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Research Paper

Scope for design suggestions of hand tool used in performing agricultural activities

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■ **ABSTRACT :** Work related musculoskeletal disorders mostly are major indicating parameter of occupational stress amongst the workers engaged in agricultural field and they are exposed to a combination of risk factors. Controlling of these problems or risks is accomplished by matching workers characteristics/work and workplaces/work tools details in a manner that improves worker's efficiency and productivity while decreasing the worker's risk of injury and discomfort. Keeping this in view a study was carried out to explore the scope for design suggestions for mostly used hand tool in performing selected agricultural activities. Survey was conducted to gather information from the selected households by following Probability Proportionate to Size (PPS) technique from two districts *i.e.*, Jorhat and Karbi Anglong. The study further revealed that Machete was used by the farmers and found that they faced difficulty while using this tool due to handle design. Attempt was made to explore the design modification in the existing handle of the machete. While modifying the handle three parameters *i.e.*, length, diameter and weight of the handle were considered. Accordingly suggestions for design modifications were generated based on ergonomic principles and recommendation suggested by Konz *et al.* (1993). Based on the feedback from the field trials handle length of 15 cm with diameter 4 cm and weight 2.30 kg was found to be very comfortable.

■ **KEY WORDS:** Agricultural activities, Hand tool, Machete, Musculoskeletal disorders, Occupational stress

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Mismatch between man and the tools are one of the main problems contributing to work related problems. Poor design of hand tools and their usage for a long time may cause early hand fatigue and different hand and arm related musculoskeletal injuries. During the use of hand tools, the characteristics of the surface in contact with human hand directly affect the comfort and discomfort of the user (Kuijt-Evers *et al.*, 2004). When a design fulfills design criteria to its inbuilt features, it becomes a good design, relieves the user from harmful contact features, awkward postures and other safety and health risks, finally will be liked to use it. A tool which is not designed by following principles does not fit the hand and the task, injury may be developed. These injuries do not developed because of single event; instead they result from repetitive movements being

performed for a long period of time, force application which in combination may result in damage to muscles, tendons, nerves, ligaments, joints, cartilage, spinal disc, or blood vessels. Kadefors *et al.* (1993) have shown that by improving the compatibility properties of hand tools, the health of users and their job satisfaction might be positively affected. Thus, the design of the hand tools should follow compatibility (ergonomic) principles. To suggest modifications in design of tools, identification of problems for work-related health hazards (body pains and injuries) in using the hand tool is helpful to set priorities for which design issues should be addressed first in work situation. In the process, identification of problems faced by the users that effect on the body parts is first. Next, each problem is evaluated looking into the root causes. This is repeated until common causes for the presence of risk factors are found. In the present study effort was made to study the problems faced by the workers in using the most frequently used hand tool *i.e.*, machete. Machete is a multipurpose cutting tool used for clearing field, cutting bamboo and making strip, wood etc. It is made of mild steel with one side cutting edge and fixed on wooden handle. The sizes of the handles were found varies from household to household because handles were made by farmer themselves following traditional poor design. These handles were made with the available resources like wood, bamboo etc. The present study aimed at modifying one commonly used hand tools, *i.e.* Machete.

The specific objectives of the design development were set:

– To determine the design parameters and specific considerations,

– To finalize the design modification necessary for improving comforts in using machete.

■ RESEARCH METHODS

For the present study multi stage sampling was adopted for selecting the representative sample in order to fulfill the objective of the investigation. Jorhat and Karbi Anglong districts were purposively selected for the study. A total of 120 households were selected by following Probability Proportionate to Size (PPS) technique and there by 60 respondents were selected from each district. The data were collected through personal interview and observation with an interview schedule.

For design finalization following experiment was carried out:

Experimental details (design finalization):

In the whole design devevelopment process participatory approach was adopted. Design parameters considered for modification were circumference/ diameter and length of the handle as suggested by Konz *et al.* (1993).

No. of subjects: 10 farm workers

Replication: 3 numbers

Trial duration: 30 minutes

No. of treatment: 5 (4+1) (Four modified handles, after several trials with different size parameters finally four sizes were selected for final field trials and one existing handle)

Parameters for comparison to evaluate benefits of using modified tools:

Ease of comforts and Grip stress

■ RESEARCH FINDINGS AND DISCUSSION

For exploring the design suggestions for handle of the machetes following factors were considered:

Weight of the tool:

Weight is often a problem with power tools as well as manual tools such as axes, hammers, saw, machete etc. To reduce hand, arm, and shoulder fatigue, the hand tool should not weigh more than 2.3 kg (Ergonomics, 2010). In case of machetes heavy weight was observed due to the blade and handle. Data from the survey revealed that respondents had the problem of weight of the tool was too heavy. In the present study the average weight was found to be 4.30 kg, which ranged from 2.70 kg to 6.5. Highest weight of blade was observed in case of tribal machetes.

