DESIGN OF IMPROVED ANIMAL DRAWN IMPLEMENTS AND HAND TOOLS BASED ON ERGONOMICS

Thesis

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Pantnagar
July, 2019

(Bhawana Negi)
Authoress

CERTIFICATE

This is to certify that the thesis entitled **"Design of Improved Animal Drawn Implements and Hand Tools Based on Ergonomics",** submitted in partial fulfillment of the requirements of the Degree of **Master of Technology (Agricultural Engineering)** with major in **Farm Machinery and Power Engineering** of the college of Post-Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar is a record of bona fide research carried out by Ms. **Bhawana Negi,** Id. No. **42941** under my supervision and no part of the thesis has been submitted for any other degree and diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Pantnagar
July, 2019

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CERTIFICATE

We, the undersigned, member of the Advisory Committee of **Ms. Bhawana Negi,** Id. No. **42941** a candidate for the degree of **Master of Technology (Agricultural Engineering)** with major in **Farm Machinery and Power Engineering** agree that the thesis entitled **"Design of Improved Animal Drawn Implements and Hand Tools Based on Ergonomics"** may be submitted in partial fulfillment of the requirements for the degree.

(Jayant Singh)
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(Deepa Vinay)
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AICRP	All India Coordinated Research Project
CIAE	Central Institute of Agricultual Engineering
CV	Coefficient of variation
ESA	Ergonomics and safety in Agriculture
HESA	Human Engineering and Safety in Agriculture
ISE	Indian society of ergonomics
ISO	International Standard organization
MSD	Musculoskeletal disorder
NASA	National Aeronautics and Space Administration
OSH	Occupational Safety and Health
SD	Standard deviation
SEM	Standard error of mean
%	Percentage
=	Equal to
et. al.	And others
i.e.	That is
cm	Centimeter
kgf	Kilogramme force
mm	Millimeter
N	Newton

Introduction

1-INTRODUCTION

India is seventh largest country in the world with population of 1,210.85 million with 623.72 million males and 586.469 million females **(Census, 2011)**. Economy of the region is dominantly agrarian where more than 70 percent of the workers earn their livelihood from agriculture and related activities **(Sengupta, 1996)**.

Agriculture plays a vital role within the economy of Uttarakhand. Owing to its vivid topography and various agro-climatic endowments, farming is practiced in most component of Uttarakhand. About 75% of the people living in Uttarakhand have taken agriculture as their main occupation as for their livelihood. While those residing in the vulnerable parts are untouched by modernization so they lack knowledge about the new agricultural techniques which results in less produce.

The role of crop production machinery, from tillage to post harvest operations, is of great importance. Farm productivity is directly linked with level of farm mechanization. Agricultural machinery not only provides timeliness in operation but also helps in efficient use of inputs. It also helps in reducing drudgery to a great level making a farm labor more efficient and productive. Farm machines are not only helpful for large farms but it is also beneficial in small, irregular and scattered fields like hilly region of country in general and Uttarakhand in particular.

The main power source for the agriculture in Uttarakhand state is draught animals. These animals vary in sizes, capacities and according to breed in different region. This study will provide reliable information about draught animals being used for various operations including transportation. The total population of draft animal is estimated as 49.85 millions in India during 2011-2012. Out of which bullocks are 44.48 million, Buffalo are 4.25 million, camel are 0.29 Million, Mule 0.15 Million. Horse and Pony are 0.25 Million, Mithun are 0.17 Million, Donkey are 0.21 Million and Yak are 0.05 Million in our country. The population of draft animal in Uttarakhand is estimated about 7, 11,472 during 2011- 2012. Out of which bullocks are 6, 62,923, buffaloes are 33,467, horses and Tattu are 14,632, Mules are19, 307, Donkey are 580 and Yakes are 151. In hill region of Uttarakhand only bullocks are used for agricultural draft purpose where as in Tarai Bhabhar area the buffaloes as well as bullocks are used as draft animal. In hill, Mules, Donkey and Yakes are generally used for transportation purpose.

The most of the villages of hilly region local implement such as Nasooda (plough), Danala (interculture implement), Damala (paddy paddler) and wooden patela are being used by the farmers for various tillage operations. In addition, hand tools such as Kutla, Kassi, Spade, Daranti and Thamali are commonly used by women in the hill region. The farmer in hilly region are using improved sickles for harvesting of crops including fodder/grass harvesting. The number of winnowing fan (hand operated) and chaff cutter is also more majority of it were supplied by the state government. The rotarvator, reaper and threshers are existing in few districts of Uttarakhand. The farmers of hilly region are practicing tillage by their traditional nasooda or iron plough, harvesting as well as threshing operations are being performed by manual labour, similarly the bullock carts ware observed only in the district located in plain region**.**

Manual tools and animal- drawn implements are extensively used for different farm operations in Uttarakhand and other states of India. These agricultural tools/implements are not designed ergonomically, and this leads to increase in accidents and health hazards to agricultural workers. Proper matching of machine requirements with operator's capabilities is necessary to achieve better performance. The use of female anthropometric data along with those of the male can help in the proper designing of new equipment and modifying the existing machine.

Ergonomics is the scientific study of relationship between men and their working environment engineering anthropometry and biomechanics are disciplines of ergonomics. Ergonomics is sometimes defined as the science of fitting the work to the user, instead of forcing the user to fit the work. The goal of ergonomic is to increase efficiency and thereby productivity of the workers without jeopardizing their health and safety. To provide due consideration to the worker's capabilities and limitations, application of ergonomics aims to improvise the quality of life.

A good match can be obtained if anthropometric data are used. Large scale anthropometric research was started in the 1940s in Western European countries and United States. Anthropometry can provide solutions to resolve problems in operator to machine and equipments **(Wang *et al.,* 1999).**

In order to design a product for human use, engineers have to rely on anthropometric data, otherwise the final product may turn out to be ergonomically incompatible **(Lewin, 1969)**. The design of equipment is always a compromise between

the operator's biological needs, which are determined by the ergonomics guidelines, and physical requirements of the machinery / equipment (**Das and Grady, 1983; Das and Gupta, 1969).** In this regard, the basic information required is the anthropometric body dimensions of the users of tools and equipments. One of the important principles of ergonomics is that workplace dimensions should match the body dimensions of the expected users. A good match between farm workers and agricultural operations can be obtained if anthropometric data are applied. Incorrect workplace design where anthropometric data are ignore can cause psychological discomfort, physical fatigue and could be harmful and damaging for the design to make safe, comfortable an effective agricultural machines, tools and workplaces.

The safety of worker and productivity of work during agricultural activities is a matter of great concern. Hence, human drudgery can be impacted for the safety and productivity of farm workers. When there is excessive physical stress on our bodies, fitness tends to decline and productivity may suffer. By managing the stress and strain performance are enhanced and the risk of disorders is controlled within accepted limits.

Presently most of farm equipments of hills which are being used in Uttarakhand are not designed ergonomically. Most of the farm equipments are designed based on all India anthropometric data. The hill farmers of Uttarakhand are not considered under all India anthropometric data. In order to make more suitable hill equipment for hilly region to reduce drudgery and stress of hilly farmer, it is necessary to design the hilly equipment based on hilly anthropometric data.

Keeping in view the importance of ergonomics for the design of agriculture implement the study will be undertaken with following objectives:

1. To collect the anthropometric data of hill farmers of Uttarakhand.
2. To design the component of hill plough, danala, damala, khurpi, sickle, fork and thamali-cum-chopper based on collected anthropometric data.

Review of Literature

2-REVIEW OF LITERATURE

This chapter overviews the work done by several researchers in the field of applications of anthropometric data of human engaged in agriculture and its allied activities. It helps in analyzing the research problem and helps in interpreting the findings and results drawn from the previous works. The available literature relevant to the present research problem has been presented under the following headings.

2.1 Ergonomic Evaluation and Anthropometric Data of Agricultural Workers

Davies *et al*. (1980) conducted an anthropometric study of female workers hand dimensions of 92 subjects. 51 Europeans, 21 Indians from Punjab and 20 West Indians were included in the study and their data were compared. There were no significant differences found between each of the groups.

Grandjean (1981) suggested that a comfortable range of an elbow angle should be 100-110°. He measured the elbow height (standing) at this elbow angle for 5^{th}, 50^{th}, and 95^{th} percentile male and female agricultural workers of Meghalaya.

Grandjean (1982) reported that muscular force depends on the age and that the peak of muscle strength for both men and women is reached between the age of 15 to 35 years. The workers aged between 50 to 60 years can exert only 75 to 85 percent of their muscular strength.

Sanyal (1982) measured ten different body dimensions of 34 subjects. The result showed that the body dimensions and the stature were linearly related. The percentile values were used to design work place layout of a power tiller seat.

Das and Grady (1983) found the workplace layout design parameters by using the existing anthropometric data. He carried out the test for performing industrial tasks in sitting, standing and a combination of sitting and standing positions for the general male, female and a combination of male and female operators and the individual male and female operators for the 5^{th}, 50^{th} and 95^{th} percentiles, the data were duly adjusted to account for the clothing, shoe and posture allowances. The reach dimensions were based on the most commonly used industrial operations which require a grasping movement. Appropriate allowances were provided to adjust the reach dimensions for other types of operations. The horizontal and vertical clearance dimensions and

reference points for the horizontal and vertical clearances were established for the determination of the normal working area in the horizontal plane, squires concept was recommended in preference to Farley's concept.

Gupta *et al.* (1983) carried out anthropometric measurement of 40 subjects of the Punjab. The standing height, seat height, seat depth, hip breadth, elbow rest height and body weight from seat design point of view were measured. The reported values of standing height of the 5^{th}, 50^{th} and 95^{th} percentile were 155.20, 168.50, 179.00 cm respectively. A linear relationship was found between the standing height and other dimensions except hip breadth. It was observed that the data if Indian workers were significantly different from the data of U.S and Dutch people; therefore it could not be applied in India.

Haslegrave (1986) analyzed that the 5 percentile female and 95 percentile male were frequently chosen by the equipment designers with dimensions as design limits. However, in the more complex design problems which involve several body dimensions, it was important also to consider the interaction between body dimensions. These have been investigated by author using data from an anthropometric survey, in order to develop models which represent the extreme body sizes of the male and female population.

Moustafa *et al.* (1987) carried out an anthropometric survey in Egypt in the period between June 1982 and March 1983.A set of 44 body dimensions were taken from a sample of 4960 Egyptian female subjects, age ranging from 20-65 years, the subjects were selected randomly and covered all socio-economic, religious, and ethnic groups. A specially designed portable anthropometer and four other traditional instruments were used throughout the survey. The results show that there were significant differences in the body build, dimensions and proportions between Egyptian women and European and American women.

Gite (1990) conducted a laboratory study to find out optimum handle height for push-pull type manually operated dry land weeder from ergonomical considerations. Handle height of 0.6, 0.7, 0.8 and 0.9 times the shoulder height of eight subjects was evaluated. The results indicated that when the handle height was within 0.7 to 0.78 of shoulder height, the physiological cost and muscular fatigue were minimum for operating a push-pull type weeder. Considering this range and the anthropometric data of Indian workers, a handle height of 100 cm was recommended.

Gite and Yadav (1989) reported that in Indian agriculture, hand tools, animal-drawn equipment and tractor/power operated machinery were extensively used for majority operations. The equipment were either operated or controlled by human workers. The anthropometric data can be used for the proper designing of equipment for better efficiency and human comfort. They identified 52 body dimensions for the design of the equipment and proposed that extensive surveys should be carried out in different regions of the country to generate the necessary data useful in farm machinery design.

Gite and Yadav (1990) collected body dimensions (n=52) on farm worked (n=39) for the design of agricultural equipment. The 5^{th}, 50^{th} percentile and standard deviation values were calculated. Study recommended such extensive surveys were required in different parts of countries to generate necessary data for designing purposes.

Mebarki and Davies (1990) conducted an anthropometric survey in Algeria between March 1986 and September 1987. A set of body dimensions were taken from a sample of 666 Algerian Female Subjects, with age group 16-65 years. The subjects were selected randomly and covered a mix of occupational groups. The measurements were taken as part of a fuller study. And were chosen for their relevance to furmiture design and the domestic workplace layout, Results were presented, discussed, and compared with those of other female populations to make it more comprehensive in nature.

Mathur (1991) worked on paddy harvester with a rotary cutting element from engineering and ergonomic consideration. He took 200 subjects and 6 different body dimensions. He found that the coefficient of variation for stature, shoulder height, waist height and arm reach varied from 3.66 to 4.87 percent and for body weight it was 11.06 percent.

Fransson and Winkel (1991) worked on the grip strength using plires. They concluded that the maximum force exerted by a particular finger in a handgrip depens on the grip span of the other fingers. They observed that (i) the finger/hand grip span affects the pre-contractile length of the finger flexor muscles; (ii) at wide grip spans all fingers cannot grip a tool handle properly; (iii) gripping at wide grip spans results in loss of grip force.

Ghugare *et al*. (1991) collected anthropometric data on 18 body dimensions of 10 subjects. The relevance of the collected data in sprayer design was discussed. Mean, standard deviation, range, 5^{th} and 95^{th} percentile were computed.

Pheasant (1991) suggested three steps for collection and use of anthropometric data. These were defining of user population, establishing of design criteria and deciding of the design limits. According to him, the anthropometric design criteria can be grouped into four categories namely those dealing with clearance, reach, posture and strength. He also mentioned that the design limit should usually be either the 5^{th} or 95^{th} percentile value of the parameter.

Fernandez and Uppugonduri (1992) presented the results of an anthropometic survey conducted on south Indian male workers in the electronic industry. The data were collected as part of a project to modify work stations that utilized equipment from other countries. A set of 27 body dimensions were taken from a sample of 128 workmen (aged 18-35 years). The anthropometric measurements were compared with those of Indian men from Central, Western, and Northern parts of India.

Imrhan *et al.* (1993) measured the 24 dimensions of the right hand in 30 female and 41 male Americans of Vietnamese origin. The means, standard deviation. Range; and 5^{th}. 50^{th} and 95^{th} percentile values of each measurement were tabulated. The means of the female measurements were compared with the means of the corresponding measurements in females from Hong Kong. United Kingdom, United states, and japan with the help of data from other published studies.

Marras and Kim (1993) collected anthropometric data from industrial workers working in various manufacturing industries in the mid-western United States. Around 384 males and 124 females participated during the conduct of study. Descriptions and statistics were assessed for 11 length dimensions, weight, and age at the worksites. Analyses of the industrial anthropometric data were summarized and compared to other civilian and military anthropometric data. Significant differences between the groups were found. These industrial anthropometric data can be used in the design of industrial workplaces and equipment as well as for use with biomechanical models.

Yadav *et al.* (1995) reported an anthropometric data of 134 male farm workers of Eastern India as a reference for the ergonomic design and modifications of agricultural tools and devices such as khurpi or power tiller. Subjects were chosen

randomly among tractor/ power tiller operators, farm mechanics and farm labourers. The anthropometric data for the various body dimensions and the estimates of mean, standard deviation, coefficient of variation and percentile values (5^{th}, 50^{th} and 95^{th}) were presented and compared with the south and central Indian workers. The anthropometric data collected were compared with median value of three different ethnic groups, indicating that the East Indians were smaller than German, USA and Japanese males in all body dimensions except popliteal height of Japanese.

Anonymous (1996) reported about the anthropometrical measurements of 1000 rural women, 500 women were in age group of 21-31 years and others were of age group 31-40 years. The results indicated the age of subjects made no difference in measurement of various body dimensions in standing position and squatting posture, except for shoulder height and thigh height were significant.

Das and Sengupta (1996) reported that for efficient design or design refinement of equipment, it was necessary to follow ergonomics guidelines and principles, which provide an orientation towards physiological and psychological needs of operator. In this regard, the basic information required was the anthropometric body dimensions of the users of equipment.

Gite and Singh (1997) found out that there was a large variation in the strength data between Indian and western workers. Therefore, the data of foreign workers cannot be utilized for the design of farm equipments and hand tools for Indian workers, as it only leads to operator discomfort and fatigue, resulting in decreases in decrease in operator efficiency.

Ramos and Saavedra (1997) stated that there was an inadequate use of anthropometric data for work stations design in Puerto Rico, as these designs were based on data coming from the U.S. population which were not suitable to the physical characteristic of Hispanic worker. They proposed an anthropometric table for the industrial Puerto Rican population which can be used for the design of work stations requiring any of the following twelve measures. Height elbow height, sitting height. Eye height (sitting), elbow height (sitting) knee height (sitting) shoulder to shoulder breadth, hip breadth, arm reach, popliteal height, weight, and thigh height (sitting) they also concluded there were significant differences between the anthropometric measures of the Puerto Rican and U.S. industrial populating validated this way the data

considered for work stations design in Puerto Rican industry was inadequate. The table developed by them allowed the design of work stations according to the ethnic characteristics of Puerto Rican worked reducing the risk of developing cumulative trauma disorders.

Jarosz (1998) collected the anthropometric data of elderly people of Poland to take into account the needs of elderly people while shaping their living environment. Such data have never been developed in Poland. The results of the measurement of 33 anthropometric characteristics of 106 women aged 60 and above constitute a set of basic data for the design of functional space and devices, as well as clothes, for this age group. The values of the 5^{th} percentile of elderly women determine the lower limit of the anthropometric standard for the whole adult population and thus allow transgenerational design.

Karwowski (1998) stated that neglect of ergonomics principles brings inefficiency and pain to the operator. An ergonomically deficient workplace can cause physical and emotional stress, low productivity and poor quality of work.

Mital and Kumar (1998) reported a decline in the isometric muscle strength on the basis of the entire body from 100% at age 24 years to 80% at 55 years of age. The variation in the decline of the muscle strength may be due to the physical fitness, health conditions and socioeconomic conditions of the subjects under study.

Yadav *et al.* (1997) reported anthropometric data (n=29) of male farm workers (n=134) of esteem India as a reference for the ergonomic design and modifications of agricultural tools and devices such as khurpi or power tiller.

Kumar and Paravathi (1998) measured 14 body dimensions of 15 female maize sheller operators. The data were analyzed and three subjects having similar anthropometrical parameters related to maize shelling operation were selected to operate three manually operated maize shellers.

Blackwell *et al.* (1999) pinpointed the importance of hand anthropometry and handle size or shape in influencing the hand posture or grip strength. They suggested that handle shape designs should be influenced by the different lengths of the fingers for achieving maximal cross bridge attachments in muscles when gripping the handles.

Yadav *et al.* (2000) carried out anthropometric measurements useful for farm equipment design on female workers from Gujarat, India it was found that the mean stature of west India female workers was 154.6 cm while those for male workers from Eastern. Southern, central, northern and esteem regions were 162.1, 160.7, 162.0 168.5 and 164.4 cm respectively it is recommended to carry out similar surveys in other parts of the country.

Yadav *et al.* (2000) collected the anthropometrical data of farm workers of eastern India. They compared the mean value of the data with male farm workers in south and central India as well as with different ethnic group. The analysis indicated that there was significant difference in the body dimensions.

Geetha and Tewari (2000) conducted an anthropometrical survey of the female workers in southern region of India. 23 body dimensions of the subjects having direct implication on agricultural tools/ implements design were collected from 137 female workers. They compared the data with other ethnic groups and with male farm workers of the same region. The results indicated that Indian female workers were smaller than British, French, German, Egyptian and Turkish female workers. Further male body dimensions were higher than that of female workers.

Jafry and O' Neill (2000) highlighted the importance of ergonomics issues in rural development, key areas for future ergonomics research were identified, focusing on the needs of communities living and working in the agricultural sector where most of the population in the industrially developing world was located. They further stated that multi-disciplinary nature of ergonomics can play a unique role in the protection of people's health and in the prevention of work-related health hazares, by integrating concepts from the social sciences with technological advancement to enhance productive capacity and improve people's health.

Kathirval and Ananthaskrishan (2000) conducted an investigation to identify the body dimensions and strength parameters relevant to farm machinery design. They collected and documented anthropometrical data of male and female agricultural workers. 42 body dimensions were identified and measured. Mean, standard deviation, 5^{th} and 95^{th} percentile value were computed. The mean statures of male and female agricultural workers were 164.19cm and 156.53cm respectively.

Kumar *et al.* (2000) collected anthropometrical data of 12 experienced weed operators using standard measurement procedures. A total of 13 dimensions related to their study were selected. The data were analyzed and two subjects having distinct anthropometrical characteristics were selected to operate the weeder.

Okunribido (2000) conducted an anthropometric survey measuring 18 dimensions of the right hand in 37 female rural farm workers living in Ibadan, western Nigeria, the means, standard deviations and percentile values were reported for these. The means of the collected data were compared with those for females from the UK. From Hong Kong and from America, using data from other published studies. The results suggest that the Nigerian female hand was wider and thicker, but shorter than that of their foreign counterparts. The results from the study have the potential of encouraging production of better fitted hand tools for industrial and peasant farm work in Nigeria as it hopes to reveal what differences there are between Nigerian female hands and those of females of other nations.

Dewangan and Datta (2001) conducted a survey of 100 jhum cultivators belonging to 20 major tribes covering the entire state. Majority farmers were in the age group of 18-60 years and in total 88 body dimensions were identified from the data range. The mean, standard deviation, coefficient of variation, 5^{th}, 50^{th} and 95^{th} percentile values for each items were calculated. The average values were than compared with those of available data from Central India They found that jhum cultivators were shorter in stature than the agricultural workers of central India. Similar trend was also observed for most of the other dimensions.

Pund *et al.* (2002) carried out an extensive survey to collect anthropometric data of male and female agricultural workers involved in different agricultural operations in Saurashtra region (western India). They found that average stature male and female workers recorded where 163.1 ± 4.92 and 150 ± 5.60 cm respectively.

Victor *et al.* (2002) carried out an anthropometric survey and compared with available data of other regions. Anthropometric measurements were carried out on 5 males from each village randomly chosen from 6 districts of Chhattisgarh region, the data showed that the Indians people of Chhattisgarh region are smaller than western people of Americans. Sweden's and Germans. The other body dimensions were also

found to be lower than the western people except politely height (sitting) and buttock political length in which Indians have the higher value of body dimensions.

Kar *et al* (2003) collected different hand dimensions of right and left hands of agricultural workers from both male and female agricultural workers fields of Midnapore district. West Bengal state, Eastern India and compared them with the data of other parts of India and abroad. It was noted that there was a significant difference in body dimensions was found between right and left hand in both sexes.

Nag *et al*. (2003) studied to generate anthropometric data of women. Working in informal industries (beedi, agarbatti and garment making). The hand measurements of the right hand (lengths, breadths, circumferences, depths, spreads and clearances of hand and fingers) were taken and analyzed to determine the normality of data and the percentile values of different hand dimensions and regression analysis was done to determine better predictors of hand length and grip strength. Results showed that the hand breadths, circumferences and depths were approximately normally distributed, with some deviation in finger lengths. Hand length was significantly correlated with the first, wrist and finger circumferences. The hand lengths, breadths and depths, including finger joints of the Indian workers studied were smaller than those of American, British and East Indian Workers.

Lee (2004) examined height of healthy males (n=7) match for their maximum isometric letting strengths across 13 exertion heights. Ranging from 25cm to 133cm in increment of 9cm the results show a nonlinear (increasing- decreasing) strength-height relationship for all subjects.

Yadav *et al*. (2003) conducted an anthropometrical survey of female farm workers of Gujarat region. Thirty body dimension necessary for designing farm equipment were collected from 40 female farm workers in the age group of 18-50 years. They compared the data with those of Indian male farm workers. The results indicated that Indian female workers were smaller than male in all body dimensions except hip breadth and waist circumference. The female anthropometrical data were also compared with the median values of three different ethnic groups. It was found that Indian females were smaller in all body dimensions as compared with that of German, USA and Japanese male.

Rahi (2003) conducted anthropometric survey of 50 male and 50 female agricultural workers in Rajasthan. He identified 28 body dimensions. The mean stature and body weight for male and female agricultural were 166.7 cm, 53 kg and 153.7 cm, 44.3 kg respectively.

Singh *et al.* (2003) developed an anthropometrical database of agricultural workers Meghalaya state. Total 48 subjects from 20 different villages were selected randomly from three districts of the state. 71 body parameters useful for farm machinery design were selected for this study. The results showed that the average weight of female workers was found to be about 13 per cent lower than their male counterpart whereas the average stature of male was nearly 6 per cent higher than the female. Comparison of the other body dimensions showed that all body dimensions of female workers except chest depth and hip breadth were relatively smaller than male agricultural workers of the state. Comparison was also made for agricultural workers of different north eastern and other selected state of the country.

Viren *et al.* (2003) carried out an anthropometrical survey of female farm workers from Chattisgarh region during 1999-2000, to identify constraints related to the ergonomics during the operation of farm machinery. A total of 9 body dimensions were measured for 300 subjects between the age group of 21 to 48 years. Collected data were statistically analyzed. Maximum variation was found in body weight of the subjects. It was observed that the mean value of weight and stature were 49.33kg and 156.16 cm respectively. The data collected were compared with the available data of other regions of the country.

