 2 Comparison of mean and SD values of anthropometric data of male agricultural workers of Ladakh region, India with those from different regions of India

Body dimension	Ladakh region	Southern India[a]	Central India[b]	Western India[c]	North eastern India[d]	Eastern India[e]	Ladakh Vs Southern India	Ladakh Vs Central India	Ladakh Vs North eastern India	Ladakh Vs Eastern India
Stature	157.7 (4.2)	160.7 (6.0)	162.0(5.0)	164.4	162.7 (6.5)	162.1 (5.8)	-1.37	-2.43	-5.72*	-3.38*
Sitting height	80.5 (4.0)	79.1 (4.0)	83.8 (2.5)	86.2	84.2 (3.8)	80.9 (2.2)	2.24	-5.05*	-7.07*	-0.73
Sitting eye height	71.0 (3.8)	70.1 (4.6)	73.9 (2.6)	-	73.1 (4.4)	71.4 (2.0)	1.41	-4.51*	-4.20*	-0.77
Acromian height (sitting)	55.4 (3.7)	52.9 (3.9)	55.7 (2.1)	-	56.1 (3.1)	53.4 (2.1)	4.24*	-0.51	-1.45	3.91*
Popliteal height	37.7 (3.0)	47.1 (3.5)	41.6 (2.1)	42.0	40.2 (2.2)	42.0 (1.7)	-18.96*	-7.60*	-6.40*	-10.38*
Buttock popliteal length	43.0 (2.8)	44.7 (2.3)	46.6 (1.8)	45.6	41.4 (3.2)	46.2 (2.3)	-4.10*	-7.79*	4.34*	-7.76*
Fore arm hand length	41.4 (2.7)	40.1 (2.5)	45.9 (2.0)	-	44.3 (2.6)	44.6 (2.0)	3.15*	-9.51*	-8.21*	-8.23*
Hand length	19.1 (0.7)	16.4 (1.4)	18.3 (0.8)	19.1	17.6 (1.0)	17.8 (1.6)	6.53*	-5.74*	-2.15	-2.42
Ratio of sitting height to stature	0.50	0.49	0.52	0.52	0.52	0.50	-	-	-	-

Note: Unit: cm unless otherwise stated, *Significant (p<0.01); [a] Fernandez and Uppugonduri (1992), [b] Gite and Yadav (1989), [c] Sen (1964), [d] Tewari et al.(2007), [e] Yadav et al. (1997).

Table 3 Comparison of mean and SD values of selected body dimensions for female agricultural workers of India and other foreign countries

Body dimensions	Indian data (Ladakh region)	Egyptian[a]	Japanese[b]	British[c]	Thailand[d]	Mexican[e]	Chinese[f]
Stature	149.80 (3.10)	160.60 (7.18)	159.60	162.45 (5.50)	157.94 (5.32)	153.50 (5.50)	158.62 (5.13)
Eye height	140.70(3.50)	149.20 (6.98)	144.80	-	146.29 (5.15)	142.80 (5.60)	148.03 (7.60)
Acromial height (standing)	126.90 (2.30)	130.60 (5.99)	127.00	-	129.71 (4.94)	-	132.03 (6.10)
Elbow height (standing)	97.40 (1.90)	95.50 (4.35)	98.30	-	99.02 (6.15)	95.60 (3.80)	-
Sitting height	69.50 (5.90)	83.80 (4.30)	85.00	-	83.70 (5.00)	-	84.85 (3.16)
Popliteal height (sitting)	33.60 (4.30)	-	36.20	-	40.17 (1.41)	-	38.27 (2.08)
Buttock knee length	49.20 (3.00)	56.50 (3.99)	53.10	60.09 (2.70)	54.54 (2.51)	-	52.78 (3.13)
Buttock popliteal length	40.80 (3.40)	42.60 (3.34)	43.70	-	46.43 (2.22)	-	43.18 (3.03)
Hip breadth (sitting)	34.10 (1.60)	36.60 (2.51)	-	36.40 (2.69)	36.15 (2.18)	-	-
Hand length	15.80 (0.70)	17.10 (1.24)	-	-	16.61 (0.73)	16.90 (0.90)	-
Forearm hand length	34.60 (2.30)	41.20 (2.60)	-	42.68 (1.83)	-	41.50 (1.90)	-
Thigh clearance	9.20 (1.10)	14.00 (1.16)	-	15.60 (1.57)	12.01 (1.03)	-	-
Ratio of sitting height to stature	0.46	0.52	0.53	0.53	0.53	-	0.54

Note: Unit: cm unless otherwise stated. [a] Moustafa et al. (1987), [b] Anonymous (1994), [c] Haslegrave (1980), [d] Pheasant (1988), [e] Liu et al. (1999), [f] Shao and Zhou (1990).

3 Results and discussions

The computed minimum, maximum, mean, standard deviation and coefficient of variation, 5th and 95th percentile values of selected 23 anthropometric measures recorded using Microsoft excel (USA) software package are presented in Table 1. The z-test was performed to determine the differences between mean values of the Ladakh male data and the five other regions of the country. A set of 8 body dimensions (viz. Stature, Sitting height, Sitting eye height, Acromian sitting height, Popliteal height, Buttock popliteal length, Fore arm hand length, Hand length and Ratio of sitting height to stature) were selected for comparison.