Length of the handle:

A short handle can cause unnecessary compression in the middle of the palm and long handle add extra weight. The handle length should be long enough not to compress the median or ulnar nerve at the distal palm or wrist (Johnson, 1993). Length of the handle should extend across the entire breadth of the palm. Tool handles should be not less than 100 mm (4 inch) to reduce the negative effects of any compression exerted. Some researchers

(Konz, 1990 and Johnson, 1993) recommended that 125 mm may be more comfortable. Handles around 120 mm (5 inch) are generally recommended. To provide good control of the tool and prevent pain and pressure, hot spots in the palm of the hand, handles should be at least 120 mm long. Based on the previous findings, it might be concluded that optimum handle length can vary across grip types and task characteristics. In the present study length of the handle was found long by majority of the respondents. Therefore, effort was made to find out the comfortable length of the tool. In the present study the average length was found to be 230 mm, which ranged from 160 mm to 320 mm.

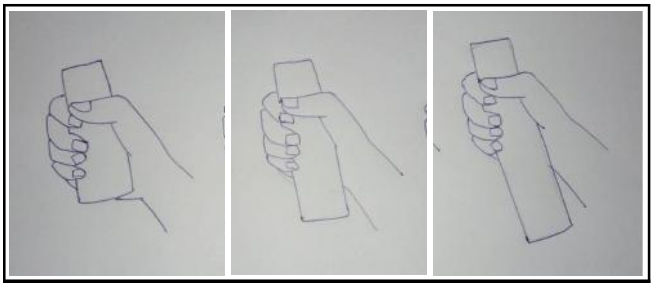

Fig. 1 : Handle length

Diameter of the handle:

A recommendation for handle diameter varies. Numerous previous studies have long considered the effect of handle diameter on the force exertion in use of hand tools. Handle diameter is an important factor that can significantly influence force exertion, torque performance, finger force distribution, joint configuration, stress on the upper extremities, and subjective user's preferences to a hand tool in performing manual work. For the optimum handle diameter for the power grip, Rubarth (1928) recommended 45 mm. However, Ayoub and Lo Presti (1971) reported 38 mm is the most efficient and the least fatiguing in terms of grip force. In general, cylindrical handles at 40mm (1.5 in) offer a better power grip, with a range from 30-50mm (1.25 to 2 in). Replogle (1983) found that 30-50mm is the best for maximum torque.

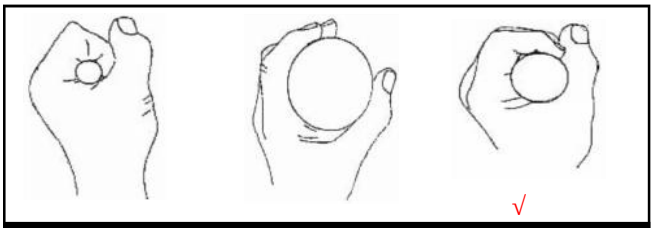

Fig. 2 : Handle diameter

The larger diameter will allow for maximum torque, while the smaller diameter helps with dexterity and speed. Handle diameter can vary with respect to hand size and task characteristics. Many of the respondents face problem with the diameter of their existing handle. The average diameter was found 53.8 mm and the ranges were from 45 mm to 65 mm.

Workers reported discomfort with the hand tool *i.e.* machete, which was found to be used by the respondents from both the areas. Respondents were found using the tool while performing most of the agricultural activities. Effort was made to explore the design specifications to be followed while making handle for machetes. The design modification attempt focussed on developing handles of proper diameter and length to reduce discomfort in using it, thereby increasing the productivity.

To address the research objectives, the following steps were adopted:

Determining the design parameters:

In the process of design modification, design parameters decided were length, diameter and weight of the handle. Accordingly using various length, diameter and weight, handle were developed for field trials to get the users opinion.

Design parameters:

Handle length:

According to the design principles, the length of the handles should be larger than the palm width in order to avoid excessives tissue compression. Keeping this in view handle length was taken. Many of the researcher's suggestion over handle length varies. So handle length of 125mm and 150mm was followed as suggested by Konz *et al.* (1993).

Diameter:

To know the handle diameter, grip circumference of the respondents were taken with the help of paper cone with measurements. Grip circumference of the ten respondents was taken by letting them to hold the cone in such a way that their thumb touches the other fingers comfortably. It was found between the ranges of 30-50mm. After with different sizes finally the measurement considered for field trials are presented in (Table 1).