Singh *et al.* (2013) collected the anthropometric data of 150 farm women from 3 villages of Dantiwada taluka in North Gujarat. A set of 20 body dimensions, which were found to be in the design of various agricultural equipments, were selected, which includes structure, vertical reach, vertical grip reach, eye height and so on. The data was further analyzed and the efforts had been made to illustrate the application of these measurements for designing and standardization of women friendly equipment. In addition to the descriptive values, 5^{th}, 50^{th} and 95^{th} percentile values were also calculated.

Agrawal *et al.* (2010) presented the anthropometric data of the agricultural workers of Meghalaya, which will help to develop/modify the improved tools and

machinery suitable for people of northeastern Region. Total 1027 subjects (566 male and 461female) of five different tribes namely Khasi, Garo, Jaintia, Hajong and Koch from 35 different villages were selected randomly from seven districts. Thirty-four body dimensions useful for agricultural equipment design were selected and measured. The average weight of female workers was found to be about 10.1% lower than the male agricultural workers whereas the average stature of male is nearly 6.9% higher than the female. Similar trend was observed in most of the measured body dimension. Comparison of collected data with other northeastern states suggests non-significant difference among various body dimensions.

2.2. Application of Ergonomics in Agricultural Equipment Design

Qing (1990) described the design principles of drivers – seat static comfort from an ergonomic consideration. Some problems in the design associated with anthropology were discussed. The design parameters on static characteristics of drivers –seat and static matching relationship of operator – seat – machine system were identified and discussed.

Gite (1991) suggested that the optimum handle height for implement should be equal to 1.15 of the metacarpal III height of the operator. The 5^{th} and 95^{th} percentile value of metacarpal III height agricultural workers were considered. Therefore the optimum handle height should be designed 1.15 times of 5^{th} and 95^{th} percentile of metacarpal height. The value for height of a fixed type handle has been given slightly on lower side as there will be less discomfort and better depth.

Dinesh and Rajesh (1992) conducted an ergonomical study to determine the main causes of injuries among farmers in 9 villages in the state of Haryana in Northern India. The study revealed that the largest number of traumatic injuries was caused by fodder cutting machines and threshers. The designs of these machines have been made safer using ergonomic principles. A large number of minor injuries were caused by hand tools.

Gite (1993) has reviewed the work done in India during last three decades in the field of ergonomics applied to farm machinery and power ranging from hand tools to tractors. Available information suggested that the quantum of work done is rather small. According to him, the awareness about the need of application of ergonomics is increasing.

Agrawal (2017) proposed the design requirement of hand tools and animal drawn equipments, tractor etc. seventy five body dimensions and four skinfold were identified and the recommendation of previous work had been considered. A survey was conducted different part of India for anthropometric data of farm workers the data was compiled and statistical analysis were considered. The mean, standard deviation, 5^{th} and 95^{th} percentile values were calculated. The designs of different agricultural implements were proposed on 5^{th} and 95^{th} percentile values of anthropometric data.

The above review revealed that lot of work has been done for anthropometric data collection of worker engaged in agriculture work in India. The data were analyzed and compiled. Procedure of designing the agricultural implements and hand tools on ergonomics basis were standardized by various researchers. However, the above studies shows that the anthropometric data of workers engaged in agriculture in Uttarakhand were not included in All India data compiled under AICRP on EAS. Presently most of agriculture implements and hand tools which are being used in hilly region of Uttarakhand are not ergonomically designed as per agricultural workers of Uttarakhand. Hence, there is a need of anthropometric data collection of workers of Uttarakhand and modify agriculture implements and hand tools based on ergonomics to reduce drudgery.

Materials and Methods

3-MATERIALS AND METHODS

This chapter deals with methodologies adopted and procedures followed to achieve the objectives of the present investigation. The study was confined specifically to conduct ergonomical studies on agricultural workers of hill region of Uttarakhand for selected farm operations. In order to carry out the study an anthropometrical survey was conducted according to AICRP on HESA standards and compared with survey data of other region of the country. Then, animal drawn implements and hand tool were designed.

3.1 Anthropometric Measurements

Anthropometry is basic criteria to design of an agricultural implement based on ergonomics. At present lots of studies are available on collection of anthropometrical data on Indian agricultural workers but there is no data available for farmers of hill region of Uttarakhand. Keeping these points into consideration, anthropometric data as given in Table 3.1 on agricultural workers were identified, compiled and analyzed to build the data bank.

3.2 Selection of Subjects

The study was conducted to generate the anthropometric data of farm workers of hill region of Uttarakhand. An anthropometric survey was conducted in which the subjects were selected randomly among male farm workers working in different agricultural operations. Two hundred male farm workers in the age group of 18-60 years of age were randomly chosen. Personal information of farm workers also collected as per standard practice. Subjects selected for anthropometric measurements were free from physical abnormalities, musculo-skeletal problems and history of chronic or acute illness. They were volunteered to make themselves available.

3.2.1 Determination of sample size

Subjects were selected to assist in the field trials. They were selected from the existing agricultural workers population of the region. Male agricultural subjects were selected. For this selection process a representative sample size was taken. Anthropometric measurements were carried out on the individual in the selected sample. For determining the sample size the formula suggested by **Roebuck *et al*. (1975)** was followed, as given below:

$$N = \frac{(k * S)^2}{d} \quad \text{... (3.1)}$$

Where,

N= sample size required

S= estimated standard deviation of the data

d= the desired accuracy of the measurement

K= a value chosen for the statistic of interest
(for 5^{th} and 95^{th} percentile statistic, it is 4.14)

The sample size was calculated according to the required dimension i.e. metacarpal height, inside grip diameter, middle finger palm grip diameter and hand breadth across thumb.

a) Sample size for metacarpal III height

$$N = \frac{(4.14 * 4.52)^2}{d} \quad \text{... (3.2)}$$

On the basis of all India Anthropometric data the range of metacarpal III height is from 500 to 930 mm. Therefore for design purpose the desired accuracy can be considered from 1 to 2 mm for metacarpal III height. Hence, the accuracy, d is taken as 1.75 mm. By putting the value in equation the sample size was obtained as 200.09.

b) Sample size for middle finger palm grip diameter

$$N = \frac{(4.14 * 2.37)^2}{d} \quad \text{... (3.3)}$$

On the basis of all India Anthropometric data the range of middle finger palm grip diameter is from 13 to 70 mm. Therefore for design purpose the desired accuracy can be considered from 0.25 to 0.75 mm for middle finger palm grip diameter. Hence, the accuracy, d is taken as 0.5 mm. By putting the value in equation the sample size was obtained as 192.54.

c) Sample size for grip diameter inside

$$N = \frac{(4.14 * 3.95)^2}{d} \quad \text{... (3.4)}$$

On the basis of all India Anthropometric data the range of grip diameter inside is from 30 to 95 mm. Therefore for design purpose the desired accuracy can be considered from 1.0 to 1.5 mm for grip diameter inside. Hence, the accuracy, d is taken as 1.30 mm. By putting the value in equation the sample size was obtained as 205.7.

d) Sample size for hand breadth across thumb

$$N = \frac{(4.14 * 4.60)^2}{d} \quad \ldots (3.5)$$

On the basis of all India Anthropometric data the range of hand breadth across thumb is from 64 to 135 mm. Therefore for design purpose the desired accuracy can be considered from 1.0 to 2.0 mm for hand breadth across thumb. Hence, the accuracy, d is taken as 1.75 mm. By putting the value in equation the sample size was obtained as 207.1.

Accordingly, it was decided to select the subjects from the available agricultural workers of the region. Thus, 200 would be the minimum sample size for the anthropometric survey.

3.3 Instruments used for Data Collection

The different anthropometric parameters as shown in Table 3.1 for the study will be measured by using following Instruments:

i. Anthropometric Kit
ii. Anthropometric cone
iii. Hold- On cylinder
iv. Vernier calliper
v. Weighing machine
vi. Hand grip dynamometer

3.3.1 Anthropometric kit

Anthropometric Kit of Harpenden is used to measure the anthropometric parameters, the height, eye height, acromial height, elbow height, olecranon height, illiocrystale height, illiospinale height, trochantric height, metacarpal height, knee height, medial malleolus height, lateral malleolus height, waist back length, bideltoid

breadth, sitting height and sitting height. Its counter recording instrument is effortlessly operated from the tips of its branches. By means of their free fingertips, the Harpenden Anthropometer user can actually feel their way to their desired measuring points in order to obtain a degree of accuracy not possible with conventional anthropometers. This instrument gives a direct and accurate reading, to the nearest millimeter, over a range of 50 mm to 570 mm. It is primarily constructed of light alloy anodized to its natural color. Its sliding member operates via miniature ball-bearing rollers in order to ensure a movement which is free yet without cross play as shown in Plate 3.1.

3.3.2 Wooden cone type grip span meter

It is used for measuring grip diameter. It has graduations on its diameter with range 14.23 to 86 mm. This cone has 26 divisions on its diameter and the height of the cone is 342 mm as shown in Plate 3.2.

3.3.3 Hold-On cylinder

It is wooden rod used for measuring the middle finger palm grip diameter. It has graduations on its diameter. At one end the diameter of the rod was 20 mm and at the other end it was 40 mm. This rod is divided into 11 sections of 100 mm length. The diameter of rod was increased by 2 mm in each division as shown in Plate 3.3.

3.3.4 Vernier caliper

It is a device used to measure the distance between two opposite sides of an object. The tips of the caliper are adjusted to fit across the points to be measures and the caliper is then removed and the distance read by measuring between the tips with the measuring tool. A precise digital Vernier caliper was used for the study. The resolution of the caliper was 0.01mm or 0.0005”/0.01 mm with accuracy of $\pm$0.02 mm. It was used for measuring the Index finger diameter, hand breadth across thumb. Grip span, grip diameter outside were measured by Vernier caliper as shown in Plate 3.4.

3.3.5 Weighing machine

`The weight of the subject was measured by Krups weighing machine and the capacity of the machine is 125 kg with minimum graduation of 0.5 kg.

3.3.6 Hand grip dynamometer

Handgrip Dynamometers are instruments for measuring the maximum isometric strength of the hand and forearm muscles, used for testing handgrip strength of worker. The subject holds the dynamometer in the hand to be tested. The arm hanging by the side and the extended arm being swung from above the head to by the side during the squeezing motion. The handle should rest on middle of the four fingers. The subject squeezes the dynamometer with maximum isometric effort, which is maintained for about 5 seconds. No other body movement is allowed. The subject should be strongly encouraged to give a maximum effort. The range of the grip dynamometer was 5-100 kg shown in Plate 3.5.

3.4 Measurements of Different Body Dimensions

Thirty six body dimensions including age and body weight recommended necessary by the All India Coordinated Research Project (AICRP) on Ergonomics and Safety in Agriculture (ESA), for the design and design modification of agricultural hand tools, animal drawn implements and machines from ergonomic considerations were selected for this study. Standard technologies as given in the Anthropometric Source Book (NASA, 1978) have been used in this study. The definitions of the dimensions measured are presented in Table 3.1.

Table 3.1 Description of different body dimensions for anthropometric measurement

S. No.	Dimensions	Description
1	Weight	The weight of an object is related to the amount of force acting on the object, either due to gravity or to a reaction force that holds in the place. It is measured on a calibrated weighing scale.
2	Stature	The vertical distance from the standing surface to the top of the head. The subject stands erect and looks straight forward. Fig.3.1(a)
3	Vertical Reach	The vertical distance from the standing surface to the height of the middle finger when arm hand and finger are extended.
4	Vertical Grip Reach	The vertical distance from the standing surface to the height of the pointer held horizontal to the subject's fist when the arm is maximally extended upward. Fig. 3.1(e)
5	Eye Height	The vertical distance from the standing surface to the external canthus. The subject stands erect and looks straight forward. Fig. 3.1(a)
6	Acromial Height	The vertical distance from the standing surface to the drawn acromial landmark on the tip of the right shoulder. Fig. 3.1(d)
7	Elbow Height	The vertical distance from the standing surface to the top of radial. The subject stands erect and looks straight forward. Fig. 3.1(a)
8	Olecranon height	The vertical distance from the standing surface to the height of the under surface of elbow, measured with arm flexed ninety degree and upper arm vertical. Fig. 3.1(b)
9	Iliocrystale Height	The vertical distance from the standing surface to the top of the ilium in the mid auxiliary plane. The subject stands erect and looks straight forward. Fig. 3.1(d)
10	Iliospinale Height	The vertical distance from the standing surface to the height of Iliospinale. The subject stands erect and looks straight forward. Fig. 3.1(d)
11	Trochanteric Height	The vertical distance from the standing surface to the height of the trochanterion. The subject stands erect and looks straight forward. Fig. 3.1(d)
12	Metacarpal III Height	The vertical distance from the standing surface to the height of the knuckle where the middle finger joins the palm. The subject stands erect and looks straight forward. Fig. 3.1(d)

13	Knee Height	The vertical distance from the standing surface to the midpoint of kneecap. The subject stands erect and looks straight forward. Fig. 3.1(d)
14	Medial Malleolus Height	The height of the most medially projecting points of the medial anklebone. Fig. 3.1(c)
15	Lateral Malleolus Height	The height of the most lateral projecting points of the medial anklebone. Fig. 3.1(c)
16	Hand breadth across thumb	The breadth of the hand as measured at the level of distal end of first metacarpal of the thumb. This dimension is used for design of handle, control panel, hand tool, safety gloves, hand grip and knapsack sprayer trigger design. Fig. 3.3(d)
17	Waist Back length	The vertical distance along the spine from the waist level to the cervical. The subject stands erect and looks straight forward. Fig. 3.1(c)
18	Middle Finger Palm Grip Diameter	The distance of widest level of the cylinder which the subject can grasp with his palm and middle finger touching. Fig. 3.3(d)
19	Span	The distance between the tips of right and left middle fingers when subject's arms are maximally extended laterally. Fig. 3.1(B)(i)
20	Span Akimbo	The distance between the elbow points measured with the arms flexed, held horizontally, palms down, fingers straight and together and palms and thumbs touching the chest. Fig. 3.1(B)(i)
21	Arm reach from the Wall	The distance from the wall to the grip of the middle finger measured with subject shoulder against the wall, his and arm extended forward. Fig. 3.1(f)
22	Thumb Tip Reach	The distance from the wall to the tip of the thumb measured with subject shoulder against the wall, his arm extended forward, and his index finger touching the tip of his thumb. Fig. 3.1 (B)(g)
23	Shoulder Grip Length	The horizontal distance from pointer held in the subjects fist to a wall against which he sits, measured with the arms extended forward and horizontal. Fig. 3.1(B) (h)
24	Wall to Acromion Distance	The horizontal perpendicular distance from the wall to acromion. Fig. 3.1(B)(h)

25	Hand Length	The distance from the base of the hand to the top of middle finger measured along the long axis of the hand. Fig. 3.3(b)
26	Palm length	The distance from the base of the hand to the furrow where middle finger folds upon the palm. Fig. 3.3(b)
27	Grip Diameter(inside)	The grip of the widest level of a cone, which the subject can grasp with thumb and middle finger touching. Fig. 3.3(a)
28	Grip Diameter (outside)	The distance between the joint of the 1^{st} and 2^{nd} phalanges of the thumb and knuckles of the middle finger measured with the hand held to the grip.
29	Bideltoid breadth	The horizontal distance across the maximum lateral protrusion of the right and left deltoid muscles. The subject stand erect and look straight forward. Fig. 3.1(d)
30	Grip Span	Maximum distance between the palm and the fingers in grip position. Fig. 3.2(a)
31	Sitting Height	The height from sitting surface to the top of the head. The subject sits erect and looks straight forward. Fig. 3.2(a)
32	Sitting Eye Height	The height from the sitting surface to the external canthus. The subject sits erect and looks straight forward. Fig. 3.2(a)
33	Functional Leg Length	The distance from the back at the waist level to the heel, measured along the long axis of the leg with the subject sitting erect on edge of the chair, his extended forward with his knee straightened. Fig. 3.1(b)
34	Index Finger Diameter	The diameter of the index finger of the right hand as determined by the smallest hole in which the finger can be inserted.
35	Hand grip strength (Right)	The grip strength of the right hand measured with handgrip dynamometer when the subject stands erect with his arms hanging downwards. This dimension is used for design of control lever, hand clutch, hand brake and sprayer trigger.
36	Hand grip strength (Left)	The grip strength of the left hand measured with handgrip dynamometer when the subject stands erect with his arms hanging downwards. This dimension is used for design of control lever, hand clutch, hand brake and sprayer trigger.