The results (Table 2) indicated that Ladakh male workers are smaller in stature, eye height, popliteal height, buttock popliteal length, fore arm hand length and hand length than other regions of the India except Southern India. Similarly there is significant variation in other body dimensions also.

In stature, Ladakh male workers are shorter by 4.7 cm as compared to Western Indian male agricultural workers. Acromian height of Ladakh male workers was found higher than those of Southern and eastern Indian male workers. Ratio of sitting height to stature of male population surveyed was computed. The value was compared with those from different regions of India and also presented in Table 2. The results from the z-test showed that geographical origin had an effect on Indian anthropometric data. This might be due to variation in races and ethnic group. The comparison between the populations from different regions of the country indicated that there were some dimensions that were significantly different. Male agricultural workers from Ladakh region were significantly shorter than the Central, Eastern and North-eastern Indian male workers. However, there was no significant difference between Ladakh and Southern India workers in terms of stature. The geographical locations have reflected their influence on body dimensions of Ladakh worker with that of Southern region (Fernandez and Uppugonduri, 1992), Central region (Gite and Yadav, 1989), Western region (Sen, 1964), North eastern region (Tewari et al., 2007), and Eastern regions (Yadav et al., 1997). There was also significant variation in most of the body dimensions among populations from different regions of the country (Table 2).

Differences in anthropometric characteristics exist between different populations (Liu et al., 1999). Similar view is expressed for four ethnic groups, namely Chinese, Japanese, Korean and Taiwanese (Lin et al., 2004). These suggest that the morphological characteristics among the four people in East Asia are dissimilar. Further, ethnic differences in body shape are also affected by heredity, economic development, social environment, type of work and labour structure (Lin et al., 2004). Significant differences in most of the body dimensions have also been reported between female agricultural workers from Adi tribe with Apatani, Nishi and Mizo tribes of North-east region of India (Dewangan, et al., 2008).

The anthropometric data of female workers from this study were then compared with the anthropometry of the population from six foreign countries viz. Egyptian (Moustafa et al., 1987), Japanese (Anonymous, 1994), British (Haslegrave, 1980), Thailand (Pheasant, 1988), Mexican (Liu et al., 1999) and Chinese (Shao and Zhou, 1990). The results from the anthropometric data of Ladakh female workers varied subsequently from that of other foreign countries (Table 3). It could be seen that Ladakh female workers were shorter by 12.65, 10.8, 9.8, 8.14, 3.7 and 8.82 cm than British, Egyptian, Japanese, Thailand, Mexican and Chinese, respectively. However, elbow height standing of Ladakhi female was higher than those of Egyptian and Mexican female workers. Similarly, there is variation in other body dimensions too. The value of ratio of sitting height to stature of female workers surveyed was calculated and compared with other foreign countries (Table 3). It can be seen that sitting height to stature ratio of Ladakhi female is lower (0.46) than those of Egyptian (0.52), Japanese (0.53), British (0.53), Thailand (0.53) and Chinese (0.54) female workers. Anthropometric dimensions appeared to differ among various nationalities as shown in Table 3. The selected workers in this study belong to Mongoloid race, and it was observed that variation exists among the Mongoloid race of different regions (Bhasin and Nag, 2002). Similar views have been expressed by Dewangan et al. (2008). The differences found in the anthropometric dimensions of the different population groups emphasize the usefulness of this study in the context of design of farm tools and implements.

This study provides some selected body dimensions required for the design/design modification of agricultural tools and machinery.

Therefore, the anthropometric data of other regions of India and foreign countries can not be used for designing of farm machinery to be used in the region, as it might lead to lower efficiency, which will be contrary to the expectation from farm mechanization. This implies that the house appliance and farm equipment designed at other places should be suitably modified before introducing these to local conditions.

4 Application of Anthropometric Measures in hand tools/equipment design

For the scientific design of hand tools/equipment, an anthropometric database is prerequisite. The real value of anthropometric database lies in its applications. However, from a survey among the professional designers and engineers it appears that many of the professionals are not familiar with the use of anthropometric data in the design of machinery (Wang et al., 1999). In order to illustrate the application of collected anthropometric data of the study for developing/modifying some existing hand tools used in the region, some examples are given below:

4.1 Size of handle for hand tools

The farmers of the hilly regions commonly used various hand tools like sickle, spade, hand hoe (*khurpi*) etc. These hand tools consist of a wooden handle and functional part. Design of a handle depends on factors like mode of operation, material of handle, shape of handle and anthropometric data of user population. The proper size of handle of hand tools increases the efficiency and reduces the drudgery. Handle grip and grip length are two important parameters to be considered for the size of handle of hand tools. The newely design handle for hand tools might be helpful in improving the work output per unit time of the workers.

