ABSTRACT - A large proportion of the workforce in the world is involved in agriculture or related occupations. In India, about 300 million workers are associated with farm work constituting one fifth of the world's Agricultural work force. Hand tools have been in use for a very long time and have developed in an almost evolutionary manner. It has been reported that an overall agricultural injury incidence rate is 1.25/1000 workers/year in Madhya Pradesh, India. An estimated 77.6% of all incidents were due to farm machinery, 11.8% were due to hand tools, and the remaining 10.6% were due to other factors. It has reviewed hand injury statistics from literature and inferred that hand tools cause 9 of all reported disabling injuries, and 75% are because of manual tools. Hand tool constitutes significant number (58%) in farm injuries, involving a very high number of female farm workers (65%). Design of a handle depends on many factors like mode of operation, anthropometric data of user population, material of handle and shape of handle. Research has shown that there are anthropometric differences between different populations in almost every part of the human body. Anthropometric measurements regarding hand implements and manually operated equipments like screw driver, hand saw, sickle, pliers, scrapers, shovel handle, Khurpi, weaving tools, weeder etc. were found to be appropriate in the context of various studies based on material and size. The studies are based on modification in tools in reference to descriptors associated with comfort, safety and functionality. The paper presents a review of anthropometric studies conducted with regard to agricultural and hand implements. This review is an attempt to discuss the design consideration and improvements in agricultural and hand implements exhibited by anthropometry.

Keywords- agricultural hand implements, anthropometry, design considerations

1.0 INTRODUCTION

Over the centuries, human have used tools to accomplish a variety of tasks, typically related to agricultural jobs. Today, there is growing demand among professional hand tools users to have ergonomically designed product (Schmidtke, 1984; Snow, 1984).

India is an agriculture-based country. A large section of Indian population engages in agriculture. Although agriculture is generally recognized as the nation’s most hazardous industry and is plays high rates of MSDs with evidence in which the ergonomic risk factors are involved and be pointed out, there is very little history of application of ergonomic approaches in agricultural equipment design (Vyawahare et al., 2012).

Reliability of agricultural tools can be greatly enhanced when designed with due consideration to anthropometric dimensions.
of target users. Agricultural workers play a significant and crucial role in various agricultural operations starting from land preparation to post harvest operations where they use different types of farm tools, machinery and equipment. The efficient use of Agricultural farm machines require a good knowledge and proper design of equipment capable of increasing work efficiency, safety and safeguarding of the comfort of these using the machines (Onuoha et al., 2013).

The availability of an anthropometric database has unlimited applications. Western countries, where ergonomic awareness is much higher than in other areas of the world, have created huge databases for anthropometric design reference (NASA, 1978; Syed, December, 2012 Anthropometric and strength data of Indian agricultural workers for equipment design: a review Vol. 14, No.4 103 1993).

As per the census 2001, The Indian workforce is over 400 million strong, which constitutes 39.1% of the total population of the country. Distribution of main workers by industrial category shows that agriculture sector still employs largest number of workers. The dependence on agriculture is brought out by the fact that of the 313 million main workers in the country, 166 million (56.6%) has been engaged in ‘Agricultural and allied activities’. This is followed by ‘Manufacturing Industries’, which employed about 42 million (13.4%). There are 31.1 million workers in the service sector forming 10% of the total main workers with similar number engaged in wholesale retail trade and repair work, hotel and restaurant. Majority of female workers are from rural areas.

In order to safeguard the workers against accidents and ill health, a large number of safety legislations exist in India. However, the ergonomic factors concerning safety are not adequately addressed in these legislations. While environmental factors such as noise, ventilation, illumination etc. have been dealt with in detail, factors relating to man-machine interaction need more emphasis in the legislation (Periyan and Iqbal, 2009). Ergonomics can be used as a tool for retaining employees and increasing productivity. It is therefore recommended that such tools could be used.
to reduce turnover rates and increase employee engagement. High rates of attrition not only increase costs but signify poor working conditions and low brand equity. Ergonomic interventions are increasingly used to reduce labour turnover rates, lower costs, increase revenue and accomplish more work with a little work force (Dempsey, 2007; Sen, 2009; Singh and Arora, 2010; barghouei and Nasab, 2012). Gordon et al., 1962 indicated that the rate of disabling injuries among four villages in India was 116 per 1000 populations in 1959 as Compared to 49 in 1976 in USA.