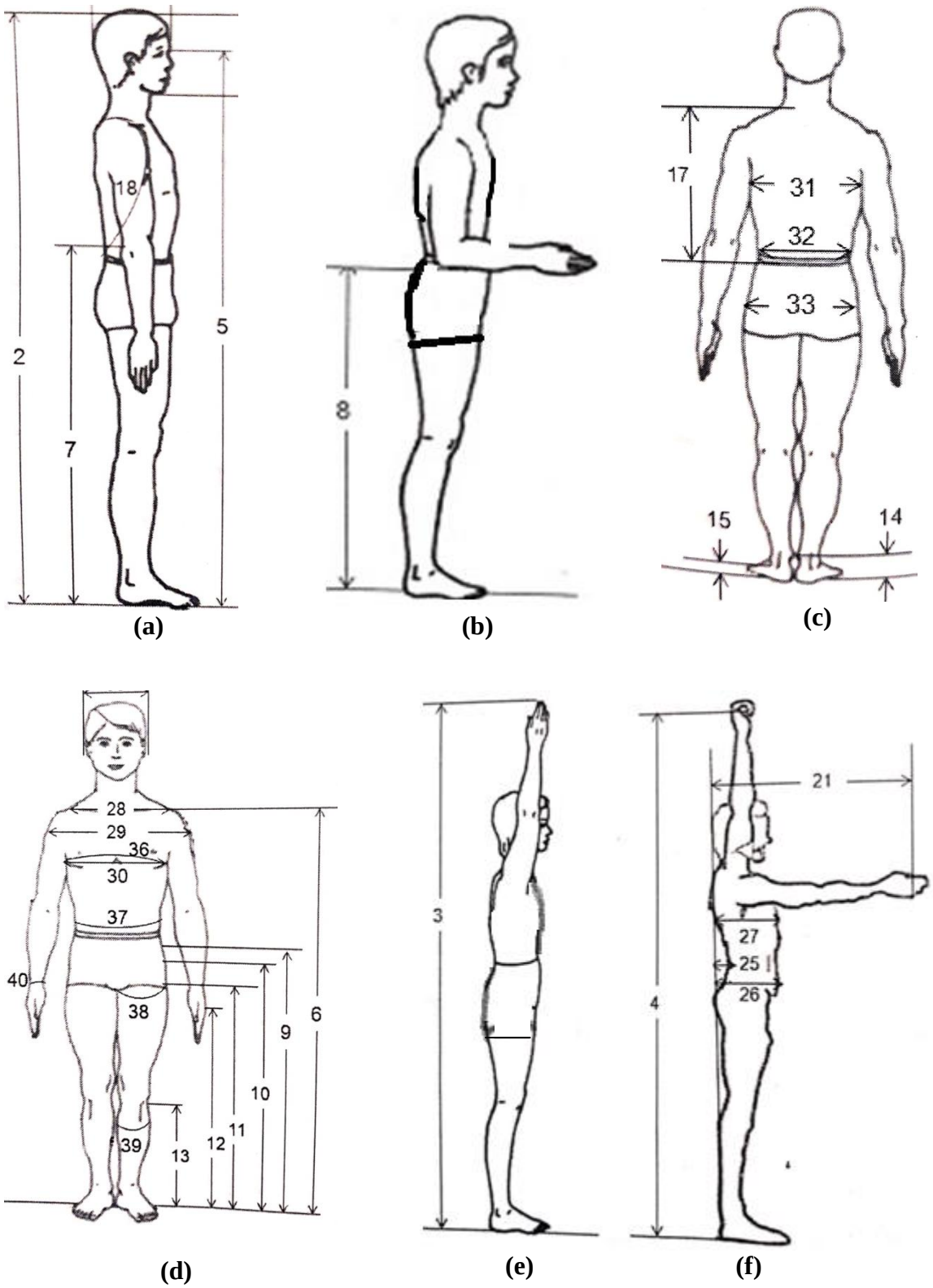


Fig. 3.1(A) Measurement of body dimensions in standing posture

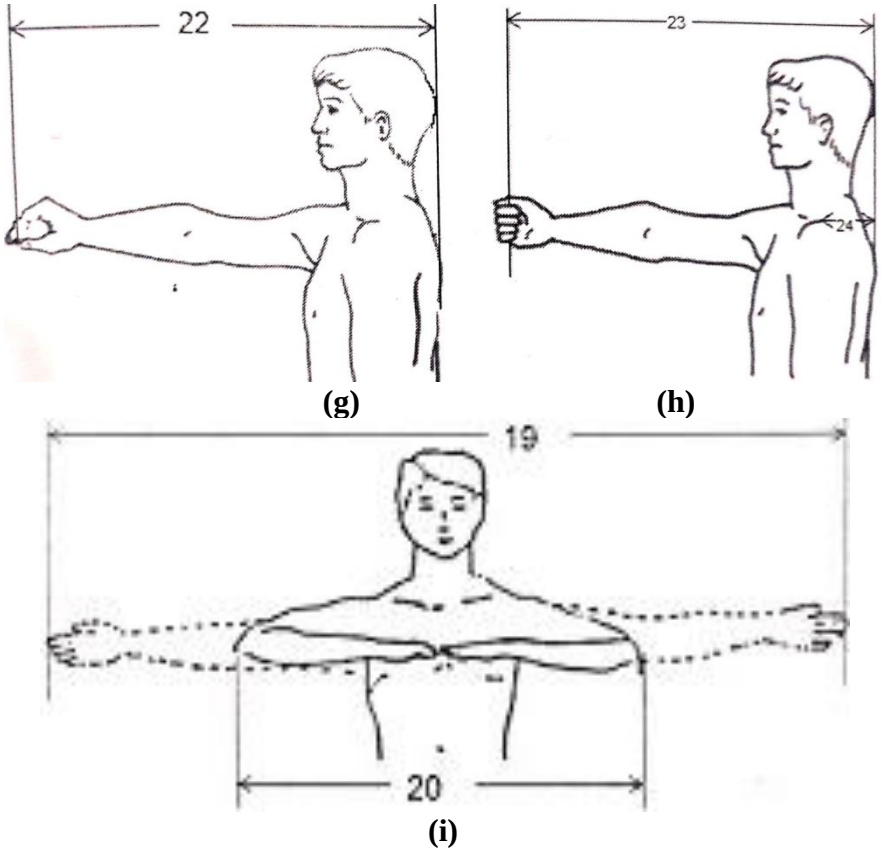


Fig. 3.1(B) Measurement of body dimensions in standing posture

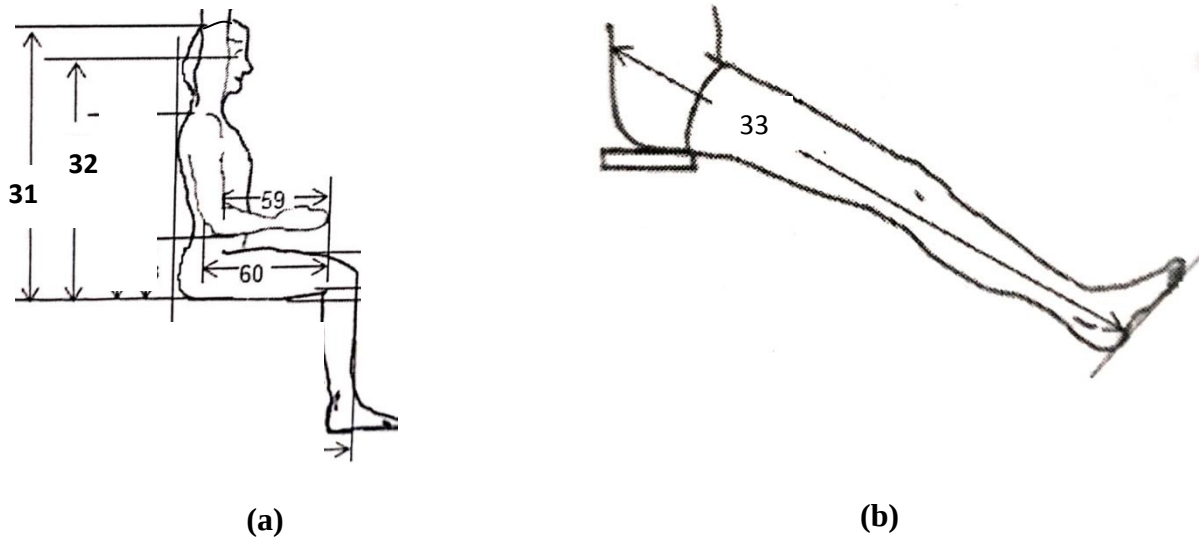


Fig. 3.2 Measurement of body dimensions in sitting posture

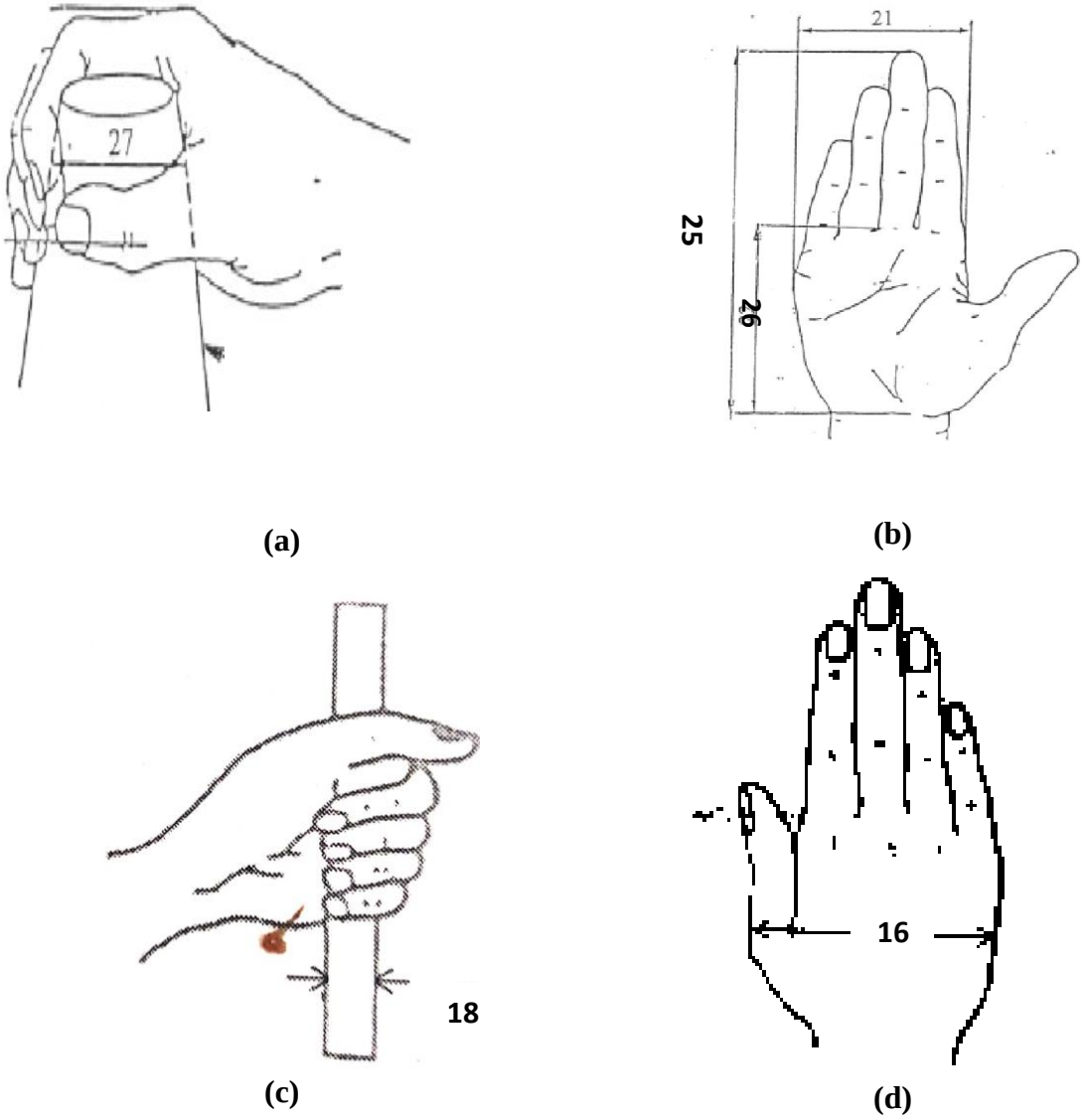


Fig. 3.3 Measurement of miscellaneous body dimensions

3.5 Procedure for Measuring Body Dimensions

To collecting anthropometric measurement it is prior that the persons those selected were screened to ensure that they were in normal health, free from physical abnormalities and musculoskeletal disorders. Before obtaining the data, the subjects were familiarized with the measurement set up and the procedure for collecting data and then the data were collected. Before taking measurements, the subjects were advised to be barefooted and to wear light cloths so as to reduce the margin of errors during measurement. During the process of taking data on body dimensions, instruments were handled such that excessive compression of underlying tissues were avoided as far as possible. While taking measurement in standing posture, the subjects were asked to stand erect on the ground with their feet closed and their body vertically erected, while heels, buttocks and shoulders touched the vertical plane. The anthropometric rod was adjusted according to the height of the subject.

Similarly for measurements in sitting postures, subjects were asked to sit with their body vertically erected, while their shoulders and heads touched the same vertical plane. In sitting posture, feet of the subject completely touched the base platform. Both postures were maintained throughout the survey as natural as possible according to **Hertzberg (1968).** Except handgrip measurement and weight which were taken twice (average recorded), all the remaining measurements was taken just once. In order to achieve greater uniformity, all lateral dimensions were taken from the left hand side of the subject while transverse dimensions from the ground and data were noted to the nearest millimeter.

3.6 Data Analysis

The data were analyzed for the mean, range (maximum and minimum), standard deviation, 5^{th} percentile, 50^{th} percentile and 95^{th} percentile values. The raw data was fed into computer describing each dimension and subject. Microsoft excel was used for most of the statistical analysis.

3.7 Animal Drawn Implements And Hand Tools

3.7.1 Pant hill plough

The hill plough is locally known as Nasuda. It is a modified design of indigenous plough. All the parts of this implement are made of iron so there is no use of

wood. It can be easily be pulled by a pair of bullocks. Farmers can easily replace damaged share and can be repaired by village artisans. The Field capacity of the implement is 0.18 ha/day and Draught requirement is 585 N.

3.7.2 Pant danala

This is an implement used for interculture operations in the hills. The implement is similar to the bullock drawn cultivator used in plains. In the improved danala, the basic frame as well as pegs/tynes is made of steel. In local implement all the parts are made of wood only. The Field capacity of the implement is 0.4 ha/day and Draught requirement is 280N.

3.7.3 Pant damala (Puddler)

Damala is an implement used for the puddling of the paddy fields in hill agriculture. The developed damala has been provided with steel pegs in place of the wooden ones in the local damala It is used to reduce percolation and infiltration of water, kill weeds by decomposing and to facilitate the transplanting of paddy seedlings by making the soil softer. The equipment is suitable for shallow puddling. The Field capacity of the implement is 0.20 ha/day and Draught requirement is 280N.

3.7.4 Pant hill-khurpi

This tool is used for cutting weeds, interculture operation and planting of nursery. It can be used efficiently with less effort in stony and heavy soil. This is made of steel with wooden handle. The weight of hill khurpi ranges between 0.3-0.45 kg and can cover an area of 0.025 ha/day.

3.7.5 Pant hill fork

It has a wooden handle and mild steel forks. It is made in three sizes i.e. with 3, 5 and 7 tines. This tool is used for collecting stones, leaves, weeds etc. It is also used for interculture operation in row crops and pulverization of soil in small beds. It plays an important role in the preparation of seed bed in nursery sowing. The field capacity is approximately 0.06 ha/day and weighs only 0.40-0.75kg. It has gained popularity amongst hill women.

3.7.6 Pant Sickle

It has steel blade and wooden handle. Both types of sickles i.e. plane blade and serrated blade are being used by hill farmers. Sickle with serrated blade is used for

harvesting of crops where are sickle with plane blade is used for cutting of grasses and forest plants for animal feed. The weight of sickle is approximately 0.25 kg and an area of about 0.025 ha/day can be covered.

3.7.7 Pant thamali-cum-chopper

This tool is used for cutting small as well as big branches of trees and green busses in hilly areas. It is made of steel and has a wooden handle. Curved inner edge is used to cut grasses and small branches whereas outer curved edges have provision for cutting thick branches.

3.8 Design Criteria of Animal Drawn Implements and hand Tools Based on Ergonomics

The component of different animal drawn hill implements and hand tools based on anthropometric data of Uttarakhand farmers are discussed under this head. The components of implements and hand tools which were selected for design based on anthropometric data is handle, its height, length and grip diameter.

3.8.1 Design criteria for handle height

As per **Gite (1991)** the optimum handle height for implement should be equal to 1.15 of the metacarpal III height of the operator. The 5^{th} and 95^{th} percentile value of metacarpal III height agricultural workers were considered. Therefore the optimum handle height should be designed 1.15 times of 5^{th} and 95^{th} percentile of metacarpal height. The value for height of a fixed type handle has been given slightly on lower side as there will be less discomfort and better depth.

3.8.2 Design criteria for handle grip

The desirable shape of handle grip is cylindrical. The diameter of grip should be such that while holding the grip, the operator's longest finger should not touch the palm. At the same time, the grip should not exceed the internal grip diameter. As the equipment is to be operated by male workers, their 95^{th} percentile of middle finger palm grip diameter is the lowest limit and 5^{th} percentile of grip diameter (inside) is to be considered as the upper limit. Therefore, the recommended value of grip diameter was 5^{th} percentile of inside grip diameter.

3.8.3 Design criteria for handle length

Based on the anthropometric considerations, the length of handle should accommodate the maximum dimension of hand breadth across thumb. The 95th percentile value of the hand breadth across thumb, taking a clearance of 5mm on each side of the grip the length of handle should be designed.

Plate 3.1 Anthropometric Kit

Plate 3.2 Anthropometric cone

Plate 3.3 Hold on cylinder

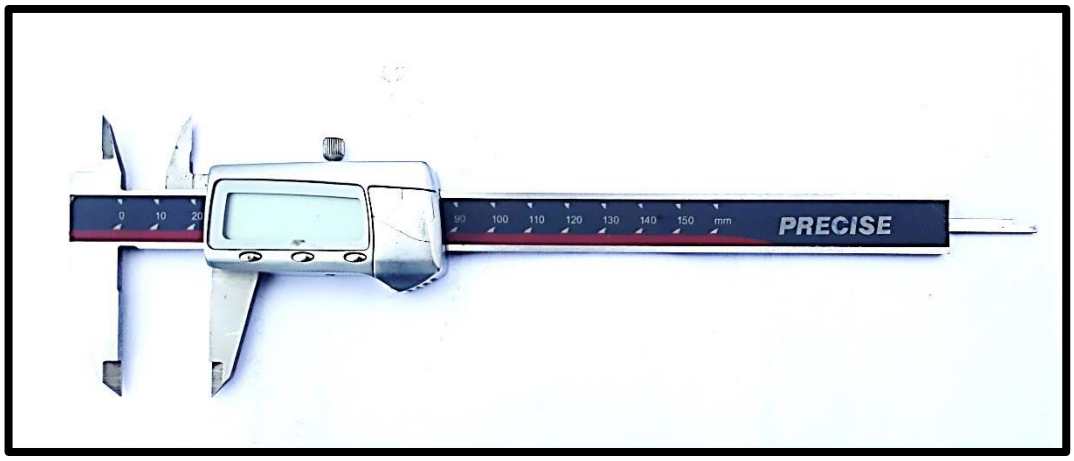


Plate 3.4 Vernier Caliper

Plate 3.5 Hand grip dynamometer

Plate 3.6 Measurement of Index finger diameter

Plate 3.7 Measurement of hand grip strength

Plate 3.8 Measurement of middle finger palm grip diameter

Plate 3.9 Measurement of grip diameter

Plate 3.10 Measurement of hand length and palm length

Plate 3.11 Measurement of hand breadth across thumb

Results and Discussion

4-RESULTS AND DISCUSSION

In order to achieve the objectives of the present study, survey and experiment were conducted, and results of the survey and experiment are presented and discussed in this chapter. This includes statistical analysis of anthropometric data of 200 male agricultural workers to evaluate mean, standard deviation (SD), coefficient of variation and standard error of mean at 5th and 95th percentile with minimum and maximum values of two hundred body dimensions and three hand strength parameters.

4.1 Anthropometric Survey of Agricultural Workers

Thirty-six body dimensions of two hundred male agricultural workers of the region were analyzed. The various observation were included to evaluate Mean, standard deviation, range, minimum, maximum,$5^{th}$and 95^{th} percentile, values of different body dimensions including age, weight and strength parameters. The consolidated data of these dimensions are presented in table 4.1.

4.1.1 Analysis of anthropometric data

Table 4.1 shows the data of various anthropometric parameters taken in three postures i.e. standing, sitting and Miscellaneous. The mean weight and stature of the farm workers of hill were observed 57.21$\pm$10.18 kg and 1657.7$\pm$70.3 mm respectively. In standing postures such as stature, eye height, vertical reach, vertical grip reach has higher standard error mean values which ranged from 0.49 to 0.71. The sitting height, sitting eye height and functional leg length shows standard error of mean 0.32, 0.31 and 0.40 respectively. The coefficient of variation ranged from 3.70 to 62.30 for all selected dimension of subjects. However coefficient of variation of palm length was higher among the subjects as compare to other body dimensions and it was found 62.6.

In this study metacarpal height, inside grip diameter, middle finger palm grip diameter and hand breadth across the thumb were used for design purpose. It was observed that the 5^{th} and 95^{th} percentile value of metacarpal height for hill area farmers of Uttarakhand were 720.5 and 807.1 mm respectively, whereas the coefficient of variation, SD and SEM, were found 6.24, 452 and 0.31 respectively. These values were used for design of optimum handle height of animal drawn hill agricultural implements (Gite 1991). Table 4.1 also indicates the values of 5^{th} and 95^{th} percentile of inside grip diameter which were 34.11 and 47.29 respectively whereas the 5^{th} and 95^{th} percentile

values for middle finger palm grip diameter were 24 and 32 mm respectively. Whereas for inside grip diameter the CV, SD and SEM were found 9.60, 3.95 and 0.27 respectively, and for middle finger palm grip diameter these values were 8.32, 2.37 and 0.16 respectively. These values were used for optimum handle grip diameter. The value of 5^{th} and 95^{th} percentile of hand breadth across thumb was observed 90.23 and 105.66 respectively whereas the CV, SD and SEM were found 4.60, 4.60 and 0.32 respectively. The 5^{th} and 95^{th} percentile values of elbow height were 959.7 and 1147.0 respectively whereas the SD, CV and SEM were 60.4, 5.70 and 0.42 respectively (Table 4.1). For olecranon height the 5^{th} and 95^{th} percentile value were found 941 and 1114.1 respectively, and SD, CV and SEM were found 64.88, 60.47 and 4.58 respectively (Table 4.1).

4.1.2 Strength parameters of agricultural workers

The maximum, minimum, mean, standard deviation, coefficient of variation, standard error of mean at 5^{th} , 50^{th} and 95^{th} percentile values of strength parameters of hilly male farm workers is indicated in Table 4.1. The range of the right hand grip strength and left hand grip strength were 370.18$\pm$71.82 and 345.31$\pm$70.92 respectively. The both strength parameters right hand grip strength and left hand grip strength had standard error of mean values 0.51 and 0.51respectively and coefficient of variation was26.92 and 28.68 respectively.

Table 4.1 Anthropometric data of male agricultural workers of hilly region in Uttarakhand in age group of 18-60 years (n=200)

S. No.	Parameters	Range		Mean	SD	CV	SEM	Percentile		
		Max	Min					5^{th}	50^{th}	95^{th}
Standing body dimensions										
1.	Weight (kg)	89	36	57.21	10.18	17.79	0.72	43	55	75
2.	Stature	1832	1441	1657.7	70.3	4.24	0.49	1547.9	1663.5	1771.2
3.	Eye Height	1724	1352	1551.4	70.7	4.56	0.50	1433.9	1557	1667.4
4.	Acrominal Height	1635	1125	1407.3	76.4	5.43	0.54	1277.8	1410.5	1552.1
5.	Elbow Height	1413	915	1059.7	60.4	5.70	0.42	959.7	1058.5	1147.05
6.	Olecranon height	1017	864	1072.8	64.88	60.47	4.58	941	1024	1114.1
7.	Iliocrystale Height	1125	757	983.5	61.5	6.26	0.43	894.8	987	1081.0
8.	Iliospinale Height	1097	545	923.4	66.1	7.15	0.46	834.9	926	1035.3
9.	Trochanteric height	1042	686	857	64.5	7.52	0.45	763.9	856.5	976.0

10.	Metacarpal III Height	865	584	723.7	452.0	6.24	0.31	656.8	720.5	807.1
11.	Knee Height	987	417	485.6	48	9.89	0.33	434.8	482	537.4
12.	Medial Malleolus Height	106	70	85.6	7.0	8.22	0.04	75	85	97
13.	Lateral Malleolus Height	90	54	72.7	7.5	10.39	0.05	61	73	85
14.	Vertical Reach	2350	1775	2093.1	101.0	4.82	0.71	1924.2	2100	2275.2
15.	Vertical Grip Reach	2300	1700	1979.6	95.7	4.83	0.67	1804.8	1990	2140
16.	Waist Back length	567	404	487.8	30.5	6.25	0.21	436.9	489	530.1
17.	Span	1970	1360	1681.8	84.6	5.03	0.59	1549.5	1680	1825.2
18.	Span Akimbo	1010	700	876.1	51.1	5.84	0.36	799.5	871.5	960
19.	Wall to Acromion Distance	135	67	90.8	11.4	12.57	0.08	75	90	111.1
20.	Arm reach from the wall	975	674	838.8	48.1	5.74	0.34	769	840	923.0
21.	Thumb Tip Reach	924	643	782.9	47.9	6.12	0.33	706.8	784	860.1
22.	Shoulder Grip Length	870	621	733.1	45.7	6.24	0.32	664	734	800.1
23.	Bideltoid breadth	495	312	417.5	25.2	6.03	0.17	381.9	415.5	460.1
Sitting body dimensions										
24.	Sitting height	133.2	109.8	123.22	4.56	3.70	0.32	115.17	123.6	130.42
25.	Sitting eye height	124.1	101.1	112.49	4.47	3.97	0.31	104.69	112.45	119.71
26.	Functional Leg Length	1110	800	947.4	57.0	28.68	0.40	849.7	950	1040
Miscellaneous body dimensions										
27.	Grip Diameter (inside)	52.41	34.1	41.20	3.95	9.60	0.27	34.11	40	47.29
28.	grip Diameter (outside)	90.1	63.82	75.64	4.38	5.79	0.31	68.29	75.18	83.10
29.	grip span	108.21	72.89	92.81	6.27	6.75	0.44	82.3	93.14	102.91
30.	Index finger Diameter	23.05	14.2	19.25	1.05	5.50	0.07	17.932	19.2	21.11
31.	Middle Finger Palm Grip Diameter	34	20	28.51	2.37	8.32	0.16	24	28	32
32.	Hand Length	20.5	15	18.21	0.86	4.73	0.067	16.97	18	19.5
33.	Palm length	105	8	10.76	6.70	62.30	0.47	9.5	10.5	11.01
34.	Hand breadth across thumb	109.36	83.48	99.91	4.60	4.60	0.32	90.23	100.99	105.66
Strength Measurement										
35.	Hand grip strength (Right), N	461.07	90.25	266.72	71.82	26.92	0.51	148.13	265.36	370.81
36.	Hand grip strength (Left), N	441.45	96.13	247.22	70.92	28.68	0.51	152.05	244.26	392.4

All dimensions are in mm, unless specified

4.2 Percentage Variation of 5th And 95th Percentile of Different Anthropometric Parameters of Farm Workers of Hilly Region of Uttarakhand with India.

The 5th and 95th percentile values of different anthropometric data of hill farmers and data based on all India values (as per AICRP on ESA Centers) are given in Table 4.2. It is evident from the Table 4.2 that the percentage variation in all the measured data of hill farmers with all India were ranged from -28.09 to 82.88% for 5th percentile value whereas for 95th percentile value the percentage variation was ranged between -27.29 to 49.07%. It is observed that the value of percentage variation for 5th percentile was maximum for grip span and minimum for right hand grip strength. Whereas for 95th percentile maximum percentage variation found in sitting eye height and minimum for right hand grip strength. The 5th and 95th percentile value of weight of hill farmers were 2.38 and 4.89 % higher than the value of All India farmers value. From Table 4.2 It was also observed that the 5th and 95th percentile value in standing measurement such as stature, eye height, acromial height, elbow height, olecranon height, illiocrystale height, illiospinale height, trochanteric height, metacarpal height, knee height, medial malleolus height, lateral malleolus height, vertical reach and waist back length for hilly farmers was more as compare to All India farmers, whereas the 5th and 95th percentile value of Uttarakhand farmers vertical grip reach and span were found less as compare to All India farmers. Table 4.2 indicates that the percentage variation of 5th percentile of span akimbo, wall to acromial distance, arm reach from the wall, thumb tip reach, shoulder grip length and bideltoid breadth were higher for hilly farmers as compare to all India farmers, whereas variation of 95th percentile for these values for hilly farmers were less than the All India farmers.

From Table 4.2 for sitting measurement it was also observed that the percentage variation of hilly farmers with all Indian farmers for 5th and 95th percentile of sitting height, sitting eye height and functional leg length were 54.59 and 43.31%, 62.31and 49.07% and -3.44 and -4.14% respectively i.e. for sitting height and sitting eye height of hill farmers of Uttarakhand had higher values of 5th and 95th percentile than the All Indian farmers whereas for functional leg length these values are less for Uttarakhand farmers as compare to all India farmers.

For miscellaneous body dimensions, it was observed that the values of 5^{th} and 95^{th} percentile of grip diameter (inside) and grip diameter (outside) were less for hill farmers of Uttarakhand than the All India farmers. The percentage variation of 5^{th} and 95^{th} percentile for grip diameter (inside) and grip diameter (outside) were found -12.53 and -18.46%, and -7.716 and -21.60% respectively shown in Table 4.2. It was also observed that the 5^{th} percentile values of index finger diameter, middle finger palm grip diameter, hand length, palm length and hand breadth across the thumb for hilly farmers were higher than the all India farmers, whereas 95^{th} percentile values of these parameters were less for Uttarakhand farmers. Grip span of hilly farmers was higher 5^{th} and 95^{th} percentile values than the all India farmers, the percentage variation were 82.88 and 23.98% for 5^{th} and 95^{th} percentile respectively.

For strength parameters, it was clear from Table 4.2 that the values of 5th and 95th percentile of hand grip strength (right) and hand grip strength (left) for hill farmers were less as compare to All India farmers. Table 4.2 indicates the percentage variation of hand grip strength (right) and hand grip strength (left) for 5^{th} and 95^{th} percentile were -28.09 and -27.29%, and -22.02 and -20.88% respectively.

It was indicated from Table 4.2 that the value of percentage variation of 5^{th} and 95^{th} percentile for metacarpal height was 5.93% and 4.91% respectively. It was also observed that the percentage variation of 5^{th} and 95^{th} percentile values for inside grip diameter were -12.53% and -18.46% respectively. Similarly for middle finger palm grip diameter the values of percentage variation of 5^{th} and 95^{th} percentile were 33.33% and -15.78%, and for hand breadth across thumb the values were 6.15% and -3.94% for 5^{th} and 95^{th} percentile respectively.