4.1.1 Handle grip

Anthropometrically, the diameter of the handle should be such that while an operator grips the handle, his longest finger should not touch the palm and also it should not exceed the internal grip diameter. Therefore, the handle diameter should be according to 5th percentile value of the inside grip diameter to accommodate larger population group. This value is 4.0 and 3.0 cm for male and female, respectively. Thus, the handle diameter recommended is 3.0 cm (Table 4).

Table 4 Modified dimensions of sickle handle

Parameter	Specifications of handles used in locally available sickles	Proposed dimensions of sickle handle
Diameter of handle/mm	34.0	30.0
Length of handle/mm	125.0	100.0

4.1.2 Grip Length

The optimum value for the grip length should be such that his/her widest palm should accommodate in the handle. Based on the anthropometric considerations, the length of handle should accommodate the maximum dimension of hand breadth across thumb. The 95th percentile value of hand breadth at metacarpal-III of male and female workers have been found to be 8.7 and 9.0 cm, respectively. Taking a clearance of 0.5 cm on each side of the grip, the length of handle comes to 9.7 and 10.0 cm, respectively. Therefore, the length of the handle recommended is 10.0 cm.

4.2 Size of Octagonal Maize Sheller

The marginal and small farmers of hilly region extensively use octagonal maize sheller for maize shelling and generally women perform this operation. It is a hand operated tool to shell maize from dehusked cobs. The unit consists of four tapered fins in the inner periphery to make an octagonal shaped maize sheller. The sheller is held in one hand, a cob held in other hand (preferable hand) is inserted into it with forward and backward twist, to achieve the shelling. The sheller is held such that finger and thumb make a grip around the sheller. The locally available maize shellers purchased from other parts of the country were not suitable for the population of this region due to variation in size of hand and other body dimensions. Hence, the proposed design based upon the anthropometric dimensions of the agricultural workers of the region might be more acceptable and efficient. Length and external diameter of sheller are two design parameters to be considered. The length and external diameter of sheller used in the region was 7.0 and 6.1 cm respectively. The diameter of fins is in taper from 3.2 to 4.2 cm (inlet to outlet). Based on anthropometric consideration, the external diameter of sheller should not exceed the grip span of user (say female). Therefore, the external diameter of sheller should be 5th percentile value of grip span to accommodate the larger population group. This value is 4.3 cm for female workers. For efficient work, the length (width) of sheller should accommodate the maximum dimension of hand breadth at metacarpal-III. The 95th percentile value of above dimension for female is 9.0 cm. The internal diameter of fins should be as per the cob specification. Based on studies, the average size of maize cobs varies from 3.0-4.2 cm. Hence the internal diameter of fins should be in taper from 3.0 to 4.2 cm. To accommodate the internal diameter (4.2 cm) of fins, the external diameter of maize cob sheller recommended is 5.0 cm. Based on the anthropometric considerations, the modified dimensions of the octagonal maize sheller are shown in Figure 2.

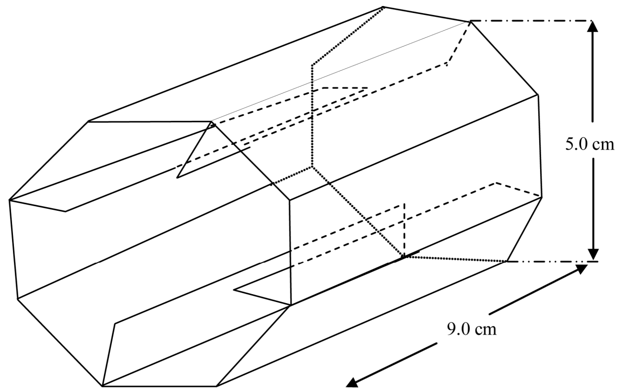

Figure 2 Modified Octagonal Maize Sheller

5 Conclusions

Anthropometric and strength data of male and female agricultural workers aged between 18-60 years, of Ladakh region of India were collected and summarized. There are substantial inter-regional differences in anthropometric dimensions. The Ladakh people are different from other regions of the India in various body dimensions due to different geographical location. The Ladakhi (1.58 m) men were significantly shorter than the other regions of India (mean height 1.62 m). When compared to Egyptian, Japanese, British, Thailand, Mexican and Chinese workers it can be seen that Indian female population of Ladakh region are shorter in most of the body dimensions. Stature were (mean + SD) Indian 149.8+3.10, Egyptian 160.6+7.18, British 162.4+5.50, Thailand 157.9+5.32, Mexican 153.5 +5.50 and Chinese 158.6+5.13 cm. There were also differences in ratio of sitting height to stature (RSH), the Chinese having highest (0.54) and the Indian the lowest (0.46). In fact in standing posture Indian are found to be shorter by 12.6 and 10.8 cm as against British and Egyptian workers respectively. Each of the other groups was significantly different from the Indian for most of the variables. In hilly region, hand tools are extensively used in agriculture. These are mainly fabricated by local artisans who do not have adequate knowledge in ergonomics. Hence, there is a great scope of design/development of new tools or modification of existing ones based on scientific application of anthropometric data of workers.

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