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Ergonomic Evaluation and Design Modification of a Traditional Machete for Reducing Drudgery Among Farm Workers

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ABSTRACT

The study was conducted during August, 2022–July 2023 at Jorhat and Karbi Anglong, Assam, India to ergonomically evaluate the traditional machete and develop a modified design to reduce drudgery among farm workers. A total of 120 households from Jorhat and Karbi Anglong districts of Assam were selected using probability proportionate to size (PPS) technique. Four numbers of villages namely Dillaji Mithiphang and Dhansiri from Karbi Anglong district and Titabor and Cinnamora from Jorhat district, were selected randomly for the study. The traditional machetes seen were locally made without any standardization due to which the farm workers suffer many musculoskeletal problems. Data on problems associated with existing machetes were collected through interviews and observations. All the data of the traditional machete like weight of the tool, length of the handle, blade size, circumference of the handle, material of the handle were taken during the observation. The major problems identified were excessive tool weight, improper handle length, uncomfortable handle diameter, poor grip, and inability to achieve an effective power grip. Based on ergonomic guidelines and anthropometric considerations, four modified handle designs were developed and evaluated through participatory field trials involving ten farm workers. Ease of comfort and grip fatigue were assessed using a rating scale and grip dynamometer, respectively. The results revealed that the modified handle provided maximum comfort and minimum grip fatigue. The study revealed that ergonomic modification of machete handles can significantly improve worker comfort, reduce drudgery and enhance operational efficiency in agricultural activities.

KEYWORDS: Ergonomics, machete, drudgery reduction, grip fatigue, agricultural workers

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1. INTRODUCTION

The agriculture sector in India specifically Assam utilizes manual power (Langthasa et al., 2019). Marginal farm workers largely depend on hard manual labour, with mechanization limited to the use of manually operated hand-held equipment (Anonymous, 2022). In traditional agriculture, hand tools play an important role. A hand tool is any tool that is powered by hand rather than a motor. It is used manually. Hand tools have been used since the Stone Age; stones were used for hammering and cutting. During the Bronze Age tools were made by casting the copper and tin alloys. Tools were sharper and harder in bronze than those made of stone. During the Iron Age, iron replaced bronze, and tools became even stronger and more durable (Muller et al., 2022). Ever since humans started to build tools, there was interaction between the humans and the machines. The interaction between man and machines evolved over time. Transition of tools from being craftsman made to factory made started to produce after the industrial revolution (Nardo et al., 2020). This industrialization brought widespread use of tools and machines to the workplace and these have steadily grown in number and complexity since that time. Hand tools have been in use for a very long time and have developed in an almost evolutionary manner. There was no drastic change in the development of agricultural tools till the turn of twentieth century. These hand tools are required to increase productivity and to facilitate workers. Traditional agricultural tools and implements are made up of locally available materials like stone, wood and iron, constructed at local level or standardized factory-made implements. These tools and implements are economical in terms of labour, money and time saving (Beg et al., 2024). Traditional hand tools are easy to operate and it is cheap. Almost all farming communities have common traditional agricultural implements like Sickle, Plough, Spade, Winnower, Khurpa, Bamboo sieve, Weeder, Axe, etc., developed by blacksmiths. Each of these tools and implements are usually used in connection with specific operation in the sequence of agricultural operations; land preparation, sowing, weeding, irrigation, harvesting, post-harvest operations and transportation (Langthasa et al., 2019). Indigenous Tools and implements are considered successful as they are economical, feasible and sustainable. It can spread quickly and easily from one region to another. (Thuijsman et al., 2022; Hainzer et al., 2022).Though the tools and implements are made to assist in work performance but in reality sometimes it creates problems among the users; may be due to improper design features. Considering ergonomics principles in designing hand tools makes possible to produce tools/implements that blend smoothly with a persons' body or action. Ergonomic establishes user friendliness, compatibility between man and his surroundings and articles for his use (Barani and Behbood, 2021). There is growing demand among hand tools users to have ergonomically designed product but there is very little history of application of ergonomic approaches in agricultural equipment design (Khidiya and Bhardwaj, 2012; Jain et. al., 2018; Das, 2023). Traditional handmade tools are needed to be standardized, keeping in mind of worker's comfort, safety and functionality. Proper designing in accordance with the farmers requirements are necessary. Also, there is necessity of ergonomic evaluation and optimization of farm equipments to reduce musculoskeletal disorders (MSDs) and prevent injuries of farm workers (Jirapongsuwan et al., 2023). Keeping this point in mind, the present study was undertaken to ergonomically evaluate the traditional machete and modify the design to reduce drudgery among farm workers.