Table 4.2 Percentage variation of 5th and 95th percentile of different parameters of farm workers of hilly region in Uttarakhand

S. No.	Parameters	Uttarakhand		India*		Percent variation	
		Percentile		Percentile		Percentile	
		5th	95th	5th	95th	5th	95th
1	Weight, kg	43	75	42.0	71.5	2.38	4.89
2	Stature,mm	1547.9	1771.2	1523	1756	1.63	0.86
3	Eye Height, mm	1433.9	1667.4	1410	1646	1.69	1.30
4	Acrominal Height, mm	1277.8	1552.1	1255	1477	1.81	5.08
5	Elbow Height, mm	959.7	1147.05	941	1121	1.98	2.32
6	Olecranon height, mm	941	1114.1	916	1090	2.72	2.21
7	Iliocrystale Height, mm	894.8	1081.0	861	1050	3.92	2.95
8	Iliospinale Height, mm	834.9	1035.3	810	1005	3.07	3.01
9	Trochanteric height, mm	763.9	976.0	700	922	9.12	5.85
10	Metacarpal III Height, mm	656.8	807.1	620	770	5.93	4.81
11	Knee Height, mm	434.8	537.4	419	530	3.77	1.39
12	Medial Malleolus Height, mm	75	97	64	96	17.18	1.04
13	Lateral Malleolus Height, mm	61	85	54	85	12.96	0
14	Vertical Reach, mm	1924.2	2275.2	1920	2245	0.21	1.34
15	Vertical Grip Reach, mm	1804.8	2140	1827	2150	-1.21	-0.46
16	Waist Back length, mm	436.9	530.1	380	520	14.97	1.94
17	Span, mm	1549.5	1825.2	1560	1842	-0.67	-0.91
18	Span Akimbo, mm	799.5	960	780	965	2.5	-0.51
19	Wall to Acromion Distance, mm	75	111.1	72	132	4.16	-15.8333
20	Arm reach from the wall, mm	769	923.0	754	925	1.98	-0.21
21	Thumb Tip Reach, mm	706.8	860.1	681	862	3.78	-0.22
22	Shoulder Grip Length, mm	664	800.1	625	814	6.24	-1.70
23	Bideltoid breadth, mm	381.9	460.1	365	475	4.63	-3.13
24	Sitting height, mm	1151.7	1304.2	745	910	54.59	43.31
25	Sitting eye height, mm	1046.9	1197.1	645	803	62.31	49.07
26	Grip Diameter (inside), mm	34.11	47.29	39	58	-12.53	-18.46
27	grip Diameter (outside), mm	68.29	83.10	74	106	-7.716	-21.60
28	grip span, mm	82.3	102.91	45	83	82.88	23.98
29	Index finger Diameter, mm	17.932	21.11	12	23	49.43	-8.21
30	Middle Finger Palm Grip Diameter, mm	24	32	18	38	33.33	-15.78
31	Hand Length, mm	169.7	195	160	198	6.74	-2.56
32	Palm length, mm	95	110.1	89	113	6.15	-3.94
33	Hand breadth across thumb, mm	90.23	105.66	85	110	6.15	-3.94
34	Functional Leg Length, mm	849.7	1040	880	1085	-3.44	-4.14
35	Hand grip strength (Right), N	148.13	370.81	206	510	-28.09	-27.29
36	Hand grip strength (Left), N	152.05	392.4	195	496	-22.02	-20.88

* Source: The AICRP on ESA Centers for all India data

4.3 Application of Anthropometric Data for Hill Agricultural Implements

The anthropometric database was used for design of agriculture implements. The original values of the database lies in its application, the marginal and small farmers of hilly region of Uttarakhand mostly used various types of animal drawn agricultural implements like hill plough, danala, damala etc. These implement consist of various parts viz. functional part, beam, handle and handle grip. Design of handle depends on various factors like shape of handle, material of handle, mode of operation and anthropometric data of the farm workers.

Gite, (1991) recommended optimum handle height for plough to be 1.15 of the metacarpal III height considering heart rate and oxygen uptake data, overall discomfort rating, body parts discomfort scores, and volume of soil handled per hour when the mean depth of operation is 11.2 cm.

The better grip diameter of handle should be such that an operator grips the handle comfortably, such that his longest finger should not touch the palm and at the same time, it should not exceed the internal grip diameter of the operator. Therefore the handle diameter should be designed according to the 5^{th} percentile value of inside grip diameter and 95^{th} percentile of middle finger palm grip diameter to accommodate larger population group. Based on an ergonomic evaluation of different hand tools with household appliances, it had been found that to allow best grip on handle, the diameter of the handle should be a little lesser than the inside grip diameter **(Nag *et al.*, 1988).**

The length of handle should be such that it accommodates the 95^{th} percentile value of hand breadth across thumb was selected and clearance of 0.5 cm on each side of the grip is also provided.

The 5^{th} and 95^{th} percentile values of required dimensions i.e. metacarpal height, grip diameter inside, middle finger palm grip diameter and hand breadth across thumb for the study are shown in Fig. 4.1 to Fig. 4.4 respectively.

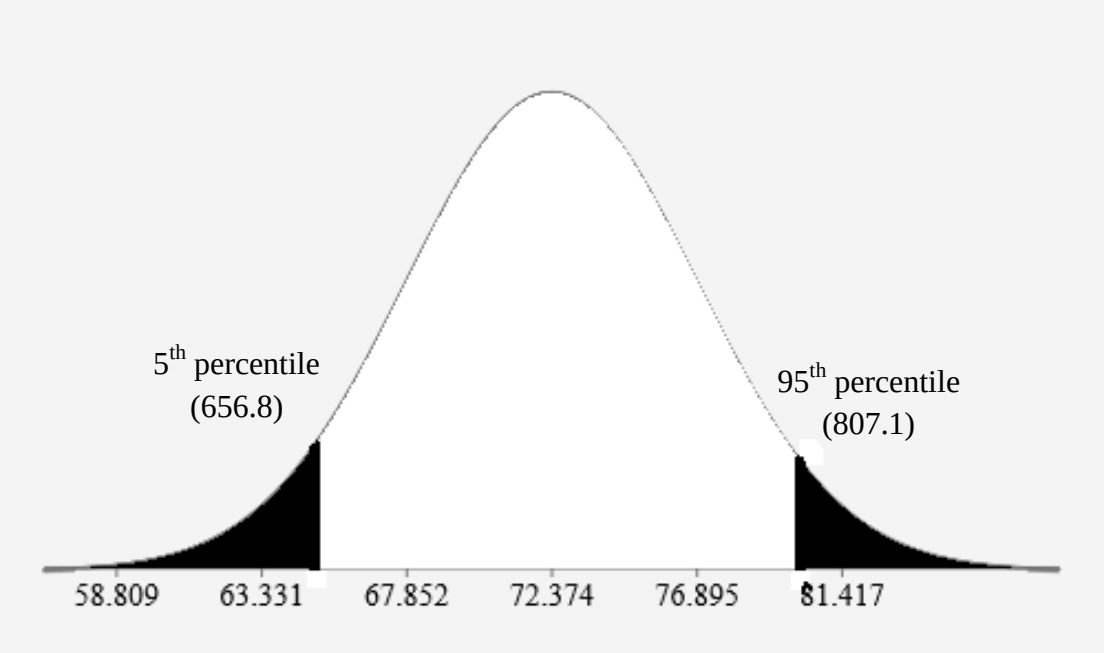


Fig. 4.1 5th and 95th percentile value of metacarpal height

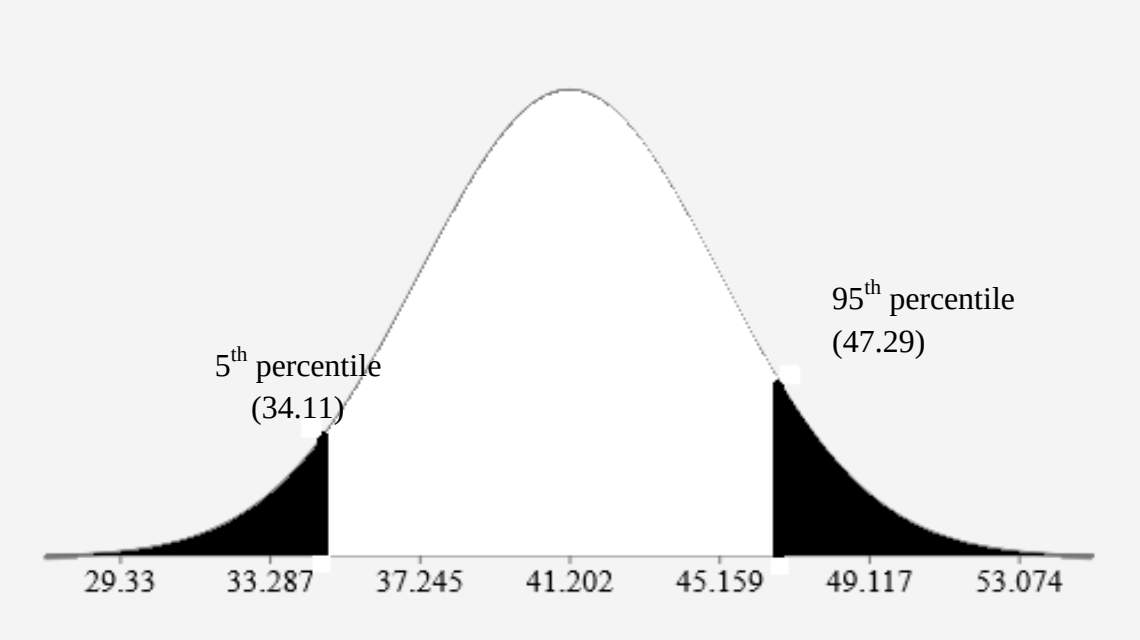


Fig. 4.2 5th and 95th percentile value of grip diameter (inside)

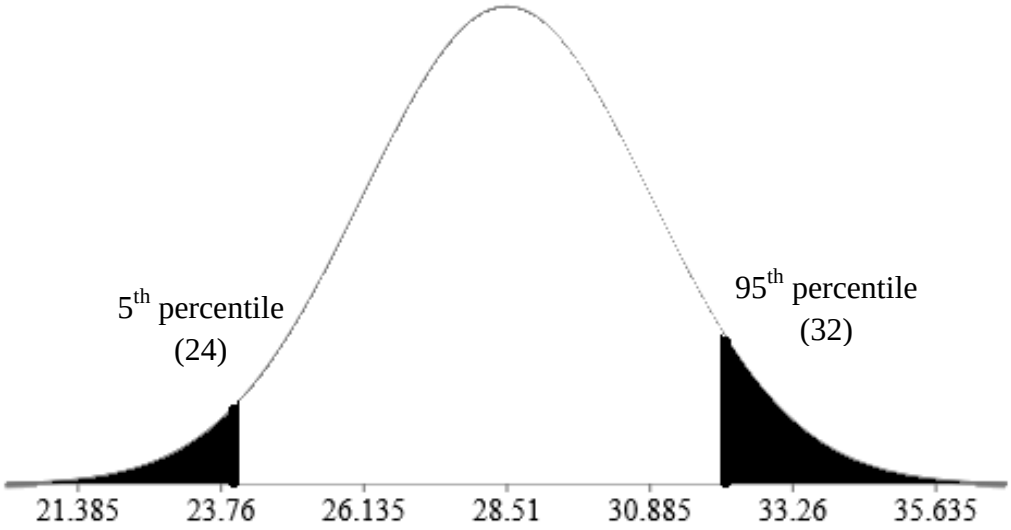


Fig. 4.3 5th and 95th percentile value of middle finger palm grip diameter

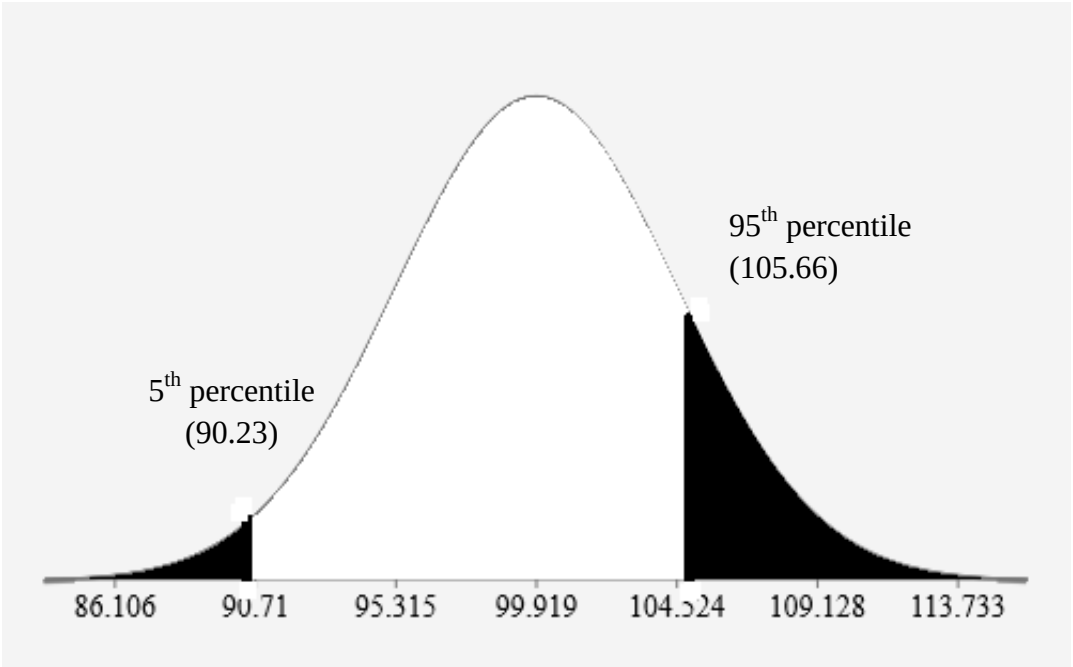


Fig. 4.4 5th and 95th percentile value of Hand breadth across thumb

Table 4.3 Percentage variation in 5th and 95th percentile for handle height, handle grip, handle length and long handle height

Parameters		As per Uttarakhand Percentile		As per all India data percentile		Percentage variation percentile	
		5th	95th	5th	95th	5th	95th
Handle height	Metacarpal III	656.8	807.1	587	729	11.8	10.7
Handle grip	Middle finger palm grip diameter	24	32	20	32	20	0
	Grip diameter (Inside)	34.1	47.3	35	57	-2.6	-20.5
Handle length	Hand breadth across thumb	90.23	105.66	85	110	6.15	4.10
Long Handle height	Acromial height	1277.8	1552.1	1173	1370	8.93	13.29
	Eye height	1433.9	1667.4	1310	1521	9.45	9.62

4.3.1 Design of handle height and handle grip of hill plough

The hill plough is locally known as Nasuda. It is a modified design of indigenous plough. All the parts of this implement are made of iron so there is no use of wood. It can be easily be pulled by a pair of bullocks. Farmers can easily replace damaged share and can be repaired by village artisans. The Field capacity of the implement is 0.18 ha/day and Draught requirement is 585 N.

The handle of hill plough is designed on the basis of 5th and 95th percentile value Metacarpal III, Middle finger palm grip diameter and Grip diameter (Inside). The 5th and 95th percentile value of Metacarpal III, Middle finger palm grip diameter and Grip diameter (Inside) of Uttarakhand farmers and all India farmers are shown in table 4.3. Table 4.3 shows that the percent variation in 5th and 95th percentile of Metacarpal III is 11.8 and 10.7 respectively, the percent variation in 5th and 95th percentile of Middle finger palm grip diameter is 20 and 0 percent, respectively and the percent variation in 5th and 95th percentile of Grip diameter (Inside) is -2.6 and -20.53, respectively.

Height of handle

Metacarpal III Height (mm)

5^{th} Percentile= 656.8 mm

95^{th} Percentile =807.1 mm

Recommended lower limit for height of the handle of animal drawn implements =

1.15 x 5^{th} percentile of metacarpal III height = 755.32mm≈ 756 mm

Recommended upper limit for height of adjustable handle of animal drawn implements

1.15 x 95^{th} percentile of metacarpal III height = 928.16 mm≈ 928 mm

The optimum height of handle should be taken as the average of recommended lower limit i.e. 756 mm and recommended upper limit i.e. 928 mm. Therefore, the height of handle was considered 842 mm.

Handle grip diameter

- Grip Diameter Inside (mm)

  5^{th} Percentile= 34.11mm

- Middle Finger Palm Grip Diameter (mm)

  95^{th} Percentile = 32 mm

Upper limit of the handle grip diameter

= 5^{th} percentile of Grip Diameter Inside (mm) = 34.1 mm

Lower limit of the handle grip diameter

= 95^{th} percentile of Middle Finger Palm Grip Diameter = 32 mm

The optimum diameter of handle should be taken as 32 mm as lower limit and 34.1 mm as upper limit. The suggested design of plough is shown in Fig. 4.5.

4.3.2Design of handle height and handle grip diameter of Danala

This is an implement used for intercultural operations in the hills. The implement is similar to the bullock drawn cultivator used in plains. In the improved danala, the basic frames as well as pegs/tynes are made of steel. In local implement all the parts are made of wood only. The Field capacity of the implement is 0.4 ha/day and Draught requirement is 280N.

The handle height of danala is designed on the basis of 5^{th} and 95^{th} percentile of metacarpal III height. Optimum handle height for danala to be 1.15 of the metacarpal

III height when the mean depth of operation is 11.2 cm. The 5th and 95th percentile values of Metacarpal III height of male agricultural workers of Uttarakhand region have been found to be 656.8 mm and 807.1 mm respectively. Considering depth of operation of about 11 cm, the optimum handle height for danala works out to be between 755.32 mm and 928.16 mm. preferably, the height should be adjustable between these ranges. For a fixed type handle, a height of 841.74 mm has been recommended.

Based on the anthropometric considerations, the handle diameter should be according to 95^{th} percentile middle finger palm grip diameter becomes the lower limit and 5^{th} percentile grip diameter (inside) of the male workers of Uttarakhand is to be considered as the upper limit. As per data, these values are 34.11 mm and 32 mm, respectively. Therefore, the recommended handle grip diameter is 34.11 mm taken as upper limit and 32 mm taken as lower limit. The suggested design dimensions of danala was shown in Fig. 4.6.

4.3.3 Design of handle height and handle grip diameter of Damala

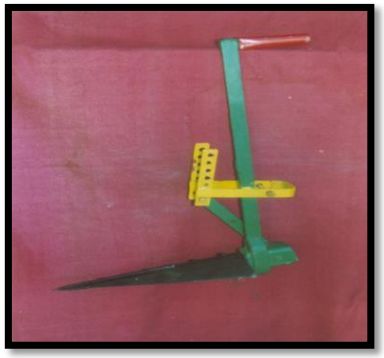
Damala is an implement used for the puddling of the paddy fields in hill agriculture. The developed damala has been provided with steel pegs in place of the wooden ones in the local damala.It is used to reduce percolation and infiltration of water, kill weeds by decomposing and to facilitate the transplanting of paddy seedlings by making the soil softer. The equipment is suitable for shallow puddling. The Field capacity of the implement is 0.20 ha/day and Draught requirement is 280N.

The dimensions of handle height of damala were considered on the basis of 5^{th} and 95^{th} percentile value of metacarpal height. The values of 5^{th} and 95^{th} percentile of metacarpal height for hill farmers were 656.8 mm and 807.1 mm respectively, whereas for All India farmers these values were 587 mm and 729 mm respectively, shown in table 4.3. Considering the mean depth of operation about 11 cm, Optimum handle height for damala to be 1.15 of the metacarpal III height, so the recommended optimum handle height should be 841.74 mm.

The dimensions of handle grip of damala were same as danala discussed in 4.3.2.The final dimensions of damala was shown in Fig. 4.7.

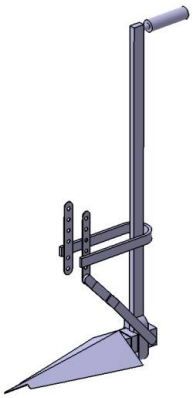
4.4 Application of Anthropometric Data for Hill Agricultural Tools

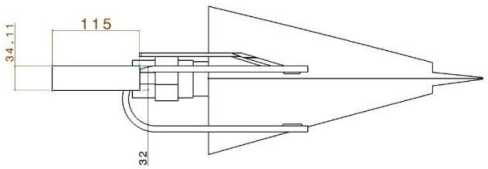
The anthropometric database was used for design of agriculture hand tools. The original values of the database lies in its application, the marginal and small farmers of



Isometric view

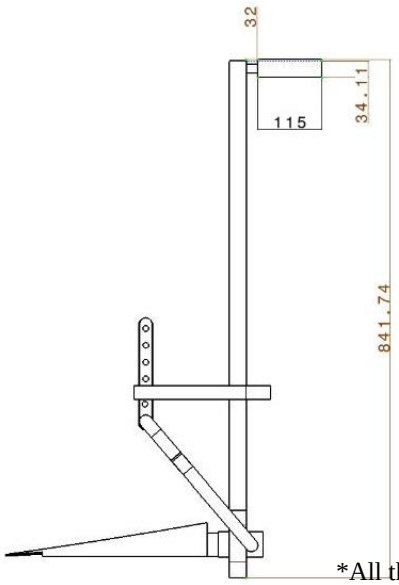
Top view

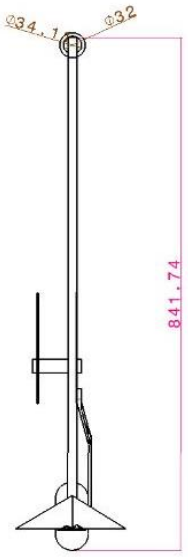




Side view

Front view



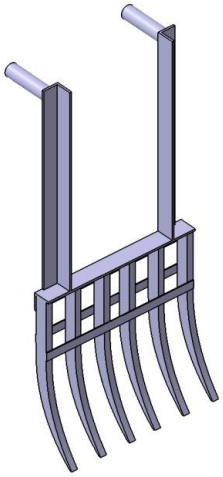


*All the dimensions are in mm

Fig. 4.5 Design dimensions of hill plough

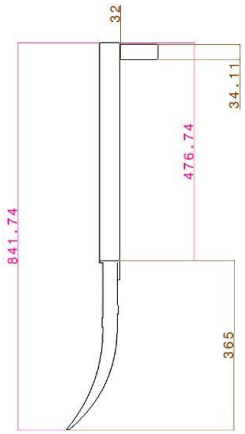
Isometric view

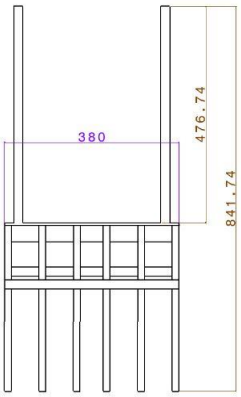
Top view



Side view

Front view

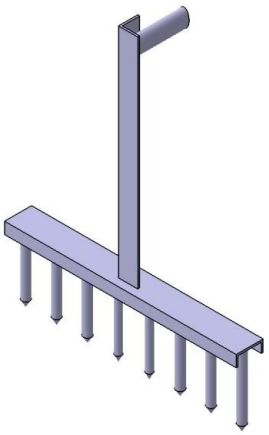


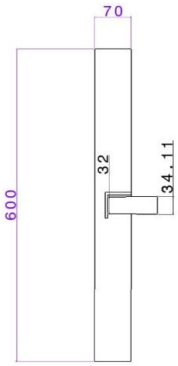


*All the dimensions are in mm

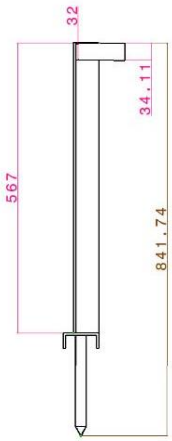
Fig. 4.6 Design dimensions of danala

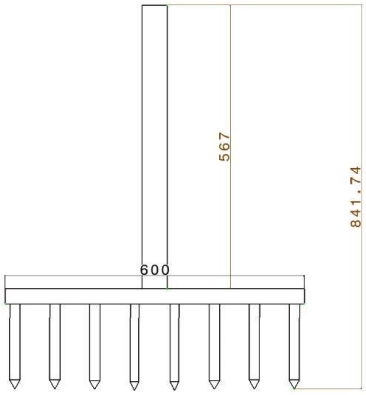
Isometric view **Top view**





Side view **Front view**





*All the dimensions are in mm

Fig. 4.7 Design dimensions for damala

hilly region of Uttarakhand mostly used various types of agricultural hand tools such as hill khurpi, fork, sickle, thamali-cum-chopper etc. These tool consist of various parts viz. functional part, handle and handle grip. Design of handle depends on various factors like shape of handle, material of handle, mode of operation and anthropometric data of the farm workers.

4.4.1 Design of handle length and handle grip diameter of khurpi

This tool is used for cutting weeds, interculture operation and planting of nursery. It can be used efficiently with less effort in stony and heavy soil. This is made of steel with wooden handle. The weight of hill khurpi ranges between 0.3-0.45 kg and can cover an area of 0.025 ha/day.

The diameter of grip should be such that while holding the grip, the operator's longest finger should not touch the palm. At the same time, the grip should not exceed the internal grip diameter. As the equipment is to be operated by male workers, their 95^{th} percentile of middle finger palm grip diameter is the lowest limit and 5^{th} percentile grip diameter (inside) is to be considered as the upper limit, and these values are 32 mm and 34.11 mm, respectively. Therefore, the grip diameter recommended is 34.11 mm. The length of handle should accommodate the maximum dimension of hand breadth at thumb. The 95th percentile value of the length of handle is 105.66, taking a clearance 5 mm on each side of the grip, the length of the handle comes to 115.66 mm. The suggested design dimensions of khurpi were shown in Fig. 4.8.

4.4.2 Design of handle length and handle grip diameter of hill fork

It has a wooden handle and mild steel forks. It is made in three sizes i.e. with 3, 5 and 7 tines. This tool is used for collecting stones, leaves, weeds etc. It is also used for intercultural operation in row crops and pulverization of soil in small beds. It plays an important role in the preparation of seed bed in nursery sowing. The field capacity is approximately 0.06 ha/day and weighs only 0.40-0.75kg.