**Design Implications towards Agricultural Approach:**

A large proportion of the workforce in the world is involved in agriculture or related occupations. In India, about 300 million workers are associated with farm work (Census 2001) constituting one fifth of the world's Agricultural work force. It is estimated that every year in three states of northern India i.e. Haryana, Punjab and Uttar Pradesh, there may be 5,000-10,000 deaths; 15,000 to 20,000 amputations and 150,000 to 200,000 serious injuries due to agricultural related activities (Mohan and patel, 1992). Tiwari et al., (2002) has reported an overall agricultural injury incidence rate of 1.25/1000workers/year in Madya Pradesh, India. An estimated 77.6% of all incidents were due to farm machinery, 11.8%were due to hand tools, and the remaining 10.6%were due to other factors. It has reviewed hand injury statistics and inferred that hand tools cause 9 of all reported disabling injuries, and 75 % are because of manual tools. The magnitude of injuries is very high as there are 1700 injuries related to hand tools per hundred thousand farm workers in rural India. Hand tool constitutes significant number (58%) in farm injuries, involving a very high number of female farm workers (65%). Fifty three different hand tools commonly used on farms were evaluated (Mohan et al., 1992; Kumar et al., 2006).

The causation factors include slippages of tool from hand because of sweat or paint etc on handle, hitting a hard surface, in impact type soil interactive tools (spade) bouncing back of hand tool, unpredictable soil conditions, improper handle diameter and length of handle, improper texture and material of handle, improper clearance for hand in handles and mismatch of anthropometric dimension and tool handles. Productivity of farm workers is impaired during recovery time for 24,000 days per hundred thousand farm workers per year because of injuries caused by hand tools on farms (Kumar et al., 2006). According to The longest finger should not touch the palm while holding the handle and at the same
time it should not exceed the internal grip diameter (De Looze et al., 2003; Kumar et al., 2006).

For manually operated implements, the handle is one of the most important components with which the operator controls and guides the implements properly during field operations. The elbow height (standing) data are helpful for designing proper handle height. Elbow height (standing) for the 5th percentile female Indian is 96.33 cm in the study. In rice cultivation rotary weeder is commonly used by the female labourers in study region. It works by the push pull action and the weeds were uprooted and buried in the field itself. The handle of the weeder should be designed such that during operation the operator stands erect as far as possible to reduce musculoskeletal discomfort (Dewangan et al., 2008). Grandjean, 1988 suggested that the elbow flexion angle should be in the range of 85-110° for maximum work efficiency. An angle in the range of 50-60° has been suggested in between ground and handle (Pradhan et al., 1987). Elbow flexion angle as 100°; angle of operation as 45°. The recommended diameters of the cylindrical handles therefore vary from 25 mm to 60 mm, and above (Harih et al., 2014). Inclination of weeder handle with the horizontal as 55° and 5th and 95th percentile values of elbow height as 89.49 and 104.53 cm, respectively, and elbow grip length for 5th and 95th percentile population as 30.95 and 36.05 cm resp, the optimum length of the handle can be found out from the geometry adopted by the operator (Dewangan et al., 2008). For female population, The optimum length of the handle for the population ranged 102.73-120.00 cm. Hence the handle of the weeder was modified as telescopic handle (Sam et al., 2013; Harih et al., 2014).

Design of a handle depends on many factors like mode of operation, anthropometric data of user population, material of handle and shape of handle. Anthropometrically, the diameter of the handle should be such that while an operator grips the handle, his longest finger should not touch the palm. It had been found that to allow good grip on the handle, the diameter of the handle should be a little lesser than the inside grip diameter (Nag et al., 1988). The handles should vary in size between the hand and finger sizes, as the maximum voluntary finger contraction force is diameter-dependent. Shape of hand doing power grasp posture must be considered during the optimal power grasp posture in order to evaluate the importance of the shape on perceived comfort and for optimizing the shapes of the handles across different populations (Harih et al., 2014). The recommended diameter of handle is 30
mm with considering grip diameter (inside) of female farm worker in concept of sickle. The optimum value for grip length should be such that the widest palm should accommodate the handle.