2. MATERIALS AND METHODS

The study was conducted during August, 2022–July, 2023 at Jorhat and Karbi Anglong district. The study was conducted for 1 year. Personal interview cum observation method was used to collect the data. For the study an interview schedule was used. The data were collected from the respondents by the investigator personally. A total of 120 households were selected from two districts Jorhat and Karbi Anglong by following probability proportionate to size (PPS) technique, 60 from each district.

2.1. Design modifation of commonly used hand tool

The present study aimed at modifying machete, in selected households of Assam. Hand tools couldbe considered to be an apparatus that compensate for human inadequacies and limitations while performing manual tasks. 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 wasa manual tool it was a labour intensive and requiredforce due to the mismatch of the diameter and length of the handle with the worker. So by improving the ergonomics and usability of handles, work efficiency, productivity and quality as well as user comfort and safety couldbe improved (Meagher, 1987).

The specific objectives of the design development were set to determine the design parameters and specific considerations and to finalize the design modification necessary for improving comforts in using machete.

2.2. Design strategies

The design development attempt focused on modifying the existing handtool, machete and developing handles of proper diameter and length. To address the research objectives, the following steps were adopted:determining the design parameters, confirmation of design features by

field trial and design finalization.

2.3. For design finalization following experiment was carried out

2.3.1. 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).

A field trial was conducted to evaluate the performance of the modified hoe handles under actual working conditions. Ten physically fit farm workers, free from any physical disabilities or chronic ailments, were purposively selected from the identified households in Assam. The experiment comprised five treatments, including four modified handles of different dimensions and one existing (traditional) handle used as the control. The four modified handle dimensions were selected after several preliminary trials involving different size parameters to identify the most suitable designs for final evaluation. Each treatment was replicated three times, with each trial lasting 30 min to ensure consistency and reliability of the observations. The benefits of using the modified handles were assessed by comparing the treatments based on ergonomic parameters, namely ease of comfort and grip stress, thereby determining the most ergonomically suitable handle design for farm workers.

2.4. Parameters for ergonomic evaluation

2.4.1. Ease of comforts

Ease of comforts while using the new design parameters i.e., modified handles were studied with a 3 point rating scale. Overall comforts/ discomforts felt by the workers while performing agricultural activities was collected, the rating scale numerically 1 being very uncomfortable, 2 being the comfortable and 3 being very comfortable was used.

2.4.2. Grip fatigue

Worker' grip strength was taken by using grip dynamometer before and after the activity and finally grip fatigue was calculated by using the following :

(Grip strength before the activity-Grip strength after the activity)/Grip strength before the activity)×100

3. RESULTS AND DISCUSSION

Machete, a multipurpose cutting tool used for clearing field, cutting bamboo and making strip, wood etc. It wasmade 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.

3.1. Problems faced while using in mostly used hand tools (Machete)

From the analysis of data it was found that farmers mostly used was machete in their day to day activity. The existing designs of machete available in the area were not standardized. Mostly, the tool was made by local people following traditional ideas. The handle of the machete was made by bamboo or wood. So, to study the problems faced by the users a three-point rating scale with always, sometimes, and never by scoring from 3, 2 and 1 respectively was used. By calculating weighted score and mean score the problems faced by the users and presented in Table 1. From the analysis of data it was found that majority of the respondents felt (with highest mean score of 2.5) length of

Table 1: Distribution of respondents according to problems perceived with the existing design of mostly used hand tools (Machetes)