The desirable shape of handle of fork is cylindrical. Generally the design of handle of hill fork is based on 5^{th} and 95^{th} percentile of grip diameter inside, middle finger palm grip diameter and hand breadth across the thumb. The handle diameter of hill fork was suggested that the 5^{th} percentile of grip diameter (34.11 mm) and 95^{th} percentile of middle finger palm grip diameter (32 mm). The 95^{th} percentile of middle

finger palm grip diameter was considered as lower limit whereas 5th percentile value of inside grip diameter was considered as upper limit. The handle length of fork was suggested on the basis of 95th percentile value of hand breadth across thumb with clearance of 5 mm each side of handle, so the dimension of the hand length of fork should be 115.66 mm which was comfortable to most of the farm workers in hill region of Uttarakhand. The dimensions of the handle of hill fork shown in Fig. 4.9.

4.4.3 Design of handle length and handle grip diameter of sickle

It has steel blade and wooden handle. Both types of sickles i.e. plane blade and serrated blade are being used by hill farmers. Sickle with serrated blade is used for harvesting of crops where are sickle with plane blade is used for cutting of grasses and forest plants for animal feed. The weight of sickle is approximately 0.25 kg and an area of about 0.025 ha/day can be covered.

The handle length and handle diameter of sickle were designed on the basis of 5th and 95th percentile of inside grip diameter, middle finger palm grip diameter and hand breadth across the thumb. These values were shown in table 4.3. Following are the suggested dimensions of handle for hill farmers:

Hand diameter = 5th percentile of inside grip diameter taken as upper limit and 95th percentile of middle finger palm grip diameter taken as lower limit.

Which were observed 32 mm as lower limit and 34.11 mm as upper limit

Grip diameter = 95th percentile value of hand breadth across thumb + clearance of 5 mm each side.

95th percentile value of hand breadth across thumb = 105.66 mm

Grip length = (105.66+5+5)

= 115.66 mm

The suggested design dimensions of sickle was shown in Fig. 4.10.

4.4.4 Design of handle height and handle grip diameter of thamali-cum-chopper

This tool is used for cutting small as well as big branches of trees and green busses in hilly areas. It is made of steel and has a wooden handle. Curved inner edge is used to cut grasses and small branches whereas outer curved edges have provision for cutting thick branches.

Handle Grip Diameter

- Grip Diameter Inside (mm)

  5^{th} Percentile= 34.1 mm

- Middle Finger Palm Grip Diameter (mm)

  95^{th} Percentile = 32 mm

Upper limit of the handle grip diameter

= 5^{th} percentile of Grip Diameter Inside (mm) = 34.1 mm

Lower limit of the handle grip diameter

= 95^{th} percentile of Middle Finger Palm Grip Diameter = 32 mm

The optimum diameter of handle should be taken as 32 mm as lower limit and 34.1 mm as upper limit. The suggested design of thamali-cum-chopper is shown in Fig. 4.11.

Handle length

- Hand breadth across thumb

  95^{th} percentile = 105.66

  Handle length = 95^{th} percentile of hand breadth across thumb + clearance of 5mm each side (105.66+5+5=115.66) mm

  Optimum handle length should be 115.66 mm.

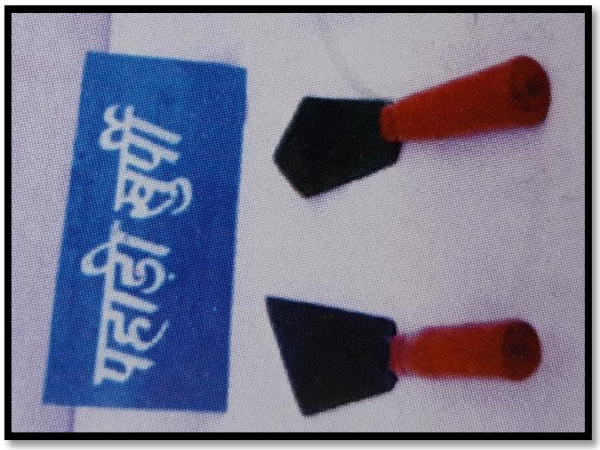
4.5 Comparison between existing and proposed dimensions of hill agricultural implements and hand tools

The proposed dimensions of hill plough, danala, damala, hill khurpi, hill fork, hill sickle, thamali-cum-chopper which were being used in hilly area are given in Table 4.4. It is evident from the table that the proposed dimensions of the Implements/Tools are not matching with existing dimensions. The proposed dimensions of hill plough were evaluated ergonomically and the diameter, height and length were 32-34.11, 841.6 and 115.6 mm respectively, whereas existing dimensions were 27-37, 801 and 130 mm respectively. The dimensions of danala and damala were also proposed ergonomically which were higher than the existing dimensions as shown in Table 4.4. With the agricultural implements hand tools like khurpi, fork, sickle and thamali-cum-chopper were also ergonomically

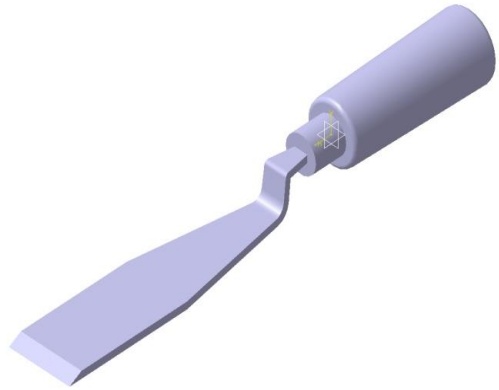
designed. From Table 4.4 it is clear that the proposed dimensions were not matching with the existing dimensions.

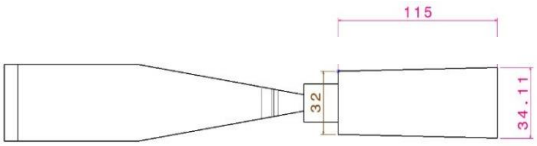
Table 4.4 Comparison between existing and proposed dimensions of hill agricultural implements and hand tools

S. No.	Implements/ Tools	Existing Dimensions			Proposed Dimensions		
		Diameter (mm)	Height (mm)	Length (mm)	Diameter (mm)	Height (mm)	Length (mm)
1	Hill plough-handle	27-37	801	130	32-34.11	841.6	115.6
2	Danala- handle	25-31	970	135	32-34.11	841.6	115.6
3	Damala- handle	25-31	830	140	32-34.11	841.6	115.6
4	Hill khurpi- handle	27-31	-	145	32-34.11	-	115.6
5	Hill fork- handle	25-27	-	155	32-34.11	-	115.6
6	Hill sickle- handle	25-35	-	120	32-34.11	-	115.6
7	Thamali-cum-chopper- handle	38-40	-	390	32-34.11	-	115.6

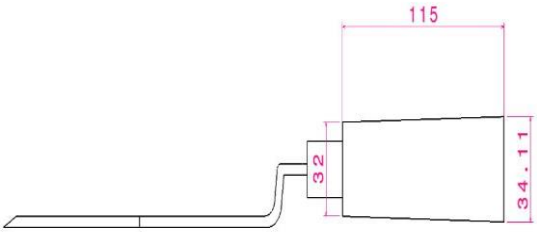


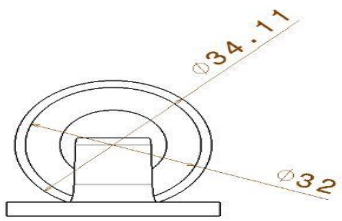
Isometric view **Top view**





Side view **Front view**

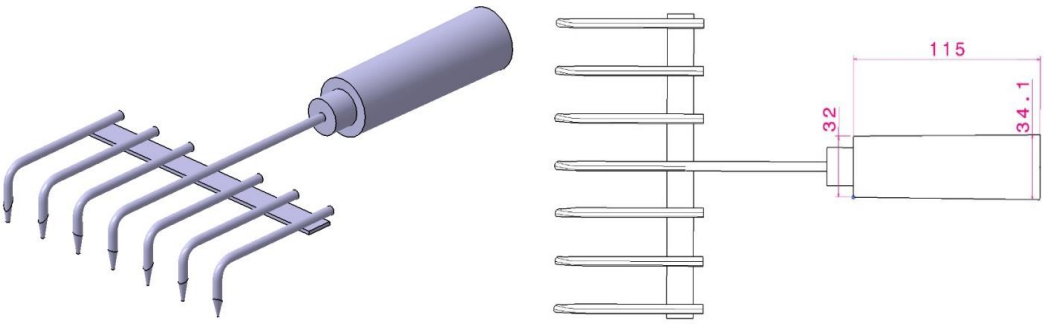




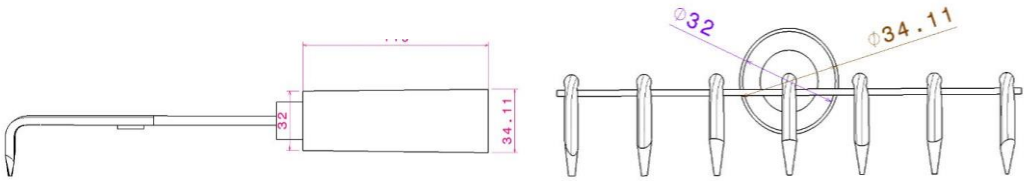
*All the dimensions are in mm

Fig. 4.8 Design dimensions for Khurpi

Isometric view **Top view**

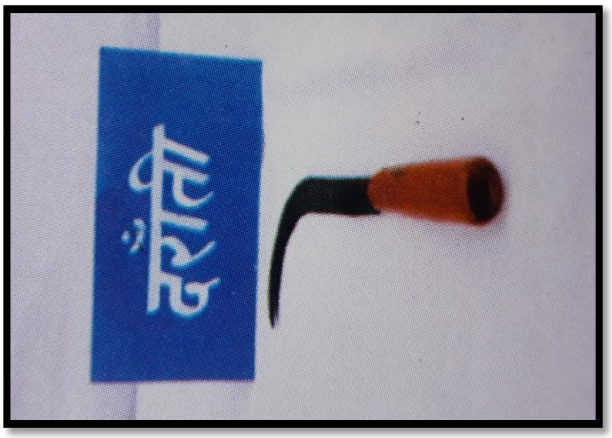


Side view **Front view**



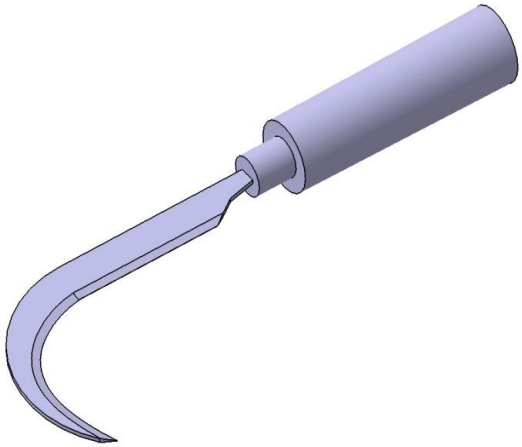
*All the dimensions are in mm

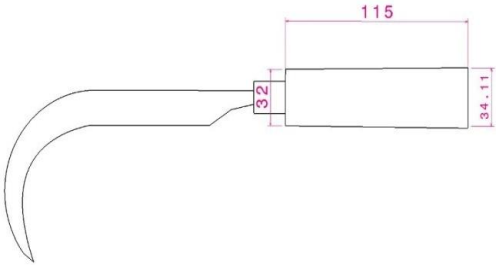
Fig. 4.9 Design dimensions of hill fork



Isometric view

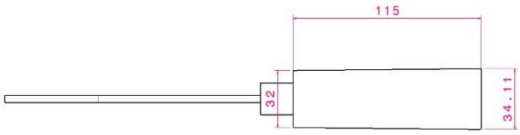
Top view

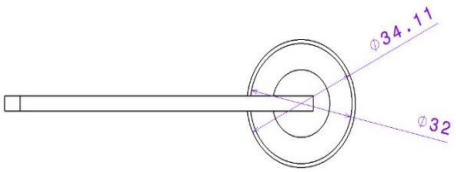




Side view

Front view



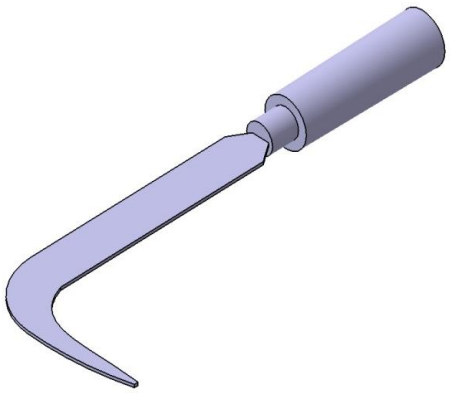


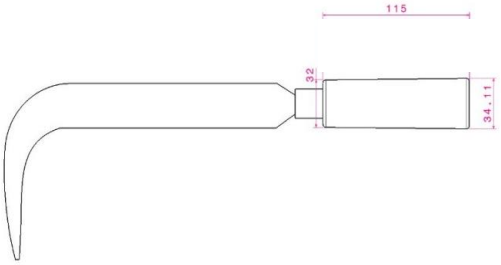
*All the dimensions are in mm

Fig. 4.10 Design dimensions of sickle

Isometric view

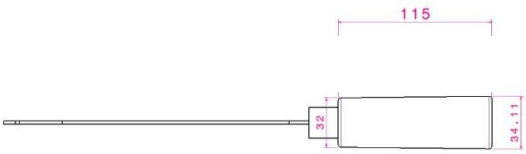
Top view

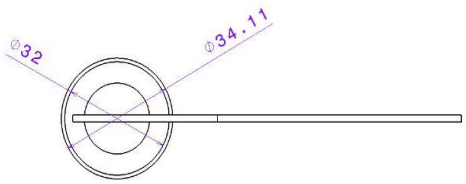




Side view

Front view





*All the dimensions are in mm

Fig. 4.11 Design dimensions for thamali-cum-chopp

Summary and Conclusions

5-SUMMARY AND CONCLUSION

The present study was conducted on collection of anthropometric data of farm workers of hill region of Uttarakhand. Thirty four body dimensions and two strength data of 200 farm workers were taken for the design of animal drawn implements and hand tools. Further the statistical analysis was carried out in order to get the 5^{th} and 95^{th} percentile value of all the anthropometric data. The design of animal drawn hill plough, danala, damala and hand tools were made with the help of CATIA software. Based upon the results the following conclusions were drawn:

1. It was found that the mean weight and stature of farm workers of hill region were observed 57.21$\pm$10.18 kg and 1657.7$\pm$70.3 mm respectively.
2. It was observed that standing postures such as stature, eye height, olecranon height, vertical reach and vertical grip reach has higher standard error mean values.
3. The coefficient of variation ranged from 3.70 and 62.30 for all selected dimension of subjects. However coefficient of variation of palm length was higher among the subjects as compare to other body dimensions and it was found 62.6.
4. The value of 5^{th} and 95^{th} percentile of hand breadth across thumb was observed 90.23 and 105.66 respectively whereas the CV, SD and SEM were found 4.60, 4.60 and 0.32 respectively.
5. The 5^{th} and 95^{th} percentile value of elbow height were 959.7 and 1147.0 respectively whereas the SD, CV and SEM were 60.4, 5.70 and 0.42 respectively.
6. For olecranon height the 5^{th} and 95^{th} percentile value were found 941 and 1114.1 respectively, and SD, CV and SEM were found 64.88, 60.47 and 4.58 respectively.
7. The range of the right hand grip strength and left hand grip strength were 370.18$\pm$71.82 and 345.31$\pm$70.92 respectively.
8. The percentage variation in all the measured data of hill farmers with all India were ranged from -28.09 to 82.88% for 5^{th} percentile value where as for 95^{th} percentile value the percentage variation was ranged between -27.29 to 49.07%.

9. It was also observed that the 5^{th} and 95^{th} percentile value in standing measurement such as stature, eye height, acromial height, elbow height, olecranon height, illiocrystale height, illiospinale height, trochanteric height, metacarpal height, knee height, medial malleolus height, lateral malleolus height, vertical reach and waist back length for hilly farmers was more as compare to All India farmers.

10. The 5^{th} and 95^{th} percentile value of Uttarakhand farmers vertical grip reach and span were found less as compare to All India farmers.

11. The values of 5th and 95th percentile of hand grip strength (right) and hand grip strength (left) for hill farmers were less as compare to All India farmers.

12. The value of percentage variation of 5^{th} and 95^{th} percentile for metacarpal height was 5.93% and 4.91% respectively. It was also observed that the percentage variation of 5^{th} and 95^{th} percentile values for inside grip diameter were -12.53% and -18.46% respectively.

13. The 5th and 95th percentile values of Metacarpal III height of male agricultural workers of Uttarakhand region have been found to be 656.8 mm and 807.1 mm respectively. Considering depth of operation of about 11 cm, the optimum handle height for danala works out to be between 755.32 mm and 928.16 mm. preferably, the height should be adjustable between these ranges. For a fixed type handle, a height of 841.74 mm has been recommended for hill plough, Danala and Damala.

14. Based on the anthropometric considerations, the handle grip diameter should be according to 95^{th} percentile middle finger palm grip diameter becomes the lower limit and 5^{th} percentile grip diameter (inside) of the male workers of Uttarakhand is to be considered as the upper limit. As per data, these values are 34.11 mm and 32 mm, respectively. Therefore, the recommended handle grip diameter is 34.11 mm.

15. The handle length of hand tools was suggested on the basis of 95^{th} percentile value of hand breadth across thumb with clearance of 5 mm each side of handle, so the dimension of the hand length of fork should be 115.66 mm which was comfortable to most of the farm workers in hill region of Uttarakhand.

On the basis of above conclusion the handle height of animal drawn hill plough, danala and damala should be 841.66 mm from the bottom of the implement. The grip of the handle should be 32 mm as lower limit and 34.11 mm taken as upper limit. The handle length of the animal drawn implements and hand tools should be 115.66 mm, for hill farmers of Uttarakhand.

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Appendices

Appendix-A

Table A-1 Details of the farmers selected for survey

S. No.	Farmers Name	Age	Hand Used	Address
1	Narayan Singh Kholia	53	Right	Debuajala, Nainital
2	Bhawan Singh Kholia	65	Right	Debuajala, Nainital
3	Rajendra Singh Kholia	54	Right	Debuajala, Nainital
4	Deewan Singh kholia	50	Right	Debuajala, Nainital
5	Dinesh Singh Kholia	48	Right	Debuajala, Nainital
6	Udit Kholia	21	Right	Debuajala, Nainital
7	Bharat Kholia	24	Right	Debuajala, Nainital
8	Nirmal Kholia	23	Right	Debuajala, Nainital
9	Lokesh Kumar	17	Right	Bakarkhor, Nainital
10	Gulab Singh	60	Right	Bakarkhor, Nainital
11	Neeraj Singh Bisht	42	Right	Bakarkhor, Nainital
12	Gopal Singh Negi	22	Right	Bakarkhor, Nainital
13	Mohan Singh Negi	34	Right	Bakarkhor, Nainital
14	Manoj Singh Negi	36	Left	Bakarkhor, Nainital
15	Harendra Singh Negi	32	Right	Bakarkhor, Nainital
16	Bishan Singh Negi	65	Right	Bakarkhor, Nainital
17	Chandan Singh Negi	37	Right	Bakarkhor, Nainital
18	Jeevan Singh Bisht	33	Right	Bakarkhor, Nainital
19	Deewan Singh Bisht	60	Right	Bakarkhor, Nainital
20	Jagdish Kumar	55	Left	Bakarkhor, Nainital
21	Harish Arya	23	Right	Bakarkhor, Nainital
22	Ajeet Singh Bisht	30	Right	Bakarkhor, Nainital
23	Nirmal Singh Bisht	19	Right	Bakarkhor, Nainital
24	Bahadur Singh Negi	46	Right	Bakarkhor, Nainital
25	Vinod Kumar	46	Right	Bakarkhor, Nainital
26	Pankaj Kumar	22	Right	Bakarkhor, Nainital
27	Vijay Chandra Arya	33	Right	Bakarkhor, Nainital
28	Lalit Bisht	45	Right	Bakarkhor, Nainital
29	Gopal Ram	59	Right	Bakarkhor, Nainital
30	Rajendra	32	Right	Bakarkhor, Nainital
31	Mohan chandra	59	Right	Amel, Betalghat
32	Ganga Singh	54	Right	Amel, Betalghat
33	Mohan Singh	47	Right	Amel, Betalghat
34	Shankar Ram	60	Right	Tiwarigaon, Betalghat
35	Anand Ballabh Joshi	35	Right	Tiwarigaon, Betalghat
36	Godhar Singh	43	Right	Amel, Betalghat

Contd…

37	Dhan Singh	60	Right	Amel, Betalghat
38	Bhopal Singh Bisht	59	Right	Amel, Betalghat
39	Uday Singh	58	Right	Amel, Betalghat
40	Trilok Singh	56	Right	Amel, Betalghat
41	Bacchi Singh	54	Right	Amel, Betalghat
42	Pratap Singh	59	Right	Amel, Betalghat
43	Kundan Singh	60	Right	Amel, Betalghat
44	Anand Singh	57	Right	Amel, Betalghat
45	Mohan Singh Bora	52	Right	Amel, Betalghat
46	Param Chandra	48	Right	Amel, Betalghat
47	Gopal Singh	60	Right	Amel, Betalghat
48	Pan Singh	49	Right	Amel, Betalghat
49	Prem Singh	45	Right	Amel, Betalghat
50	Dev Singh	52	Right	Amel, Betalghat
51	Ram Singh	40	Right	Raulia, Betalghat
52	Prem Ballabh	42	Right	Tiwarigaon, Betalghat
53	Bahadur Singh	60	Right	Tiwarigaon, Betalghat
54	Goverdhan Joshi	58	Right	Tiwarigaon, Betalghat
55	Pankaj	25	Right	Tiwarigaon, Betalghat
56	Balam Singh	60	Right	Tiwarigaon, Betalghat
57	Anand Singh	50	Right	Amel, Betalghat
58	Shyam Singh	54	Right	Amel, Betalghat
59	Chandan Singh	37	Right	Amel, Betalghat
60	Nandan Singh	60	Right	Amel, Betalghat
61	Balam Singh	50	Left	Amel, Betalghat
62	Heera Singh	48	Right	Amel, Betalghat
63	Laxman Singh	58	Right	Amel, Betalghat
64	Pratap Ram	60	Right	Amel, Betalghat
65	Badri Singh Negi	55	Right	Amel, Betalghat
66	Ram Singh	56	Right	Amel, Betalghat
67	Bacchi Singh	60	Right	Amel, Betalghat
68	Kumer Singh	58	Right	Amel, Betalghat
69	Padam Singh	59	Right	Raulia, Betalghat
70	Ishwar Singh	58	Right	Raulia, Betalghat
71	Rahul Singh Bohra	18	Right	Raulia, Betalghat
72	Dan Singh	32	Right	Raulia, Betalghat
73	Thakur Singh	54	Right	Raulia, Betalghat
74	Ganga Singh	60	Right	Raulia, Betalghat
75	Kheem Singh	30	Right	Raulia, Betalghat
76	Pooran Singh	48	Right	Raulia, Betalghat

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77	Bishan Ram	58	Right	Raulia, Betalghat
78	Heera Lal	60	Right	Raulia, Betalghat
79	Paan Singh	50	Right	Raulia, Betalghat
80	Hayat Singh	41	Right	Raulia, Betalghat
81	Bishan Singh	54	Right	Raulia, Betalghat
82	Surendra Lal	60	Right	Raulia, Betalghat
83	Shankar Ram	55	Right	Raulia, Betalghat
84	Paan Singh	53	Right	Raulia, Betalghat
85	Bishan Ram Arya	57	Right	Raulia, Betalghat
86	Kishan Singh	60	Right	Raulia, Betalghat
87	Arjun Singh	31	Right	Bhidapani, Okhalkanda
88	Pani Ram	51	Right	Bhidapani, Okhalkanda
89	Harish Chandra	41	Right	Bhidapani, Okhalkanda
90	Krishna	58	Right	Bhidapani, Okhalkanda
91	Ram Singh	55	Right	Bhidapani, Okhalkanda
92	Deewan Ram	50	Left	Bhidapani, Okhalkanda
93	Bhawani Ram	60	Right	Bhidapani, Okhalkanda
94	Jeevan Singh	38	Right	Bhidapani, Okhalkanda
95	Rajendra	22	Right	Bhidapani, Okhalkanda
96	Pan Singh	42	Right	Bhidapani, Okhalkanda
97	Pushkar Singh	23	Right	Bhidapani, Okhalkanda
98	Aan Singh Bargali	37	Right	Bhidapani, Okhalkanda
99	Jagat Singh	60	Right	Tanda, Okhalkanda
100	Hem Chandra	33	Left	Tanda, Okhalkanda
101	Ghanshyam	45	Right	Tanda, Okhalkanda
102	Manoj Pargain	34	Right	Tanda, Okhalkanda
103	Bhawani Dutt	60	Right	Hedakan
104	Harish Chandra	34	Right	Hedakan
105	Narayan Dutt	60	Right	Khansyu, Okhalkanda
106	Suresh Chandra	53	Right	Khansyu, Okhalkanda
107	Shekhar Chandra	24	Right	Ban Pokhra, Okhalkanda
108	Neelambar	35	Right	Hedakhan
109	Tara Dutt	42	Right	Khansyu, Okhalkanda
110	Daya Kishan	56	Right	Khansyu, Okhalkanda
111	Mohan Chandra	42	Right	Ban Pokhra, Okhalkanda
112	Pani Ram	51	Right	Kador, Okhalkanda
113	Laxman Singh	60	Right	Tanda, Okhalkanda
114	Kesav Dutt	60	Right	Tanda, Okhalkanda
115	Diwan Singh Bora	58	Right	Tanda, Okhalkanda
116	Satish Chandra	32	Right	Tanda, Okhalkanda