Table 1: Dimensions of existing and modified Machete handle

Dimensions	Existing handle	Modified handles			
		Handle A	Handles B	Handles C	Handles D
Length of the tool (Including blade and handle)	46 cm	36.5 cm	39 cm	36.5 cm	39 cm
Weight of the tool	3.10kg	2.15kg	2.30 kg	2.25 kg	2.45 kg
Handle weight	155 g	75 g	90 g	85 g	105 g
Handle diameter	4.5 cm	3.5cm	3.5cm	4cm	4 cm
Handle length	22 cm	12.5 cm	15 cm	12.5 cm	15 cm

Weight:

For tool weight, ergonomic guideline was followed. According to the guideline the weight of the tool should not weigh more than 2.3 kg. But average weight of the existing tool was found to be 4.30 kg. Hence, for necessary modifications in weight trials were carried out. For design finalization four weights *i.e.*, 2.30 kg, 2.15 kg, 2.25 kg and 2.45 kg were considered (Table 1).

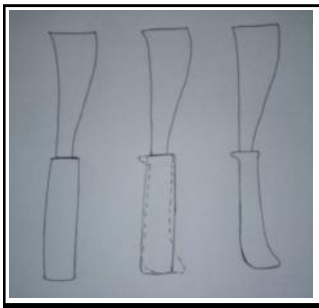

Fig. 3a : Handle design for machete found in tribal area

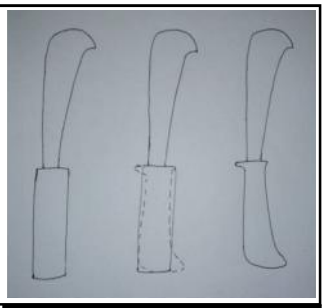

Fig. 3b : Handle design for machete found in non-tribal area

Design finalization:

In this phase, four handles were developed after screening different sizes and shapes for field trials and ergonomically tested on the users. Field trials were conducted to evaluate the tool. For evaluation ease of comfort felt by users was recorded. Grip fatigue was measured by using grip dynamometer. The handle was modified to enhance the work comfort

Participatory approach was followed while designing the tool. Ease of comfort while using the handle was studied by using Borg's scale (Borg, 1970). Grip strength using grip dynamometer was taken before and after the activity with 30 minutes interval. It was repeated after working with each of the four handle.

Ease of comforts while using the modified handle was studied with a 3 point rating scale. Overall comfort/ discomfort felt by the workers while performing agricultural operation was done; the rating scale numerically 1 being very uncomfortable, 2 being the comfortable, and 3 being very comfortable was used.

Handle A Handle B Handle C Handle D

Fig. 4 : Selected handles for field trials

Handle B

Dimension

Length: 150mm

Diameter:35mm

Fig. 5 : Design parameters for suggested handle of machete

Finally, the handle B was found to be comfortable as felt by the workers. Grip fatigue of the selected respondents while performing the activity was found minimum (7.82 %) with handle B in comparison to Handle A (10.89 %), Handle C (14.96 %) and Handle D (15.23 %) presented in Fig. 6.

The final words of design concepts, effectiveness and acceptance come from the end-user; their overall views must be brought into confidence. After the trials

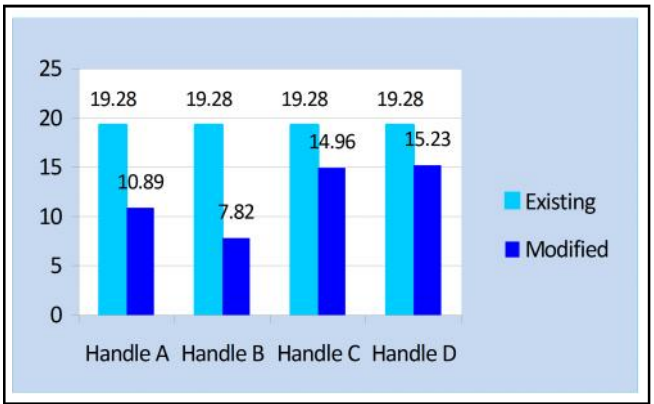

Fig. 6 : Grip fatigue of modified and existing handle

and the evaluation, users valued its positive attributes and had favourably responded to the modified handle B and found the modified handle comfortable, light in weight, and easy for power grip.

Conclusion:

Hand tools can be considered to be an apparatus that compensate for human inadequacies and limitations while performing manual tasks. In the preceding finding, it was observed that machete was commonly used in each and every household but the dimension of the tool varies from house to house, no proper measurement of the handle length and diameter was used. As machete is a manual tool it is a labour intensive and requires force due to the mismatch of the diameter and length of the handle with the user. So by improving the ergonomics and usability of handles, work efficiency, productivity and quality as well as user comfort and safety can be improved. Moreover while using these tools user needs to operate in bending or squatting posture and needs to apply forceful exertion, which cause drudgery and serious health issues such as wrist pain, shoulder pain, back pain, knee pain and sometimes also causes injury. All these problems occur due to improper dimension of the tool and the awkward posture the users assume. The level of comfort and efficiency were seen to be increased while using the modified machete and also health related problems of the users were reduced.

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