The handles for two commonly used hand tools, the chisel and pliers were designed following ergonomic principles. Results clearly showed that the ergonomically designed handle allowed higher work efficiency than existing handles (Lewis and Narayan, 1993).

Based on the anthropometric considerations, the length of handle should accommodate the maximum dimension of hand breadth at thumb. The 95th percentile value of the length of handle is 9.8 cm, taking a clearance 0.5 cm on each side of the grip, the length of the handle comes to 10.8 cm. The handle diameter should be according to 5th percentile value of the inside grip diameter to accommodate the larger population group. This value is 3.82 cm. Based on the studies of men and women with reference to an ergonomic evaluation of different hand tools with household appliances (Nag et al., 1988), the recommended handle diameter is 3.7 cm (Dixit et al., 2012; Dewangan et al., 2008).

The recommended length of sickle handle for female worker works out to 117 mm allowing a clearance of 5 mm on each side of the grip (Grandjean, 1988). The handle of the weeder should be designed such that during operation the operator stands erect as far as possible to reduce musculoskeletal discomfort. Taking the elbow flexion value of 100°, inclination of weeder handle with the horizontal as 55° and 5th and 95th percentile values of elbow height as 90.20 and 104.60 cm, respectively, and elbow grip length for 5th and 95th percentile population as 30.20 and 35.70 cm, respectively, the optimum length of the handle can be found out from the geometry adopted by the operator. The handle length ranges 101.93–118.44 cm in case of north eastern women farmers (Devangan et al., 2008).

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 5th and 95th percentile values of Metacarpal III height of male agricultural workers of NE region have been found to be 62.2 and 76.1 cm respectively. Considering depth of operation of about 11 cm, the optimum handle height for an indigenous plough works out to be between 71.5 and 87.5 cm. preferably, the height should be adjustable between this ranges. For a fixed type handle, a height of 79.0 cm has been recommended. Gite and Yadav, 1990 has recommended the handle height to be within 0.7 and 0.8 of
shoulder height for minimum physiological cost and muscular fatigue. The 5th and 95th percentile values of shoulder height of male agricultural workers of NE region have been found to be 125.0 and 144.2 cm respectively. Considering this range, a handle height of 100.0 cm is recommended for male agricultural workers of the north eastern India (Kumar et al., 2006; Devangan et al., 2010).

Nag et al., 1988 analyzed the effect of sickle design on manual harvesting and the harvester. The study was justified on the basis that manual harvesting is a moderately heavy task, which requires agricultural workers to adopt many awkward postures. Hence handle height, length of handle, handle inclination, etc of hand held agricultural tools are the key design elements to be considered so that maximum force can be exerted to operate the equipment with less effort comfort and work output from the operator.

Grandjean, 1981 suggested that a comfortable range of elbow angle should be 100-110º. He measured the elbow heights (standing) at this elbow angle for the 5th, 50th and 95th percentile male and female agricultural workers of Meghalaya. Tewari, 1985 showed that for push and pull operation of a machine, the elbow flexion angle should be about 90 degrees. Yadav et al., 1997 reported anthropometric data (n=29) of male farm workers (n=134) of Eastern India as a reference for the ergonomic design and modifications of agricultural tools and devices such as khurpi or power tiller.

Goel et al., 2008 developed a manually operated weeder for dry land crops and evaluated its performance. It was compared with other available weeders namely a wheel finger weeder, a wheel hoe and conventional weeding by using a trench hoe. The highest performance index of 3689.74 was found with developed weeder at 11.63% moisture content. For maximum work efficiency, it was suggested that the elbow flexion angle should be 85-110º (Grandjean, 1988). For push-pull operation of a machine, the elbow flexion angle would be 90º (Tewari, 1985) and the optimum holding height for males is 630-677 mm and that of females is 534-630 mm (Tewari et al., 2007).

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 Indian female workers was 154.6 cm, while those for male workers from eastern, southern, central, northern and western regions were 162.1, 160.7, 162.0, 168.5 and 164.4 cm, respectively.