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117	Dharmanand	34	Right	Tanda, Okhalkanda
118	Kheem Ram	60	Right	Tanda, Okhalkanda
119	Hem Chandra	21	Right	Tanda, Okhalkanda
120	Bhuwan Chandra	50	Right	Tanda, Okhalkanda
121	Hari Ram	59	Right	Tanda, Okhalkanda
122	Girish Chandra	60	Right	Tanda, Okhalkanda
123	Kanti Ballabh	42	Right	Tanda, Okhalkanda
124	Laxmi Dutt	55	Right	Tanda, Okhalkanda
125	Harendra Singh	40	Right	Tanda, Okhalkanda
126	Ghanshyam	25	Right	Tanda, Okhalkanda
127	Pramod	34	Right	Tanda, Okhalkanda
128	Gopal Dutt	45	Right	Majela, Okhalkanda
129	Girish Chandra	43	Right	Majela, Okhalkanda
130	Sher Singh	48	Right	Majela, Okhalkanda
131	Govind Ram	60	Right	Majela, Okhalkanda
132	Kushal Ram	49	Right	Majela, Okhalkanda
133	Mohan Tamta	36	Right	Majela, Okhalkanda
134	Kheemanad	60	Right	Majela, Okhalkanda
135	Lal Singh	56	Right	Majela, Okhalkanda
136	Mohan Chandra	30	Right	Majela, Okhalkanda
137	Deepak Chandra	26	Right	Majela, Okhalkanda
138	Moti Ram	55	Right	Majela, Okhalkanda
139	Gopal Singh	52	Right	Majela, Okhalkanda
140	Trilok Chandra	26	Right	Majela, Okhalkanda
141	Bhagwan Ram	50	Right	Majela, Okhalkanda
142	Kamal Ram	38	Right	Majela, Okhalkanda
143	Harish Bora	55	Right	Talla Okhalkanda
144	Rajendra Bisht	32	Right	Gaulapar
145	Laxmi dutt	40	Right	Khansyu, Okhalkanda
146	Satish Chandra	42	Right	Galni, Okhalkanda
147	Ram Mohan	43	Right	Tanda, Okhalkanda
148	Satish Chandra Kafaltiya	43	Right	Khansyu, Okhalkanda
149	Ganesh Puri	60	Right	Galni, Okhalkanda
150	Man Singh	45	Right	Bhadretha, Okhalkanda
151	Bhim Singh	55	Right	Bhadretha, Okhalkanda
152	Dev Singh	32	Right	Bhadretha, Okhalkanda
153	Deewan Singh	60	Right	Bhadretha, Okhalkanda
154	Laxman Singh	58	Right	Bhadretha, Okhalkanda
155	Dhyan Singh	55	Right	Bhadretha, Okhalkanda
156	Bachi Ram	46	Right	Bhadretha, Okhalkanda
157	Vikram Singh	24	Right	Bhadretha, Okhalkanda

Contd…

158	Balwant Singh	47	Right	Bhadretha, Okhalkanda
159	Chandra Singh	60	Right	Bhadretha, Okhalkanda
160	Dhyan Singh	58	Right	Bhadretha, Okhalkanda
161	Harish	18	Right	Bhadretha, Okhalkanda
162	Manoj Joshi	45	Right	Turshar, Okhalkanda
163	Rajkumar Paneru	60	Right	Dhalkandya, Okhalkanda
164	Krishna	30	Left	Dhalkandya, Okhalkanda
165	Prakash Paneru	32	Right	Dhalkandya, Okhalkanda
166	Raj Singh Bisht	44	Right	Dhalkandya, Okhalkanda
167	Dev Ram Arya	60	Right	Dhalkandya, Okhalkanda
168	Kesav	36	Right	Talli Pokhri, Okhalkanda
169	Bacchi Ram	58	Right	Talli Pokhri, Okhalkanda
170	Prem Ballabh	58	Right	Talli Pokhri, Okhalkanda
171	Prakash	24	Right	Lowaldoba, Okhalkanda
172	Arjun Kumar	37	Right	Matela, Okhalkanda
173	Bhuwan Chandra	60	Right	Matela, Okhalkanda
174	Narayan Dutt	52	Right	Matela, Okhalkanda
175	Ram Singh	31	Right	Matela, Okhalkanda
176	Rivadhar	50	Right	Pashya, Okhalkanda
177	Richandra	60	Right	Pashya, Okhalkanda
178	Mohan Ram	55	Right	Pashya, Okhalkanda
179	Kamal Ram	58	Right	Pashya, Okhalkanda
180	Hayat Singh	60	Right	Bhadretha, Okhalkanda
181	Chinta Mani	34	Right	Bhadretha, Okhalkanda
182	Kesav dutt	40	Right	Bhadretha, Okhalkanda
183	Chandan Ram	55	Right	Bhadretha, Okhalkanda
184	Kamal Ram	60	Right	Bhadretha, Okhalkanda
185	Suresh ram	35	Right	Bhadretha, Okhalkanda
186	Girish Chandra	32	Right	Bhadretha, Okhalkanda
187	Pan Singh	60	Right	Bhadretha, Okhalkanda
188	Madho Ram	59	Right	Bhadretha, Okhalkanda
189	Nayan Singh	60	Right	Bhadretha, Okhalkanda
190	Pooran chandra	52	Right	Bhadretha, Okhalkanda
191	Rewadhar	60	Right	Bhadretha, Okhalkanda
192	Kamal Kishore	33	Right	Amjar, Okhalkanda
193	Baldev Arya	44	Right	Amjar, Okhalkanda
194	Mahesh Singh	35	Right	Amjar, Okhalkanda
195	Krishna Singh	38	Right	Amjar, Okhalkanda
196	Gopal Dutt	33	Right	Amjar, Okhalkanda
197	Panchi Gonyal	48	Right	Gonyaro, Okhalkanda
198	Pan Singh	45	Right	Bhidapani, Okhalkanda
199	Harendra Singh	40	Right	Okhalkanda
200	Pramod	34	Right	Okhalkanda

Appendix-B

Table B-1 Eighteen different anthropometric parameters of 200 farmers of Uttarakhand

S. No.	Weight	Stature	Eye Height	Acrominal Height	Elbow Height	Olecranon height	Iliocrystale Height	Iliospinale Height	trochanteric height	Metacarpal III Height	Knee Height	Medial Malleolus Height	Lateral Malleolus Height	Vertical Reach	Vertical Grip Reach	Waist Back length	Span	Span Akimbo
1	65	166.6	156.4	138.5	102.6	99.7	99.4	92.5	83.4	69.7	47.5	8.8	6.6	212.5	200	52.9	175.2	95.2
2	62	171.9	160.4	147.5	113.2	108.2	104.1	98.2	90.7	75.2	50.8	7.6	6.1	217.2	206.6	53.5	175.8	91.8
3	60	171.4	159.8	144.1	107.4	104.2	97.4	94.5	88.5	71.1	49.1	8.3	7.4	215.2	203.5	52.5	174.2	93.8
4	54	167.9	156.1	140.9	106.8	103.8	100.3	95.2	84.6	74.7	47.6	8.2	6.8	210.2	201.5	51.2	169.8	88.5
5	60	174.6	162.5	146.7	110.4	107.8	100.8	94.1	85.8	74.2	49.4	8.5	7.3	216.8	207.9	53.5	174.1	91.5
6	43	151.9	145.5	141.4	99.1	96.2	90.7	54.5	76.9	66.2	43.5	7.3	6.4	195.5	179.5	48.1	158.5	86.2
7	59	164.6	155.8	140.1	109.1	105.1	100.1	92.1	84.8	74.7	46.4	8.4	7.1	210.8	198.5	49.2	171.2	90.2
8	43	155.5	141.4	126.6	95.5	86.4	78.8	73.5	68.6	66.7	43.7	7.4	5.9	190.4	180.5	47.5	159.1	86.4
9	40	157.4	146.7	133.2	101.9	98.6	92.1	88.5	81.4	70.8	44.6	7.8	6.6	197.5	187.4	46.2	157.9	80.5
10	51	158.5	148.5	133.8	99.7	97.2	97.6	91.4	87.2	70.7	45.7	9.1	6.9	198.5	188.5	48.5	178.5	83.2
11	46	155.9	147.2	132.4	101.4	97.8	96.4	88.5	75.2	67.5	45.6	7.2	6.4	196.3	188.4	44.4	163.2	81.1
12	58	167.6	154.6	143.3	104.8	102.1	103.5	89.5	93.2	71.8	53.6	7.8	6.5	219.8	205.2	49.2	182.5	91.2
13	54	159.1	148.1	134.8	101.3	96.1	98.2	94.1	89.8	70.8	48.8	7.5	6.2	203.5	193.1	47.1	162.2	81.5
14	52	168.2	158.6	146.2	106.8	10.3.5	108.4	104.8	97.5	74.5	51.5	7.6	6.2	216.2	200.5	51.5	175.1	93
15	65	157	147	131	100	96.5	89.5	81.1	74.6	69.6	45	8.1	7.7	200	186.5	44.5	156	80.5
16	57	172.5	162.5	144.6	111.6	109.3	103.7	96.3	88.5	78.7	47.1	8.1	7.6	218	203.5	49.5	169	86.8
17	65	164	152.9	134.9	101.2	100.5	95.5	89.7	79.6	70.2	45.6	10.5	9	208	196	49.2	167.3	84
18	47	151.2	141.5	125.9	93.1	92.9	90.4	83.8	73.9	65.7	41.7	8.9	6.1	189.5	178	41.1	144	78
19	55	159.1	147.8	131.9	100.5	99.3	94.1	85.1	76.9	67.1	42.6	8.2	5.4	179	173.5	44.4	160.5	82.2
20	54	171.4	159	143.3	109.6	106.8	102.1	94.9	87.9	72.7	50.8	8.6	7.2	215.5	204.2	49.5	172	86
21	65	160.7	143.7	133.7	100.7	97.8	93.6	88.4	80.7	68.4	47.6	9.4	7.1	203	194	44.6	165	87
22	68	166.5	155.6	143.3	106.5	104.3	100.3	94.4	88.8	72.7	48.2	9.2	8	211	199.5	48.2	168.7	87.1
23	64	153.2	141	128.7	96	97.2	94.4	87.9	82	68.5	45.7	7.5	6.2	177.5	173.2	42	150.5	80
24	47	151.2	138.4	125	91.8	88.8	91.4	82.5	76.4	61.5	43.5	8.5	7.9	188.2	177	42.3	150.2	85
25	46	151.6	140.2	126.4	93.4	92.8	89.6	81.4	78.9	71.1	45.6	8.2	7.5	217	202.9	49.2	168	86

Contd…

26	46	164.5	152.4	137.8	106.1	98.7	96.4	91.1	82.6	69.8	68.7	8	6.5	210	201	41.8	169	89
27	65	173.1	160.6	146.6	111.1	108.5	100.5	92.2	83.1	76.1	52.5	8	7	207	205	52.5	174	90
28	70	170.1	155.4	144.2	106.5	105.8	98.1	91.7	83.1	75.7	50.4	9	7.8	208	204	51.5	181	100
29	47	160.2	149.4	134.2	91.5	98.4	90.6	81.2	76.6	69.5	57.7	8.2	7.5	202	190	47	157	85.1
30	50	160.2	150.7	134.6	102.1	99.4	93.1	85.2	78.8	68.7	45.7	8.5	7.4	198	190.5	45.8	164.2	83.5
31	44	159.6	148.8	136.5	102.1	97.4	94.3	87.8	82.4	69.4	48.1	8.4	7.4	205.5	191	44.5	161	87.2
32	48	167.6	156.6	140.8	106.4	104.3	101.5	93.3	86.3	71.8	49.8	8.4	7.5	210	198	46.4	170.3	94.5
33	72	177.6	164.5	150.3	114.6	112.4	102.5	93.8	85.7	80.7	54.5	9.5	8.5	220	205	50.1	169.5	90.5
34	46	162.2	151.6	137.8	103.6	99.7	92.6	83.5	79.1	70.6	46.7	8.5	7.5	202	190	47.5	157	85
35	89	180.9	168.4	157.4	118.4	116.2	100.7	93.7	90.8	83.8	54.5	9.8	8.8	231	217	56.2	183.5	101
36	63	171.9	159.4	144.9	109.1	105.6	98.7	94.6	87.9	75.8	51.7	7.4	6.5	230	206	49.4	177	92
37	48	168.8	157.6	141.6	106.1	103.4	100.5	95.5	87.7	71.5	50.9	9	7.5	217	207	49.6	176.5	89
38	60	175.7	162.8	147.6	109.8	108.4	100.54	92.6	86.8	78.1	52.7	9.5	7.8	221	207	52.1	197	96
39	62	173.6	161.8	147.5	113.7	109.8	100.6	85.5	86.8	78.8	51.1	8.5	7.5	221	206	49.5	177	92
40	48	154.6	143.2	127.4	93.8	92.2	86.6	79.8	74.1	63.6	45.2	8	7	195	180	44.5	156	84
41	45	161.3	148.6	135.6	101.6	99.5	91.5	86.4	79.8	71.5	47.8	8.2	7.6	200	192	47	161	86
42	64	167	157.5	142.7	109.1	107.1	102.8	94.2	83.5	73.5	48.2	8.1	6.4	220	207	48.5	180	94
43	55	155.5	143.7	128.5	95.5	94.2	93.2	89.2	84.6	67.1	47.5	9	6.5	198	189	45	156	83
44	55	163.7	153.2	137.2	101.7	101.8	99.6	91.9	88.7	68.4	47.8	8	6.5	210.5	197	43.7	169	88
45	39	150.1	138.7	125.7	93.2	90.4	92.1	89.4	83.7	62.5	43.2	7.5	5.5	189	176	41.4	153	78
46	84	173.2	162.7	147.6	113.5	107.7	108.2	105.2	97.2	76.4	49.4	10	8	224.5	210	48.5	186	96
47	45	157.3	147.2	130.1	94.5	93.2	88.4	85.3	80.3	86.5	43.7	8.5	6.5	204	194.5	46.5	157	80
48	40	156.2	151.2	135.2	101.2	98.3	95.3	88.7	88.4	66.1	44.7	8.7	7	207	200	45.3	162	83
49	58	172.8	162.5	150.1	113.2	111.3	109.5	108.7	101.7	78.4	52.2	8.5	6.5	231	217	46.4	172	93
50	43	158.1	146.8	131.8	101.6	97.6	96.5	90.4	85.6	68.7	46.4	9.2	7	200	190	46	156	82
51	57	161.4	162.5	139	104.1	98.6	95.2	89.4	84.2	67.5	44.7	7.8	6.1	204	194	43.2	163	88
52	89	171.2	159.5	145.5	108.2	104.7	98.4	95.2	90.5	74.2	47.2	8.4	7.6	214	204	51	167	86
53	56	165	153.8	140.4	103.4	98.9	96.5	94.5	94.8	69.9	49.4	9.1	7.3	217	205	45	178	92
54	52	179.5	168.5	155.4	121.8	118.5	112.5	105.4	101.4	83.8	55.2	9	8.5	227.5	216	52	186	97

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55	49	167.1	160.4	142.6	105.6	102.5	98.4	93.5	87.7	70.7	51.6	9	8	214	200	53	170	90
56	42	165.8	164.5	158.2	104.6	101.2	97.8	91.8	84.7	73.7	48.7	9.5	8	208	195	48	167	85
57	64	164.4	154.4	134.7	103.5	103.1	100.1	94.1	87.2	72.5	47.7	9	8	210	196	40.4	168	86
58	67	172.6	160.4	147.5	109.5	108.5	102.4	94.7	88.7	79.4	48.4	9	8.5	216	201	51.6	172	92
59	60	169.4	156.2	140.9	107.4	105.2	100.1	93.6	91.4	76.7	48.2	9.5	8.5	206	194	51	162	83
60	62	172.1	161.1	144.7	108.1	106.8	100.1	94.8	89.7	76.4	48.8	9.2	8.4	218	204	49.5	177	92
61	47	162.1	153.8	136.2	104.3	102.1	97.5	92.7	85.8	73.7	46.3	9.5	8	203	190	46.5	162	78
62	55	161.1	149.8	136.8	105.4	101.5	92.4	89.3	84.8	74.4	46.1	9	8	202	190	47.5	160	70
63	66	168.5	159.5	143.1	108.5	105.1	96.8	91.8	87.6	73.6	48.4	9	8	213	198	46.6	173	90
64	47	156.7	143.2	132.2	99.1	94.7	91.2	87.4	81.4	67.1	44.8	7.5	8	191	178	48.7	155	78
65	54	164.1	153.9	138.6	104.1	103.1	94.5	89.7	85.8	72.2	49.8	8.5	9	210	196	44.5	169	86
66	62	183.2	170.2	163.5	115.7	111.4	108.7	104.7	95.8	82.8	48.5	8.5	9	235	230	48.7	184	96
67	51	174.6	164.5	149.2	108.9	105.8	106.4	99.9	93.7	75.8	51.5	9	7.5	219	207	47.4	179	89
68	71	171.6	162.1	150.8	112.7	111.5	99.8	92.2	86.7	81.5	46.5	9	8	214	200	52.8	166	85
69	63	172.6	162.2	154.8	114.7	106.7	97.7	92.6	86.8	76.6	48.2	9.5	7	210	196	50.5	173	85
70	67	171.6	160	146.6	114.2	107	103.1	100	96	81	49	8.7	6.9	213	207	50	169	90
71	71	181.1	169.1	155.2	118.6	115.6	84.5	109.7	104.2	82.6	50.5	8	6.8	231	216	49.8	183	96
72	52	166.4	154.1	143.6	109.9	105.8	98.2	92.7	87	74.7	49.4	9	7.9	207	194	49	176	84
73	57	170.5	159.8	144.1	109.8	107.2	75.7	94.7	89.8	76	50.5	9	8	216	203	49	178	92
74	48	166.5	156	159.5	112	104	100	92.6	88	71	46.5	8	7	212	202	48.8	163	88
75	78	172.5	162	146	111	110	101.7	98	94.5	69	52	9	7.5	221	207	48	181	93
76	58	161	151	133	100	96	102	100	96.3	64	43.7	7.8	6.7	201	190	47	165	87
77	52	175.5	164.5	149.7	114.5	112	112.2	105	100	77	52	8.3	6.8	224	215	52	176	99
78	75	173.2	161.8	148	115	110	107	103.5	97.8	76	50.2	8.2	7	230	202	53	167	90
79	58	163.1	151.4	137	105	98	104	102	96	65	45	8	7.5	208	195	47.2	170	94
80	62	173.5	160	141	105	101	107	102.8	97.6	71	46	8.5	7	211	197	48.8	168	90
81	62	175.5	165	147	113	107	104.5	100.5	94	74	50	8.7	6.2	223	213	51.1	180	97
82	65	169	158.2	139.4	110.2	109	102.4	98.4	87.6	72.2	46.5	8	6.9	215	204	48	172	96
83	50	158	148.4	143.9	107.9	104.2	98.2	92.7	87	74.2	48.6	8	6.7	206	195	46.8	160	87
84	63	158.5	146.8	134.6	102.7	100.5	92.8	85.6	78.6	71.1	44.6	9	7.5	196	185	46.9	157.5	85

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85	62	156.1	145.2	132.6	99.4	98.3	89.2	84.8	76.2	71.1	44.3	7.5	6.8	199	188	47	158	87
86	55	164.2	152.7	136.8	102.4	101.4	89.2	84.7	78.5	71.8	48.2	8.5	7.5	204	192	51.7	160	90
87	85	169.6	157.1	141.6	106.2	104.5	94.1	90.4	84.6	74.4	48.6	9	7.5	209	196	47.9	166.5	90
88	75	175.1	162.8	148.1	109.8	106.5	90.7	87.8	81.4	76.2	56.2	9.5	8.5	215	202	52	174	88
89	70	172.2	161.6	145.5	106.8	105.5	94.8	87.2	80.8	73.2	47.7	9	7.5	208	205	51.3	177	95
90	50	157.6	148.6	131.1	100.8	96.7	92.2	84.5	76.5	68.5	47.4	8.5	7.5	198	186	45.6	160	86
91	59	156.4	144.8	138.6	96.1	94.6	89.7	84.2	78.7	65.9	42.7	8	7	194	182	41	153	83
92	51	166.4	156.8	139.8	104.6	1017	100.2	83.4	86.4	71.4	47.8	9.5	7.5	209	200	53.5	154	82
93	64	175.5	163.4	147.6	108.4	105.5	106.7	99.7	84.4	75.5	50.7	7.6	5.9	222	209	50.1	180	95
94	71	171.8	161.6	143.7	108.5	107.5	101.7	92.7	85.5	75.2	48	8.5	7.2	214	202	56.7	170	90
95	62	159.5	147.5	146.4	99.4	96.7	80.7	85.7	81.7	69.7	48.1	8.2	7.8	202	187	51.5	169	90
96	72	171.2	159.2	145.7	105.1	104.1	102.1	86.1	86.8	69.8	48.8	9.5	8	219	205	54.1	184	93
97	48	167.7	155.8	141.9	105.2	102.3	101.9	96.1	89.2	73.3	48.1	8.5	7.5	212	197	51.1	170	85
98	64	174.7	166.7	112.5	110.7	105.7	98.7	92.7	87.6	80	50.5	8.5	7.5	221	209	56	173	85
99	68	167.4	156.4	141.1	104.1	103.2	100.5	94.8	85.7	74.5	48.4	8.5	7.5	213	198	48.5	174	89
100	65	157.8	146.5	132.5	100.6	98.5	81.8	85.1	80.2	67.7	45.7	8	6.6	188	186	49.5	158	83
101	72	167.1	158.2	143.7	109.7	106.8	100.2	94.8	86.4	65.4	50.9	8.5	8	212	202	51.8	164	85
102	47	165.5	155.5	138.7	101.1	100.2	95.8	89.8	85.7	69.7	48.8	9.5	9	206	194	52.2	165	79
103	46	168.5	158.7	144.4	107.6	105.4	103.1	96.7	87.4	77.7	51.7	8.5	8.4	206	193	51.5	168	83
104	54	160.1	149.8	155.1	100.4	98.4	94.1	90.5	86.6	71.9	47.7	9	8.5	201	182	44.3	164	84
105	36	144.1	135.2	120.8	94.4	90.2	80.2	76.5	73.5	67.5	42.5	9	8	180	170	44.5	136	74
106	51	164.6	159.2	138.4	101.5	100.5	92.7	87.8	80.5	73.6	47.2	10	8	202	181	51.7	165	90
107	44	162	158.4	152.8	102.8	101.5	94.1	87.8	83.6	72.6	46.1	9	8	201	188	51.6	168	89
108	50	162.2	152.5	137.5	104.7	101.7	92.5	87.8	81.7	74.4	48.7	9.5	8	200	190	44.7	160	81
109	54	164.1	155.7	137.8	105.5	102.5	98.4	88.7	84.6	73.7	47.8	8.5	7.5	206	195	47.5	166	86
110	53	157.1	148.2	131.6	98.4	95.4	90.7	84.1	78.4	68.4	47.2	8.5	8	195	181	44	153	82
111	68	183.2	172.4	155.8	114.2	114.7	110.5	105.1	100.5	81.2	55.8	10	9	230	214	53	183	90
112	48	165.7	153.6	139.7	107.5	105.2	94.5	90.7	86.7	74.4	48.1	7	6.5	207	194	49.5	170	85
113	74	168.1	158.5	143.5	108.1	107.2	100.5	96.1	90.6	75.1	48.8	9	8	211	199	48	166	90
114	56	165	154	141	109	106	103.5	98	94.5	74.6	49.5	9	7.8	208	194	47.4	166.5	90