Sl. No.	Statement	Always (3)	Sometime (2)	Never (1)	Wt. Score	Mean score	Rank
1.	Diameter of the handle is not comfortable	48	43	29	259	2.16	III
2.	Tool is heavy.	82	16	22	300	2.5	I
3.	Length of the handle is long/short	61	26	33	268	2.23	II
4.	Texture (conductive, sharp edges or high spots in the area of the grip)	40	26	54	226	1.88	VII
5.	Material of the handle is slippery.	37	36	47	230	1.916	VI
6.	Not proportion to the body dimension	34	24	62	212	1.76	IX
7.	Grip is not proper due to round shaped handle	42	36	42	240	2	IV
8.	No enlargement of the butt end of the handle	19	43	58	201	1.67	X
9.	Force is needed while using	33	27	60	213	1.77	VIII
10.	Power grip not possible	43	33	44	239	1.99	V

the handle is long, which was followed by heavy weight of the tool (mean score 2.23) and diameter of the handle, not comfortable (with mean score of 2.16).

It can be concluded that weight of the tool was the main problem in the existing tool (rank I) followed by length of the handle (II), diameter of the handle not comfortable (III), round shape of the handle (IV), power grip not possible (V), handle material (VI), texture of the handle (VII), force needed while using existing handle (VIII), not proportion to body dimension (IX) and no enlargement of the butt end of the handle (X).Moreover while using these tools user neededto operate in bending or squatting posture and neededto apply forceful exertion, which caused drudgery and serious health issues such as wrist pain, shoulder pain, back pain, knee pain and sometimes also caused injury (Khadatkar et al., 2022). All these problems occured due to improper dimension of the tool and the awkward posture the users assume.

From the discussions it couldbe concluded that problems were being reported by the workers. Analyzing the findings, design related problems like improper handle length and diameter, and heavy weight, etc. came into foreface; due to these problems it was found that workers have discomforts like fatigue muscles, tingling in the finger muscles, swelling in the joints, pain in fingers, shoulder, wrist and other body parts, along with work related problems in studied agricultural field activities of Assam. Therefore, scope for design modification was explored and attempt had been made to modify the existing design of machete.

2.1. Design suggestions for machete

In the process of design suggestion, emphasis was put on to redesigning of handle of machetes. Researchers have recommended some factors to be considered while designing handle. While exploring the design suggestions for handle of the machetes following factors were considered.

2.1.1. Weight of the tool

Weight wasoften 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 (Anonymous, 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 kg.

2.1.2. Length of the handle

A short handle couldcause 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 in) to reduce the negative effects of any compression exerted. Some researchers (Konz, 1990; Johnson, 1993) recommended that 125 mm mightbe more comfortable. Handles around 120 mm (5 inch) weregenerally 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 couldvary 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 (Figure 1). In the present study the average length was found to be 230 mm, which ranged from 160 mm to 320 mm.

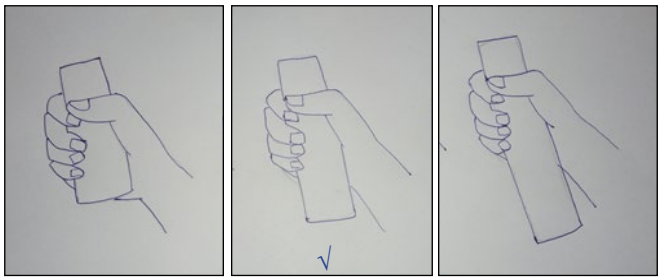


Figure 1: Handle length

2.1.3. Diameter of the handle

A recommendation for handle diameter varied. Numerous previous studies have long considered the effect of handle diameter on the force exertion in use of hand tools. Handle diameter wasan important factor that couldsignificantly 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, Seo and Armstrong (2008) recommended 45 mm. However, Ayoub and Lo Presti (1971) reported 38 mm wasthe most efficient and the least fatiguing in terms of grip force (Figure 2). In general, cylindrical handles at 40 mm (1.5 in) offered a better power grip, with a range from 30–50 mm (1.25 to 2 in). Replogle

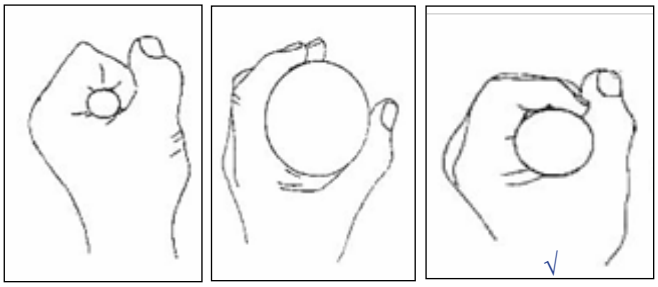


Figure 2: Handle diameter

(1983) found that 30–50 mm wasthe best for maximum torque.