Hand tools and manually operated equipments are extensively used for digging, weeding and harvesting operations in
agriculture. Weeding is one of the most important farm operations in crop production system. The most commonly used hand tools and equipments by the farmers for manual operations are spade, weeders, threshers, sprayers, ploughs, sickle, paddy puller, straw puller, hoe, hand power tiller etc. Manual weeding requires a huge labour force and accounts for about 25% of the total labour requirement (Nag and Datt, 1979). So manually operated weeders are remained first priority of the researchers. The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeders are most effective in both dry land and wet land (Nag and Datt, 1979; Gite and Yadav, 1985; 1990; Vyavahare et al., 2012). Kuijt-Evers et al., 2004 considered six factors (functionality, posture and muscles, irritation and pain of hand and fingers, irritation of hand surface, handle characteristics, aesthetics) which determine comfort/discomfort in using hand tools according to users. These six factors classified into three meaningful groups: functionality, physical interaction and appearance. The results of the study showed that functionality is most related to comfort in using hand tools, followed by physical interaction and appearance.

Khidiya and Bhardwaj, 2010 prepared a modified design of hand operated spade (phawra) using principles of ergonomics and software such as CATIA and ANSYS. The comfort level has been improved by 44.2% due to the modified design and could offer an improved working environment and a reduction in workplace injuries. The mean stature and weight of Indian agricultural workers worked out are 163.3 cm and 54.7 kg for male workers and 151.5 cm and 46.3 kg for female workers. The mean values for strength data in pushing and pulling by both hands in standing posture are 224 N and 218 N for male workers and 143 N and 158 N for female workers, respectively (Gite and Majumder, 2007). The study was made to measure the isometric strength and investigate the effects of different handle heights and elbow angles on the pushing and pulling strengths of young men (n=8) at University of Windsor, Canada. Both the highest and the lowest isometric strengths for pulling were found at shoulder height (Mean = 60.29 lb., SD = 16.78 lb.) and elbow height (Mean = 33.06 lb., SD = 6.56 lb.) respectively (Badi and Boushaala, 2008).

DISCUSSION:

Ergonomics can be defined as the application of knowledge of human’s characteristics to the design of systems (Chander et al., 2009)
In order to safeguard the workers against accidents and ill health, a large number of safety legislations exist in India. However, the ergonomic factors concerning safety are not adequately addressed in these legislations. While environmental factors such as noise, ventilation, illumination etc. have been dealt with in detail, factors relating to man-machine interaction need more emphasis in the legislation (Periyan and Iqbal, 2009). Ergonomics can be used as a tool for retaining employees and increasing productivity. It is therefore recommended that such tools could be used to reduce turnover rates and increase employee engagement. High rates of attrition not only increase costs but signify poor working conditions and low brand equity. Ergonomic interventions are increasingly used to reduce labour turnover rates, lower costs, increase revenue and accomplish more work with a little work force (Dempsey, 2007; Sen, 2009; Singh and Arora, 2010; Abarghouei and Nasab, 2012; Vyavahare et al.,2012).

The percentile values may be used for designing common agricultural hand tools like, weed spade, sickle, paddy pullar, straw pullar, hoe, hand power tiller etc. for Indian workers particularly for Eastern India. (Kar et al., 2003).

CONCLUSION:
A significant part of manual work is still done with hand-tools, despite the automation in many industries. Badly-designed hand tools can induce upper-extremity musculoskeletal disorders; such as blister, carpal tunnel syndrome, hand-arm vibration syndrome (HAVS), tendonitis, acute trauma disorders (ATD) etc. (Kumar et al.,2014) The government, engineers, designers and related agencies should give end-users of machines the opportunity to be involved in various stages of design and as well take the findings of this study as a reference. By doing this, repetitive hand injuries in many workplaces will be reduced and healthier farm workers and safer work environment assured (Onuoha et al.,2013). The equipment will have to be designed keeping in view the anthropometric data of the farm workers in consideration. It will help to make the equipment farm workers friendly and safe for operation. A large sample size can proposed for statistical significance for more accurate results and can be explored to market. Generalized measurements procedure may be adopted with help of anthropometric database with respect to race and region.
References


intra-national symposium on Ergonomics in Developing Countries, Jakarta, Indonesia.