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115	49	155.3	142.4	127.8	101	92.3	94.8	90.4	85	63	48	7.8	6.9	190	185	46.4	157	82
116	55	170.3	156.7	142.7	108	103.7	104.2	99.3	92.6	71.7	53	8.8	6.9	209	195	44.9	172	93
117	75	171	165.5	146	109	102.4	109.8	97.4	91	68.5	48.4	9	7	220	203	46.2	175	91
118	49	172.5	158	147.5	116	110	111.4	104.2	97.7	75	50	8	6.7	217	207	47.2	168	87
119	54	171	159	142	106	105.4	106.58	97.7	92.2	70	49	8	6.7	215	202	51.8	171	90
120	54	163.5	151.4	136.8	101	100.1	99.2	97	92.2	67	48.7	7.6	6.9	211	200	47.2	168	92
121	44	166.2	150	156.6	104.6	103.5	103.4	99.7	93.5	69	49	8.2	6.5	200	199	43	171	83
122	52	162.5	150.3	136.7	101.1	98.7	96.5	90.5	96.2	71.2	48.8	8	7.2	198	189	46.1	162	81
123	52	174	163	146.5	112	106	106.8	101.6	98	72	43	8	7.6	223	212	51.4	178	92
124	61	166	154.5	135	101	98.6	96.2	94.2	88.5	72	45	8.9	7.2	202	191	46.2	159	82
125	43	164	153	139	103	99.5	100.5	97.8	91	73	48	7.3	6.3	206.5	193	46.5	165	87
126	51	165.6	154.5	138	108	100	104	98.4	88.4	67	47	8.6	6.5	207	195	50.4	175	92
127	52	170	157	144.5	112	107	105.4	97.7	91.5	74.5	46	8	7.5	213	201	46	164	89
128	52	168.5	155.7	142.9	111.1	105.4	103.4	98.2	88.1	70.45	55.3	9.4	8.2	208.5	200.1	46.5	165	79
129	53	154.5	151.1	134.2	102.9	99.7	98.4	91.3	83.6	67.8	48.7	8.8	7.2	205.4	200.5	45.5	166	79
130	54	161.5	151.9	133.6	102.1	100.2	95.5	87.5	76.9	67.7	46.5	9	7.2	207.2	194.4	51.2	165.5	87.5
131	53	158.4	148.2	130.2	98.4	94.4	90.4	84.4	74.4	58.4	42.5	8.4	7.4	204.4	196.4	48.4	164.2	94.2
132	62	160	152.1	134.4	104.4	99.2	95.2	88.2	77.4	62.4	48.2	8.8	7.2	208.2	201.4	47.2	161.6	87.1
133	74	173	163.2	148.4	113.2	107.7	103.4	97.3	86.3	71.7	48.7	9.2	8.6	220.5	215.2	50.4	175.1	94.5
134	56	168.1	156.3	137.6	104.2	99.6	94.5	85.4	78.6	67.1	46.2	8.2	7.5	213.5	202.3	48.4	173	86.4
135	55	165.5	156.2	137.2	106.5	102.2	94.4	86.8	78.7	68.2	47.2	8.5	6.2	214.8	200.3	53.2	169.1	86.2
136	59	168.1	156.8	142.5	108.5	105.6	97.1	91.7	82.4	71.8	49.4	9.8	8.7	216.5	208.7	48.5	176.5	92.4
137	65	171.8	161.5	144.9	110.2	99.7	94.5	93.1	82.8	74.2	98.7	8.9	7.2	222.4	208.4	51.3	179.8	91
138	62	158.1	144.1	135.7	102.6	102.4	93.3	87.7	79.1	72.3	46.6	8.2	7.3	202.5	193.5	44.5	162.5	87
139	57	179.6	168.9	151.5	116.3	113.7	105.7	99.1	87.7	78.7	52.8	10.6	8.5	230.3	219.5	52.5	185	96.8
140	85	171.1	161.5	145.7	112.1	109.2	108.1	100	90.1	77.1	49.7	8.3	7.7	224.5	211	52.3	173.5	94
141	58	170.1	160.2	143.2	112.2	109.5	98	90.5	80.4	75.9	49.5	9.9	7.6	217.5	207	48	169.7	86.5
142	50	150.2	148.4	134.7	101.4	98.9	89.8	90.5	80.6	69.6	43.2	9	7.1	205	194.5	43.6	166.5	85.3
143	55	163.4	153.4	147.7	108.1	101.8	97.7	88.8	80.3	67.9	46.8	8	6.7	212.5	202.6	47.5	172	88
144	83	178.1	166.2	150.5	114.8	108.3	105	98.9	93.2	77.9	50.9	9.4	8.1	228	217.5	50.5	182	92.7

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145	58	163.9	152.2	135.8	101.4	96.7	92.1	85.3	78.2	68.6	46.5	9.7	7.9	207	199	51	166.9	83.5
146	63.5	163.5	152.9	136.5	103.4	96.4	100.4	93.1	80.7	70.1	46.8	9.6	7.5	207.2	200	48.5	165.5	84
147	60.2	162.2	144	132.8	102.8	99.8	95.1	87.7	79.3	70.2	44.1	8.7	7.2	203.5	194.3	49.2	163	86.1
148	60	169.1	156.7	143.3	110.3	107	100.5	94.7	83.4	76.1	50.8	7	6	214	206.5	47.7	171.6	82.3
149	44	158.6	147.2	131.9	100	95.4	93.8	86.8	77.8	68.9	44.5	7.7	6.8	195.4	184	48.9	160.5	84
150	52	167.8	158.3	143.3	110.1	106.9	103.1	97.9	91.4	74.4	47.6	8.5	7.7	212	202	47.9	166	88.9
151	50	165.5	153.7	137.4	105.5	103.5	100.7	94.3	85.2	68	46.8	9	8.2	211	199.5	47.8	168	91
152	67	166.7	155.7	142.1	107.6	104.2	101.1	95.1	83.6	74.1	49.1	8.9	6.9	215.5	205	50.1	168	88
153	66	169.8	156.7	142.5	107.8	105.9	101.7	95.7	84.9	74.9	51.4	8	7.5	213	205.5	52.6	172	89.5
154	50	162.6	152.9	136.7	103.6	101.6	99.7	95.1	84.5	72.5	46.8	8.5	6.8	205	191.8	46.4	164	82.5
155	50	154.8	144.6	126.2	97.5	94.6	92.2	86.1	77.5	66.8	44.7	8	7.3	193.5	182.5	48.4	158	85.7
156	62	173.3	159.6	147.7	111.6	105.8	103.8	97.7	90.4	74.4	50.7	8.8	7.6	216	202	51.8	179.5	87.5
157	57	159.8	149.4	134.6	105.5	99.2	94.6	85.8	79.9	72.2	46.5	9.2	8.5	201	189.5	48	157	80.5
158	46	159.7	147.2	134.7	101.8	99.6	94.2	85.5	77.9	70.3	46.4	7.5	6.3	200	196	49	165.5	88
159	48	167.1	165.1	141.1	108.1	109.1	101.1	95.6	85.1	73.8	47.5	8.3	6.5	211	198.5	50.5	168.2	85
160	62	170.5	167.6	143.6	110.1	106.2	101.5	94.9	87.3	75.6	49.2	8	6.7	211	200	51.4	169	87.2
161	61	166.4	156.6	140.4	105.7	99.7	100.3	95.6	88.7	71.1	47.4	8.3	6.9	211	199	48	173.9	97
162	56	160.3	151.9	135.4	101.8	98.3	95.5	89.1	81.4	69.8	45.7	8.2	5.9	202	191	49.9	167	87
163	46	162.7	150.5	137.5	107.1	100.1	100.6	92.7	85.3	70.7	46.1	7.9	6.6	210	200	49.7	165	81
164	51	164.8	154.4	137.6	106.6	98.2	98.3	92.3	82.6	67.4	46.1	8.8	7.4	211	200	49.6	168	83
165	55	165	155.8	140.2	105.7	101.7	98.7	91.1	85.7	75.1	49.3	8.6	6.5	209	193	50.5	164	86
166	51	177.1	165.4	148.1	113.1	110	107.6	101.1	88.6	74.7	52.6	8.7	6.9	221	206	52.1	171	93
167	43	161.2	147.4	137.4	103.4	99.5	99.4	92.5	81.8	70.5	49.5	8	6.5	203	190	48.4	163	85
168	46	155.1	143.4	127.4	98.2	96.5	92.6	85.7	78.7	66.7	42.7	7.9	6.5	192.5	180.2	45.8	150	78.3
169	52	168.3	156.2	141.1	104.3	98.4	98.1	88.9	82.2	72.1	49.5	8.5	7.3	200	196	52.8	173.2	89.9
170	54	161.1	160.6	156.8	104.4	101	98.4	90.9	82.1	67.9	44.5	8.3	6.8	203	194.5	50.8	164.9	86.9
171	68	167.5	154.9	140.3	105.1	101.9	98.4	91.8	84.3	71.6	47.7	9.2	7.6	213	203	51.1	173	87.5
172	66	165.1	152.7	141.6	107.1	103.7	98.7	91.9	83.1	74.1	48.7	8.6	7.5	210	204	50.2	169.8	84.9
173	46	158	146.5	135.1	103.1	98.9	94.5	87.4	82.2	70.1	47.1	8.9	7.1	203	194	48.2	163.9	80.5
174	48	164.5	155.3	138.6	106.3	102.3	100.6	94.1	82.8	72.1	48.2	8.2	6.8	207	196	50.7	162	85

Contd…

175	48	159.5	148.4	136.4	101.5	97.7	94.7	86.8	78.1	68.5	46.4	8.3	6.4	218	207	52.4	160	80
176	71	170.2	161.8	146.7	107.8	109.2	103.4	93.8	82.4	76.1	49.1	7.6	7.1	218	207	49.5	174.9	95.4
177	51	156.8	149.1	145.5	101.5	98.6	96.7	88.2	80.2	78.1	45.7	7.5	6.8	208.5	198	48.8	168	90
178	48	161	149.9	136.1	102.7	98.7	98.2	89.8	82.6	70.3	45.5	9.7	7	203.2	194	49.1	163.5	83
179	54	164.1	152.1	136.7	102.3	101.2	100.4	92.8	86.1	69.6	49.5	9.7	6.9	211.7	200	48.6	174.4	94
180	51	167.7	157.2	141.4	104.4	105.1	100.7	91.8	79.9	72.6	48.6	8.7	6.7	213.1	201	49.5	171.2	80.8
181	40	156.5	145.5	130.8	98.1	92.4	91.2	81.4	74.2	65.3	45.7	7.6	5.9	198	184.5	48.9	158.5	86.8
182	55	167.4	156.8	143.1	108.9	109.9	102.7	93.8	87.6	77.5	50.6	9.3	7.5	216	206	52.5	175.2	89
183	55	166.3	153.1	139.6	106.8	101.8	95.8	94.6	83.6	74.6	51.4	9.3	8.4	208	195.5	53.8	169.3	85.5
184	68	178.4	168.9	149.1	115.4	109.2	107.2	96.2	89.3	78.5	50.1	9.3	7.6	221	206.5	51.6	176.5	90.5
185	74	172.5	158.9	147.6	112.8	109.4	105.2	98.4	91.3	79.5	50.2	9.6	8.1	213	202	51.4	167.5	89.9
186	52	165.6	155.7	138.8	105.4	101.8	100.8	97.6	90.8	71.3	47.4	7.6	5.8	211	201	52.5	171.2	90.9
187	82	161.8	150.5	136.5	102.3	98.2	98.5	91.1	80.1	70.7	46.1	9	7.3	203	192	48.8	166.2	86
188	75	169.7	155.6	142.7	106.1	105.9	98.9	91.5	83.7	75.7	53.7	9.5	7.1	208	199	49.2	161.3	83.4
189	54	167.9	155.9	143.9	107.8	107.5	104.7	95.9	89.8	75.6	49.5	7.5	6.4	214	202	50.7	174.5	97
190	56	168.3	157.2	142.7	107.7	106.4	100.3	93.1	87.5	72.7	52.4	7.2	6.2	214.5	203	49.2	174.2	97
191	56	167.8	155.7	144.4	109.2	107.4	102.9	98.6	70.2	78.1	48.1	8.2	6.2	214	204	51.2	173.1	89.3
192	57	169.8	160.2	145.2	112.1	108.9	104.1	99.9	93.4	76.4	49.6	8.9	7.9	210	204	49.8	168	89.9
193	59	168.1	168.1	156.2	141.3	110.3	106.4	100.5	94.7	82.4	50.8	7.5	6.2	214	205.5	47.4	170.1	81.3
194	53	169.3	157.2	142.1	105.4	99.4	99.2	86.4	84.2	73.1	49.5	8.5	7.3	201	197.5	53.2	172.1	89.8
195	55	170.3	156.7	142.7	108	103.7	104.2	99.3	92.6	71.7	53	8.8	6.9	209	195	44.9	172	93
196	74	168.1	158.5	143.5	108.1	107.2	100.5	96.1	90.6	75.1	48.8	9	8	211	199	48	166	90
197	53	157.1	148.2	131.6	98.4	95.4	90.7	84.1	78.4	68.4	47.2	8.5	8	195	181	44	153	82
198	68	183.2	172.4	155.8	114.2	114.7	110.5	105.1	100.5	81.2	55.8	10	9	230	214	53	183	90
199	48	165.7	153.6	139.7	107.5	105.2	94.5	90.7	86.7	74.4	48.1	7	6.5	207	194	49.5	170	85
200	52	174	163	146.5	112	106	106.8	101.6	98	72	43	8	7.6	223	212	51.4	178	92

Table B-2 Eighteen different anthropometric parameters of 200 farmers of Uttarakhand

S. No.	Wall to Acromion Distance	Arm reach from the wall	Thumb Tip Reach	Shoulder Grip Length	Bideltoid breadth	Sitting height	Sitting eye height	Grip Diameter (inside)	Grip Diameter (outside)	Grip span	Index Finger Diameter	Middle Finger Palm Grip Diameter	Hand Length	Palm length	Hand Breadth Across thumb	Functional Leg Length	Hand grip Strength (RightN	Hand grip Strength (Left)N
1	9.4	84.1	79.7	77.7	45	128.1	118.1	43.06	74.88	89.51	19.07	30	19	10.5	97.64	95.2	310.9	318.8
2	10.2	87.6	85.5	80.2	40.2	126.1	115.7	39.11	73.33	93.59	19.15	32	19	11	102.88	101.5	231.5	206.1
3	9.6	92.4	87.8	76.4	45.5	124.2	114.1	43.06	77.91	93.82	19.02	30	19	10.5	101.5	101.5	227.5	212.8
4	8.2	82.6	79.5	73.6	44.8	126.1	116.1	39.11	68.3	84.82	18.18	26	18	10.5	91.02	103	257.0	272.7
5	9.1	90.2	80.9	74.9	43.2	128.8	118.4	43.06	75.02	100.3	18.61	32	18.5	11	97.64	107	261.9	278.6
6	9.2	80.1	75.5	69.6	43.1	115.2	107.1	43.06	73.29	72.89	17.69	28	18	10.5	98.34	90.5	281.5	330.5
7	9.4	89.3	80.7	74.9	45.1	126.6	117.1	43.06	77.72	99.31	19.24	28	19	11	99.56	98.5	168.7	160.8
8	8.9	77.4	71.1	66.4	38.5	121.1	108.9	38.27	63.82	79.75	18.59	28	17	10	86.34	89	284.4	390.4
9	9.4	78.1	74.4	68.2	39.2	125.2	110.1	39.11	73.99	89.66	19.04	28	18	10.5	87.09	93	254.0	268.7
10	9.2	79.5	72.3	64.5	39.1	127.3	115.4	43.02	75.41	89.06	18.5	30	17.5	10	101.5	91	174.6	163.8
11	8.6	80.2	72.5	69.1	38.2	123.5	113.5	43.05	75.68	94.09	18.99	30	19	11	90.25	92.5	365.9	310.9
12	10.5	91.1	83.5	77.2	40.2	127.1	113.7	45.86	82.27	107.1	19.76	34	20.5	11	103.67	102.5	287.4	288.4
13	9.1	89.2	74.2	68.5	41.5	125.7	111.7	40.32	73.12	91.41	18.01	28	18	10	97.46	93.5	317.8	240.3
14	8.2	97.1	79.1	75.2	41.8	128.5	114.5	39.11	75.2	91.01	19.8	30	18.5	11	99.94	100	312.9	228.5
15	9.5	76.7	72.5	68.8	38.2	124	111.5	36.87	72.24	100.4	18.31	26	17.6	10	97.56	91.5	310.9	324.7
16	9.9	78.5	71	68.1	39.2	131	123.9	46.03	75.77	92.16	18.45	30	19	11	90.58	110.5	352.1	312.9
17	10.5	83.1	77.4	68.5	40.6	128.2	117.5	39.91	74.1	93.14	19.69	28	19.5	105	89.06	92.5	252.1	308.0
18	9.2	77.1	70.4	63	37.9	122.2	113.2	34.23	69.88	89.03	20.42	24	16.5	9.5	90.54	82.5	207.9	257.0
19	9.5	70.7	70.1	66.2	41.6	130.1	118.5	43.06	77.31	94.97	14.2	28	19	11	98.9	87	249.1	199.1
20	9	85	81.1	76.1	43.8	131.9	118.8	43.06	74.97	87.13	20.75	28	18.9	10.5	100.5	102	176.5	162.8
21	9.5	80.6	78.1	72.3	41.8	129.6	118.5	39.9	76.62	86.31	19.64	26	18	10.5	103.5	94.1	220.7	281.5
22	12.3	84.8	77.1	72.9	43.9	130	118	46.23	78.19	96.32	20.19	30	20	11	103.1	99	353.1	410.0
23	9.8	79.2	70.7	67.4	38.6	124.1	112.6	36.87	69.99	86.81	18.1	28	17	10	98.4	89.5	313.9	296.2
24	8.7	72.7	66.7	63.6	40.9	125.3	112.7	39.91	64.78	90.03	18.76	28	17.5	10.5	101.6	83.91	290.3	231.5
25	9.4	78.4	70.4	68.4	38.8	121.9	112.5	34.1	69.9	89.6	20.42	28	19	11	99.1	101.5	235.4	215.8

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26	7.5	83	77.6	76	40	121.2	111.5	43.42	74.14	94.42	19.68	28	18.5	10.5	100.87	96	293.3	223.6
27	9.5	86.1	80.5	77.1	42.5	128.4	115.4	43.7	75.74	91.59	18.6	28	19	10.5	94.3	97.04	297.2	253.0
28	9.5	92.3	84.6	74.1	44.1	126.3	115.4	41.74	75.18	97.8	20.22	24	19	10.5	100.79	95	297.2	271.7
29	9.7	85.2	76.4	69.4	40.1	113.8	102.2	39.11	68.1	92.66	17.69	30	17.5	9.5	98.2	87.7	196.2	154.9
30	8.8	81.5	79.4	73.2	39.6	121.1	111.6	34.11	67.62	81.77	18.5	26	17.5	9.5	99.82	92	261.9	264.8
31	9.4	83.4	79.5	75.6	39.5	109.8	104.5	34.11	66.01	88.6	18.79	28	18	10	90	91.4	164.8	154.9
32	7.8	85.5	79.9	74.5	40.5	118.6	108.4	34.11	76.67	98.91	19.94	26	18.5	10.5	100.99	86	301.1	256.0
33	9.5	85.7	78.6	72.5	45	122.8	112.4	34.11	73.04	102.6	20.25	28	19	11.5	102.45	96	344.3	320.7
34	8.5	84.1	76.1	71.4	41.2	118.1	109.1	42.9	74.74	83.68	19.24	28	18	10.5	102.73	95	275.6	284.4
35	9.7	90.5	83.1	76.8	44.2	127.4	115.8	46.7	82.69	108.2	23.05	30	20	11.5	107.02	97.8	403.1	362.9
36	9.4	86.5	80.5	74.5	41.2	123.6	114.7	42.5	72.48	90.15	18.03	30	19.5	11	106.33	92	314.0	313.9
37	9.5	78.5	84.7	78.8	37.4	118.7	110.5	34.11	75.66	93.58	19.76	26	18	10	100.9	95	293.3	278.6
38	9.4	88.1	82.4	78.2	43	118.6	109.8	46.05	75.42	101.1	20.4	34	19.5	11	106.2	97.5	461.0	404.1
39	9.5	81.5	75.7	70.5	43	112.1	112.4	42.1	74.99	84.33	19.23	30	18.5	10.5	83.48	87.5	310.9	318.8
40	9.5	79.8	72.9	69.9	42.1	114.2	105.4	34.11	72.77	85.31	17.97	28	17.5	10	97.03	84	231.5	206.0
41	10.1	85.4	80.4	77.5	39.7	116	107.2	37.8	70.83	89.7	19.64	28	18	10.5	107.19	94	227.5	212.8
42	9.5	87.1	86	79	43.5	122.4	111.6	43.9	75.49	100.45	18.79	26	19	10	102.22	95	257.0	272.7
43	9	77	72	66	42.5	122	111.4	37	71.26	96.32	19.03	28	17	9.5	97.93	85	261.9	278.6
44	8	89	87	78	41.5	118.5	108.2	43	81.47	117..1	18.4	28	18.5	10	98.14	91	281.5	330.5
45	8	82.5	77	72	37	117.4	108	45	69.9	91.5	17.5	24	16	9	87.5	80	168.7	160.8
46	10.5	87	79	71	43.2	125	115	43.87	79.57	97.9	21.2	30	18.5	10	88.9	95	284.4	390.4
47	7.3	78	71	68	36.8	120.8	108	38.6	78.8	89.6	18.4	30	16.5	8.5	96.17	86	254.0	268.7
48	8.5	86	83	78	37.9	119	109	41.5	75.48	99.01	19.75	30	17.2	9.7	87.5	91.5	174.6	163.8
49	7.1	85	87	79	39.7	126	119	47.2	78.54	107.9	18.59	32	18.7	10.5	94.47	97.5	365.9	310.9
50	9	78	72	68	39.1	124.5	115	40	67.5	89.69	18.2	30	17.4	9.2	92.5	89	287.4	288.4
51	9.5	81	77	68.5	41.1	123.6	112.2	43.24	79.24	97.24	20.4	26	17	10	89.4	86	317.8	240.3
52	8.5	83	78	72	47	126	115	38.42	75.44	92.6	16.54	26	18.5	11	95.2	92	312.9	228.5
53	9.5	88	81.5	73	43.3	124	115	43.4	81.46	97.34	19.42	32	19	10.5	97.14	91	310.9	324.7
54	8.3	90.5	84	78	43.3	122.1	108.8	37.82	70.84	99.45	18.5	32	18	10	98.4	101	352.1	312.9
55	8	85.9	82.1	77.1	41.2	121	108.8	34.11	68.1	92.14	19.67	30	18	10.5	100.8	99	252.1	308.0

Contd…

56	8.5	83.4	77.5	72.5	38	125.4	112.2	43.06	74.14	94.14	20.67	28	19	11	101.4	93	207.9	257.0
57	8	81.1	79.8	71.4	41.7	123.5	112.4	43.11	75.18	95.17	20.98	30	17	11	103.08	94	331.5	247.2
58	8.5	82.9	75.1	71.1	44.4	127.5	114.8	43.74	80.6	97.8	21.01	32	17.5	10	100.8	101	441.4	366.8
59	8.5	81.5	77.4	71.7	42.5	125.6	112.2	41.01	70.67	93.17	18.74	28	18	10	104.3	92	291.3	209.9
60	8.9	80.5	71.5	67.4	43.6	126.6	115.6	46.06	82.76	108.1	21.11	32	17.5	10	102.6	100	347.2	398.2
61	8	82.1	74.8	72.5	41	121.5	114.1	43.06	81.01	100.01	19.24	28	18	10	100.8	96	177.5	179.5
62	8.5	75.5	70.5	66.7	42.5	120.6	107.8	34.11	69.17	93.56	18.67	28	17.5	9.5	101.6	87	146.1	96.1
63	8.5	83.4	76.5	69.8	40.6	125.7	115.4	46.06	83.1	107.67	21.01	30	17.5	11	103.2	90	249.1	199.1
64	8	77.7	70.4	66.5	39.7	120.4	105.3	36.87	66.5	90.74	18.14	28	18	8	104.3	87	176.5	162.8
65	7.5	86.5	79.5	74.4	41.5	124.4	113.3	34.11	70.17	92.57	19.76	28	15	10	103.4	94	220.7	281.5
66	8.5	97.5	92.4	81.5	42.9	125.2	114.7	43.06	81.6	98.37	19.87	32	18.5	10.5	101.98	108	353.1	410.0
67	8.5	89.4	86.1	77.9	42.9	124.7	111.8	43.06	80.76	97.57	19.24	30	18	11	102.6	101	313.9	296.2
68	9	85.4	80.5	77.4	44.4	119.5	110	34.11	78.14	94.23	18.95	26	18	10.5	100.8	102	290.3	231.5
69	9	85.5	80.5	78.5	45.9	127.6	118.4	46.06	85.15	107.68	20.17	28	18	10	104.6	102	223.6	215.8
70	7.6	79	72	67	45	130.8	119.6	43.7	76.74	92.3	19.02	32	19	11	100.87	96	444.3	441.4
71	9.5	82.4	76.4	72.4	44.1	130	119.6	46.23	79.6	94.6	19.68	30	19.5	11	100.79	92	413.0	369.8
72	8.5	85.5	82.2	75.2	43	127	117.2	34.11	72.63	93.4	19.46	28	17	9.5	99.82	94	265.8	238.3
73	9.5	90.5	85.5	79.5	42.5	121.5	110.8	34.11	74.53	94.6	20.22	26	18.5	10	100.99	96.5	249.1	246.2
74	7.1	81	78	72	40.9	127	114	43.06	76.8	97	19.68	30	18	10	102.45	92	103.0	228.5
75	8.1	84	79	73	44	125.2	111.5	43.06	77.08	96.2	18.92	26	17.5	9.5	102.73	97	304.1	257.0
76	7.5	83	79	78	44.5	122.5	106.7	34.11	74.09	98.2	19.23	26	18.5	11	106.23	87	266.8	253.0
77	8	93	89	84	45	125.3	117.2	46.23	76.23	99.2	19.63	30	19.5	10	107.02	106	161.8	133.4
78	8	93	88	80	42	126	120	43.06	78.96	97.03	19.42	26	18.5	10	100.9	104	240.3	288.4
79	9	86	82	84	44	120.2	111.3	46.23	77.06	99.6	19.89	30	18	10	106.2	92	365.9	305.0
80	8.5	83	80	72.5	41.2	133.2	119.1	43.06	78.42	98	18.6	30	19	10.5	83.48	100	426.7	401.2
81	7.5	88	85	86	44.2	129.4	118.5	46.23	76.26	99.08	20.22	30	18	9.5	100.3	98	449.2	404.1
82	9.3	83	77	72	44	121.1	113.6	34.11	78.2	98.6	19.67	30	19	11	100.2	96.5	241.3	223.6
83	9.2	79.1	71.6	67	43.2	122.3	115.4	34.11	76.8	94.8	18.72	28	18	10.5	99.6	94	304.1	294.3
84	7.4	81.5	74.4	72.1	41	124.5	113.5	39.11	66.8	87.4	20.87	28	16.5	10	94.13	86	202.0	206.0
85	7.5	78.8	77.5	75.5	43.1	125.5	115.6	39.11	71.3	89.3	18.7	28	17	10	95.14	90	239.3	258.9