The larger diameter wouldallow for maximum torque, while the smaller diameter helpedwith dexterity and speed. Handle diameter couldvary with respect to hand size and task characteristics. Many of the respondents faced 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.

2.1.4. Handle shape

Handle shape wasan important consideration affecting wrist and arm postures. For easy grip handle shape should be slightly contoured. In nature, the handle with circular cross sectional shape was found to provide the greatest torque (Seo et al., 2008). Handles should be cylindrical or oval in shape. For a power grip task, the handle shape should maximize the contact area between the palm and the handle so as to distribute pressure. While using machete the user needs to have power grip. So flat shaped was considered while exploring for design modifications.

2.1.5. Power grip not possible

Tools should be designed so they couldbe held using a power grip. There should be a large area of contact, with no spots of local high pressure to prevent strength of grip being inhibited by discomfort. In holding a handle firmly in this kind of grip, movements arc carried out by the powerful muscles of the forearm, upper arm and shoulder, and not by the fine and delicate muscles in the palm of the hand. A power grip requiredthe operator to align the fingers such that they work in conjunction with, rather than against, each other to maximize the hand capacity. For the power grip, the length should be at least 10 to 15 cm to fit the width of the palm. The length of the shaft of the tool has to be determined for each work situation. Thickness allowedthe thumb to just cover the end of the index and middle fingers. For maximum power in an adult male, it should be 3 or 4 cm. in diameter (Drury, 1980).

2.1.6. Materials and texture of handles

Grip surface/texture/materials wereanother important factor of handle designs since they have a profound effect on the local pressure produced at the hand (Sperling et al., 1993). Perceived pain and discomfort caused by high local external pressure generally couldreduce both the efficiency of the work and the user satisfaction with the tool (Fraser, 1980) Non-slip surface such as adhesive tape and suede wasnot always good since it mightabrade the hand skin and hinder hand positioning (Drury, 1980). Fellows and Freivalds (1991) reported that a foam rubber grip resulted in better subjective measure of hand/forearm fatigue and hand tenderness than wood grip. Handles should be made of non-slip, non-conductive and compressible materials. Glossy coatings and highly polished handles should be avoided.

2.1.7. Not proportion to the body dimension

Handles should be in proportion with the blade of the tool. It should be such that it couldbe balanced with a tip of the finger. Handles should be located at or above the centre of gravity of the load. Also it should match with the user's body dimension.

2.1.8. No enlargement of the butt end of the handle

Handle shape should be such that the butt end of the handle wasenlarged to avoid slippage while working which would occur with momentary relaxation of grip. It was necessary to prevent from the slippage and accident.

2.2. Design strategies followed

Workers reported discomfort with the machete, which was found to be used by the respondents. 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.The specific objectives of the design modification were to determine the appropriate design parameters and key ergonomic considerations, evaluate their utility through preliminary trials, and finalize the design features required to improve user comfort. To achieve these objectives, a systematic approach was adopted, which involved determining the design parameters, validating the proposed design features through preliminary trials, and finalizing the modified design based on the trial outcomes.

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.

2.2.1. Design parameters

2.2.1.1. 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 125 mm and 150 mm was followed as suggested by Kadefors et al. (1993).

2.2.1.2. 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 30–50 mm. After with different sizes finally the measurement considered for field trials werepresented in (Table 2).

2.2.1.3. 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, 2.15, 2.25 and 2.45 kg were considered (Table 2). Also, the handle was designed as shown in Figure 3 (a) and 3(b). The bottom of the handle was designed in such a way that it will not get slip while working.