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86	8.5	81.1	76.1	72.1	41.8	118.5	108.5	39.11	77.6	91.3	18.9	26	17.5	10	101.2	90	197.1	182.4
87	9.5	84.6	78.5	74.4	46.3	122.1	110.2	39.11	74.6	93.3	19.6	28	18.5	10.5	102.3	91	262.9	170.6
88	9.5	90.5	84.5	76.5	44.2	121.6	110.6	43.06	77.2	94.1	19.19	28	18.5	10	103.4	98	297.2	298.2
89	9.5	88.1	84.2	76.6	45.5	124.7	114.5	43.06	76.2	92.1	20.2	28	18	11	99.8	91	370.8	392.4
90	9.4	77.4	69.9	66.9	39	119.5	109	39.11	74.11	91.9	19.19	28	17.5	10	101.2	87	184.4	193.2
91	9.5	67.4	70.5	67.1	42.2	121.8	111.5	39.11	72.06	89.9	18.9	28	16.5	9	104.3	92	288.4	243.2
92	8.5	86.5	83.1	75.7	41.5	120.2	109.7	39.11	73.06	92.3	19.6	24	17.5	10	103.4	96.5	252.1	244.2
93	8.8	85.5	84.21	77.4	43.4	124.2	111.7	43.06	77.8	94.2	18.2	30	18.5	10.5	101.6	102	252.1	165.7
94	8.5	84.5	78.5	73.4	46.7	124.6	112.7	43.06	75.04	92.6	19.68	30	18	11	103.3	96	227.5	203.0
95	7	78.9	75.6	69.4	42.6	122.1	109.1	39.11	74.12	93.6	19.28	26	18	10.5	104.3	84	334.5	295.2
96	8.5	90.5	88.9	79.5	42.7	127.7	113.5	39.11	72.2	94.3	18.96	28	18.5	11	102.3	92	293.3	278.6
97	8.5	82.9	73.7	68.9	31.2	130.2	116.2	43.06	73.06	92.68	19.2	30	18.5	10.5	103.2	97	238.3	236.4
98	8.5	87.2	81.5	76.1	38.7	123	115	39.11	72.1	91.9	18.6	30	18.5	11	101.6	96	238.3	195.2
99	8.9	84.5	76.4	72.8	43.2	125.4	114.1	38	73.87	90.62	21.53	28	18	10	105.64	88	90.2	103.0
100	8	85.5	82.1	77.7	42.1	120.3	108.8	40	76.43	89.9	18.4	26	16.5	9.5	100.5	90	205.0	198.1
101	8.5	84.5	78.6	73.7	43.5	122	113.2	38	71.25	84.22	18.49	26	18	10	101.5	94	105.9	123.6
102	8.5	88.8	82.5	73.4	41.6	121.7	112.7	44	74.6	83.5	18.06	28	18	9.5	94.9	91	105.9	96.1
103	8.5	87.5	78.5	73.4	49.5	123.3	113.4	40	77.14	98.09	19.3	28	18	10	99.5	94	253.0	259.9
104	8.5	84.9	77.2	73.5	40.1	118.2	108.5	38	76.23	96.7	19.6	28	17.5	9	101.5	92	148.1	100.0
105	8.5	68.5	66.5	62.5	38.1	113.8	102.5	36	73.49	93.33	19.5	24	16.5	9	94	82	118.7	167.7
106	8.5	82.1	76.1	70.5	40.4	124.3	111.6	39.11	71.2	87.6	19.6	26	18.5	10.5	102.3	92	199.1	158.9
107	8	79.5	73.1	67.4	42.2	122.8	101.1	39.11	74.9	92.3	19.5	26	17	9.5	103.9	85	264.8	257.0
108	7	84.9	81.5	72.1	40.7	117.8	107.9	39.11	73.2	89.6	18.65	30	18.5	10.5	104.3	84	217.7	239.3
109	8.5	78.5	75.5	69.4	41.3	121.5	113	43.06	76.2	91.6	19.65	32	18	10	103.4	95	290.3	340.4
110	8.9	76.9	78.4	63.5	40	118.4	109.1	39.11	71.2	89.6	19.16	26	17	9.5	103.4	88	174.6	152.0
111	7.5	92.5	82.1	76.4	43.1	131.3	121.6	39.11	72.6	84.6	19.2	32	20	11.5	102.1	104	383.5	413.0
112	7.5	86.6	75.4	70.1	40.2	124	110.3	43.06	74.23	93.3	20.3	32	18	10	104.9	96	294.3	198.1
113	8	84.1	79.1	73.5	46.2	125.5	114.8	39.11	73.2	82.3	18.3	32	18.5	10	99.2	100	313.9	293.3
114	9	82	77	69	41.3	116	104	43.42	74.26	94.42	19.68	26	18	10.2	104.36	95	215.8	248.1
115	9	83	76	73	39.3	115.8	102.5	40	73.68	89.75	20.17	26	16.5	9	102.3	84	155.9	187.3

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116	8.5	87	79	76	40.6	124.7	112.1	40	80.58	101.8	21.36	30	19	10.5	103.76	88.5	352.1	350.2
117	8.3	88	79	75.5	43.8	125.4	115.3	40	77.14	98.09	19.13	28	19.5	11	99.6	93	293.3	262.9
118	8	85	83	79	39.9	123.4	113.3	42.31	72.18	89.37	18.15	32	18.8	10.5	100.4	90	259.9	261.9
119	8	88.5	78	75	40.2	120.6	109.8	42.31	74.6	94.42	19.13	32	19.5	11	103.4	94.5	357.0	291.3
120	7.6	83	77	71	40.2	121.4	108.1	38	71.25	84.22	18.81	26	17	9.5	101.6	92	350.2	308.0
121	6.7	83	71	74	38.2	122	114	40	74.5	96.03	19.64	32	18	10	104.26	92	268.7	257.0
122	7.7	79.5	76.8	72.9	39.2	125	111.2	38	71.68	84.6	19.19	26	17.2	9.7	102.4	90	197.1	182.4
123	7.9	90	83	77	39.5	128.5	117.3	38	72.04	86.6	19.6	32	19	10.5	103.2	99	360.0	277.6
124	8	79	77	69	44.5	125	118	40	76.2	92.6	19.2	30	18	10.5	104.6	89	313.9	278.6
125	9	84	80	74	38.9	120	108	39.11	72.8	86.2	19.8	28	18	10	103.4	95	161.8	178.5
126	10	83	72	72	38.8	111.2	120.3	40	78.9	89.3	20.2	28	18.5	10	101.6	99	309.9	270.7
127	7	80	74	70	40.9	126.1	112.7	39.11	76.4	81.6	18.49	32	18.5	10	99.6	98	369.8	309.9
128	13	88	86	76	40.2	126.9	114.7	52.41	86.35	87.71	19.21	32	18.1	10	98.7	100.1	200.1	179.2
129	10.5	84	76	86.4	44.4	125.1	114.2	46.2	79.3	87.9	19.12	30	19	11.5	101.4	94.5	290.3	243.2
130	10.5	82.1	73.5	67.5	36.4	122.1	111.1	46.23	81.01	99.64	18.85	28	18.5	10.5	102.6	92.5	176.5	161.8
131	12.5	78.4	74.4	74.1	41.1	128.2	112.4	43.06	78.45	94.21	18.64	28	18	10	101.65	98.4	197.1	215.8
132	11.4	80.4	74.5	72.4	42.4	126.4	114.2	52.41	81.1	96.24	19.2	30	17.5	10	103.4	97.2	300.1	237.4
133	11.6	82.3	71.2	71.4	43.1	130.4	119.1	49.1	84.9	106.1	19.18	32	19.1	11	104.6	99.1	245.2	190.3
134	10.4	83.4	80.4	80.5	45.2	132.1	120.2	46.23	81.97	95.22	19.5	32	18	10	103.4	93.5	279.5	262.9
135	10.5	88.8	85.3	85.4	47.1	123.9	113.8	52.41	86.67	93.94	19.41	32	18.5	10.5	101.8	100.4	255.0	158.9
136	13.5	84.4	77.5	77.5	39.2	132.4	121.9	49.42	85.77	105.1	19.3	28	19	10.5	99.8	97.4	317.8	238.3
137	11.5	88.5	78.7	78.7	38.6	130.4	120.2	49.42	84.29	105.87	19.12	28	19.5	11	101.9	100.5	205.0	182.4
138	11	80.5	75	70	40.8	122.4	111.1	43.06	80.16	85.68	18.53	32	17	10	101.6	94.5	239.3	219.7
139	12.5	88	86	78.3	39.4	133.2	124.1	52.41	90.1	100.18	18.6	28	19.5	11.3	99.8	104.5	276.6	168.7
140	10	88.7	81	77	36.4	127.4	116.1	49	81.24	99.7	18.16	28	19	10.5	103.2	101	262.9	191.2
141	10.5	82.8	78.7	71	38.2	129.7	118.9	46.23	82.46	99.79	18.04	30	18	10	102.8	99.5	180.5	215.8
142	9	84	78	74.4	40.8	125.7	113.4	46.23	79.07	91.72	20.33	30	18.5	10.5	100.9	97.9	217.7	217.7
143	12.6	88	80.9	74.5	43.2	118.2	104	46.23	84.96	88.24	19.1	28	18	10	99.1	97	317.8	246.2
144	11.7	92.6	89.5	81	41.6	132.9	119	49	82.49	89.52	20.18	32	18.5	10.5	98.8	105	283.5	236.4
145	9.4	81.8	82.5	75.2	39.2	127.5	117.2	43.06	78.78	92.54	19.84	32	17.5	10	101.5	92	259.9	238.3

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146	10.3	85	77.2	73.1	38.9	125.8	113.9	43.06	79.52	96.91	19.67	30	18.2	10	100.7	92	252.1	161.8
147	10.5	80.5	76.4	72.9	40.6	126.4	114	39.9	73.91	90.45	18.35	30	17.5	9.7	102.3	93	334.5	249.1
148	9.3	83.2	80.1	78.6	43.5	123.1	109.5	43.2	79.32	94.3	18.32	20	18.5	10	97.73	100	217.7	182.4
149	9.1	76.9	70.9	66.8	40.6	114.2	104.8	40.2	73.23	78.41	18.13	30	17	9.5	92.9	90	217.7	210.9
150	9.6	86.1	78.5	75	40.9	126.4	115.9	40.9	77.3	86.11	19.18	26	19.5	10.5	101.4	95.5	259.9	238.3
151	8.3	86.1	80	73.2	42.1	119.6	109.2	40	74.1	91.98	19.35	28	18.5	10	97.43	97.5	283.5	236.4
152	9.4	82.8	77.7	73.5	44.1	120.1	112.6	45	74.18	96.7	19.71	26	18	10	98.37	96	300.1	262.9
153	10.5	88	82	78	43.5	126.9	116.9	38	73.95	91.02	18.86	24	18	10.5	101.06	89	245.2	158.9
154	9.2	81.5	72.5	68.5	41.2	121.8	112.1	38	69.62	78.34	17.94	22	17	10	96.3	94.5	279.5	238.3
155	9.6	77.6	75.1	68.2	42.2	119.8	107.7	38	73.56	95.26	19.68	28	17.5	10	96.62	80	255.0	182.4
156	9.5	88	77.1	75	42.5	119.2	107.7	51.5	84.2	100.6	20.17	32	20	11.5	100.65	99	317.8	219.7
157	8.8	78	71	67.5	40.2	119.5	107.6	38	70.98	84.16	18.42	26	18	10.5	101.2	92.5	205.0	168.7
158	8.6	78.2	72.5	67.5	38.7	121.6	112.7	40	72.9	93.35	18.5	28	17.5	10	95.7	84.5	239.3	191.2
159	9.5	84.2	78.5	74.5	41.5	125.7	115.2	45.1	77.93	91.91	19.92	28	18.5	11	101.11	101	276.6	215.8
160	8.5	83	73	71	41.5	121.2	111.5	45.3	79.5	93.3	17.48	26	18	10	101.6	98	239.3	219.7
161	8.9	84	80.9	77.5	43.3	116.4	108.5	44.5	77.42	88.7	20.63	26	18	10	98.94	97	276.6	168.7
162	8.9	80.5	74	69.4	41.3	123.6	113.8	38	81.49	91.83	18.21	26	17.7	10	94.84	88	297.2	298.2
163	9	83.5	76.5	71.2	39.7	121.6	110.9	45.1	81.23	97.7	17.32	32	19	10.5	95.3	89.5	370.8	392.4
164	9.3	85.6	84.8	76.5	43.5	126.5	116.1	40	76.51	82.69	17.78	24	18	10	99.65	97	184.4	193.2
165	9.5	84.1	79.2	75.1	43.5	120	110.4	40	73.62	86.31	19.33	28	17.5	9.5	99.91	97.5	288.4	243.2
166	10.4	94.3	83.3	78	40	124	115.5	43.9	77.47	98.6	19.24	28	19.5	11.5	102.6	101.5	252.1	244.2
167	9.5	79.8	72.4	66.4	40.2	116.7	105.8	43.81	74.3	92.7	18.73	28	18	10.5	93.87	97.5	252.1	165.7
168	8.8	72.4	64.3	62.1	38.2	116.8	104.4	38	67.21	82.18	16.1	28	17	9.5	90.63	90	227.5	203.0
169	9.4	84.6	79.9	75.7	41.8	128.3	119.7	40	75.25	93.58	19.95	28	19	11	103.38	99	334.5	295.2
170	8.8	82.4	76.8	71.9	40.2	118.4	109.4	40	76.45	86.75	18.9	28	18.5	9.5	98.35	90.5	293.3	278.6
171	9.8	89.8	85.6	78.6	44.5	125.1	114.1	40	78.3	97.47	19.93	26	19	11.5	102.2	97	238.3	236.4
172	9.8	87.8	81.5	77.8	44.2	117.5	107.4	38	73.82	93.23	19.8	26	18.5	11	101.61	94	238.3	195.2
173	7.9	82.5	76.4	77.7	38.5	114.7	104.7	38	73.56	95.35	18.13	26	17.5	10	94.6	90	294.3	198.1
174	9.5	83.4	76.9	71.2	39.8	117.6	111.6	40	70.29	79.49	17.15	26	18	10.5	92.78	97	313.9	293.3
175	8.3	82.1	75.1	70.1	42.5	121.6	111.6	40	74.99	88.75	18.14	30	17.5	10	93.53	97.5	215.8	248.1

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176	11.1	93	88	87	45	123.5	109.1	38	83.29	98.12	22.48	26	19.5	11	108.9	98.5	155.9	187.3
177	9	83.5	80	74	41.2	113.7	104.1	38	75.16	95.13	21.44	28	18.5	10.5	97.1	90.5	352.1	350.2
178	9	83.5	80.6	74.5	41.5	119.5	108	40	78.11	96.36	21.84	30	19.3	11	107.83	93	293.3	262.9
179	10.5	83.7	77.3	72	42	115.6	105.3	43.75	76.36	101.61	19.41	30	19	10.5	100.12	97	259.9	261.9
180	10.5	85.6	82.1	74	45.5	120.1	106	38	73.87	90.62	21.53	28	18.7	10.6	105.64	102	357.0	291.3
181	7.5	74.8	72.5	69	39.4	114.6	104.6	36	69.97	77.12	18.53	24	16.5	9	92.44	91	350.2	308.0
182	10.3	90.6	79.8	74.7	41.5	116.1	107.2	42.37	72.18	89.37	18.15	32	19.3	11	97.75	104	268.7	257.0
183	10	86.6	81.4	73.8	41.1	120.3	110.6	40	73.68	89.75	20.17	26	18.5	10.5	109.36	100.5	197.1	182.4
184	9.5	84.4	77.7	74	46.7	124	110.2	40	80.58	106.8	21.36	30	19.5	11	102.29	111	360.0	277.6
185	9.5	80.2	74.7	69.6	46	124.5	112.5	40	76.43	84.4	19.49	26	17.8	10.2	99.54	101.2	313.9	278.6
186	8.5	83.5	76.1	73.8	42.3	124	117	44.6	78.22	92.27	19.71	30	18.5	10.5	103.76	99.5	161.8	178.5
187	9.3	83	78.3	71.3	46.4	124.3	110.5	36	73.49	93.33	19.5	24	18	10.5	98.5	94	309.9	270.7
188	8.8	76.4	75.7	70.1	48.4	122.2	110.6	38	71.25	84.22	18.81	26	17	9.5	96.6	101	369.8	309.9
189	9.5	84.6	78.4	72.6	41.5	118.3	107.5	40	72.86	88.01	19.23	30	18.5	10.5	100.12	99.2	205.0	198.1
190	9.5	89.8	84.3	75.4	43.2	117.4	105.7	40	77.14	98.09	19.13	28	19	10.5	101.26	99.5	105.9	123.6
191	9.6	82.2	78.3	71.3	43.5	120.9	110.9	44	74.6	93.5	18.06	28	18.5	10.5	94.9	93.5	105.9	96.1
192	9.8	88.1	79.5	77	42.9	128.4	117.9	40	79.3	88.11	19.18	26	19.4	10.6	102.4	96.5	253.0	259.9
193	9.2	80.2	81.1	75.6	43.4	121.1	108.5	43.2	79.32	94.3	18.32	28	18.6	10.2	96.24	101.1	148.1	100.0
194	9.5	89.7	80.6	73.4	42.8	129.3	120.7	42	76.25	94.16	19.95	28	18.5	10.5	102.38	99.2	118.7	167.7
195	8.5	87	79	76	40.6	124.7	112.1	40	80.58	101.8	21.36	30	19	10.5	103.76	88.5	352.1	350.2
196	8	84.1	79.1	73.5	46.2	125.5	114.8	39.11	73.2	82.3	18.3	32	18.5	10	99.2	100	313.9	293.3
197	8.9	76.9	78.4	63.5	40	118.4	109.1	39.11	71.2	89.6	19.16	26	17	9.5	103.4	88	174.6	152.0
198	7.5	92.5	82.1	76.4	43.1	131.3	121.6	39.11	72.6	84.6	19.2	32	20	11.5	102.1	104	383.5	413.0
199	7.5	86.6	75.4	70.1	40.2	124	110.3	43.06	74.23	93.3	20.3	32	18	10	104.9	96	294.3	198.1
200	7.9	90	83	77	39.5	128.5	117.3	38	72.04	86.6	19.6	32	19	10.5	103.2	99	360.0	277.6

VITA

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Department : Farm Machinery and Power Engineering

Thesis Title : Design of Improved Animal Drawn Implements Based on Ergonomics.

Advisor : Dr. Jayant Singh

ABSTRACT

Hand tools and animal drawn implements are extensively used for different farm operations in Uttarakhand. If these agricultural tools/implements are not designed ergonomically, and this leads to increase in fatigue, health hazards and even accidents to agricultural workers. Proper matching of machine requirements with operator's capabilities is necessary to achieve better performance, which is associated by the ergonomics. In this regard, the basic information is required is the anthropometric body dimensions of the agricultural workers who frequently use these tools and implements. An anthropometric survey of two hundred male agricultural workers with 36 body dimensions of hill region of Uttarakhand was carried out at the different villages of the Uttarakhand, India to generate the anthropometric database. The use of male anthropometric and strength data can help in the proper designing of new equipments and modifying the existing one.

The collected data was analyzed for the mean, range (maximum and minimum), standard deviation, 5^{th}percentile, 50^{th} percentile and 95^{th} percentile values. It was found that the values of 5th and 95th percentile of hand grip strength (right) and hand grip strength (left) for hill farmers were less as compare to All India farmers.

Animal drawn Implements like hill plough, danala and damala and hand tools like khurpi, fork, sickle and thamali-cum-chopper for hill region were analyzed and necessary dimensions were suggested regarding their handle height, handle diameter and handle lengthnto reduce drudgery and at the same time increase efficiency, safety and comfort of agricultural workers of hill region of Uttarakhand.

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Advisor

(Bhawana Negi)
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प्रमुख : फार्म मशीनरी और पावर इंजीनियरिंग

विभाग : फार्म मशीनरी और पावर इंजीनियरिंग

थीसिस शीर्षक : एर्गोनॉमिक्स पर □धारित बेहतर पशु तय□र किए गए उपकरणों का डिजाइन।

सलाहकार : डॉ. जयंत सिंह

सारांश

उत्तराखंड में विभिन्न कृषि कार्यों के लिए हाथ से बने उपकरण और जानवरों द्वारा तय□र किए गए उपकरणों का बड़े पम□मे पर उपयोग किया जाता ह□ यदि इन कृषि उपकरणों / उपकरणों को एर्गोनोमिक रूप से डिजाइन नहीं किया गया ह□ और इससे कृषि श्रमिकों के लिए थकान, स्वास्थ्य संबंधी खतरे और यहां तक कि दुर्घटनाएं बढ़ जाती हैं। हतर प्रदर्शन प्राप्त करने के लिए ऑपरेटर की क्षमताओं के साथ मशीन की □वश्यकताओं का उचित मिलान □वश्यक ह□ जो कि एर्गोनॉमिक्स द्वारा जुड़ा हु□ ह□ इस संबंध में, बुनियादी जानकारी □वश्यक ह□ कृषि श्रमिकों के मानव शरीर के □याम हैं जो अक्सर इन उपकरणों और उपकरणों का उपयोग करते हैं। उत्तराखंड, भारत के पर्वतीय क्षेत्र के 36 शरीर □यामों के साथ दो सौ पुरुष कृषि श्रमिकों का एक मानवविज्ञान सर्वेक्षण, मानवविज्ञान डेटाबेस बनाने के लिए उत्तराखंड, भारत के विभिन्न गांवों में किया गया था। पुरुष एंथ्रोपोमेट्रिक और स्ट्रेंथ डेटा के उपयोग से नए उपकरणों के उचित डिजाइन और मौजूदा को संशोधित करने में मदद मिल सकती ह□

एकत्रित डेटा का माध्य, श्रेणी (अधिकतम और न्यूनतम), मानक विचलन, 5 वाँ प्रतिशतक, 50 वाँ प्रतिशतक और 95 वाँ प्रतिशत मानों का विश्लेषण किया गया था। यह पाया गया कि पहाड़ी किसानों के लिए हाथ पकड़ शक्ति (दाएं) और हाथ पकड़ ताकत (बाएं) के 5 वें और 95 वें प्रतिशत के मूल्य अखिल भारतीय किसानों की तुलना में कम थे।

पहाड़ी क्षेत्र के लिए पहाड़ी हल, दानाला और डामला और हाथ उपकरण जस□ खुरपी, कांटा, दरांती और थमली-सह-हेलिकॉप्टर के लिए तय□र किए गए उपकरणों का विश्लेषण किया गया था और उनके हैंडल की ऊंचाई, हैंडल व्यास और हैंडल के बारे में □वश्यक □याम सुझाए गए थे, जिससे ड्रगरी कम हुई और उसी समय उत्तराखंड के पर्वतीय क्षेत्र के कृषि श्रमिकों की दक्षता, सुरक्षा और □राम बढ़ा।

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