Table 2: 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	3.10 kg	2.15 kg	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	3.5 cm	3.5 cm	4 cm	4 cm
Handle length	22 cm	12.5 cm	15 cm	12.5 cm	15 cm

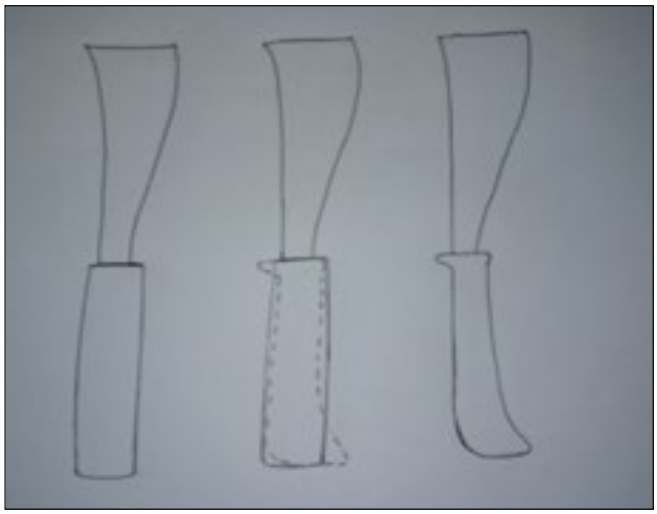


Figure 3 (a): Handle design for machete found in tribal area

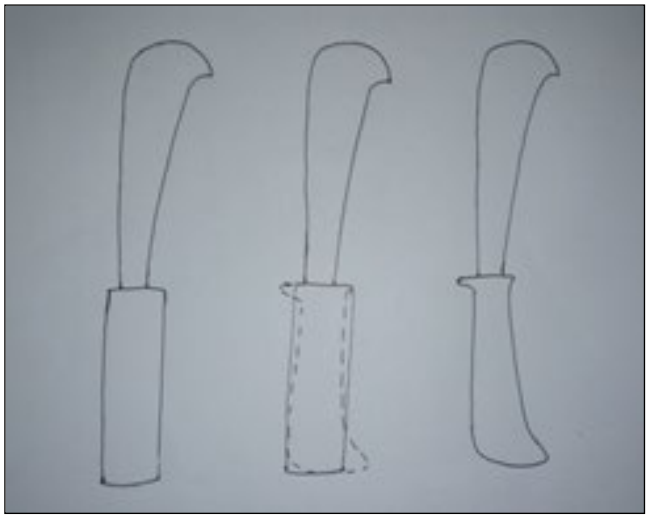


Figure 3 (b): Handle design for machete found in non-tribal area

2.3. Design finalization

In this phase, four handles were developed after screening different sizes and shapes for field trials and ergonomically tested on the users (Figure 4). 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 min interval. It was repeated after working with each of the four handle.



Handle A Handle B Handle C Handle D

Figure 4: Selected handles for field trials

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.

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 with handle B (Figure 5 and Figure 6).



Figure 5: Design parameters for suggested handle of machete; Handle B, Dimension Length: 150 mm, Diameter: 35 mm

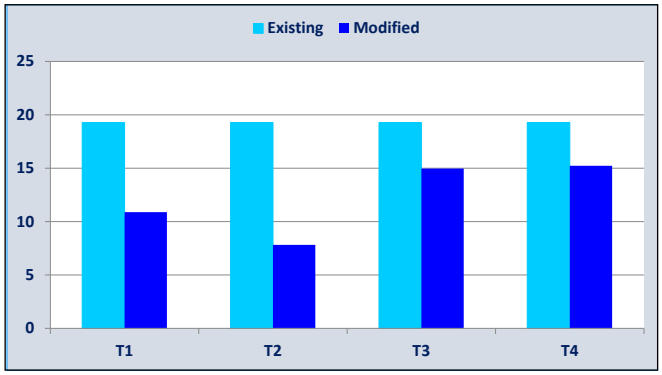


Figure 6: Grip fatigue of modified and existing handle

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

4. CONCLUSION

The traditional machetes commonly used by farmers in Assam were not ergonomically designed and varied considerably in handle dimensions and weight. Based on ergonomic principles and user feedback, modified machete handles were developed and evaluated through field trials. The modified handle reduced grip fatigue, improved comfort, facilitated a better power grip, and was highly accepted by users. The findings indicated that ergonomic intervention effectively reduced drudgery and improved the health, safety and productivity of farm workers.

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