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Bell Metal Industry Workers in Assam Using Hand Tool-Hammer: An Intervention Study

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ABSTRACT

Hand tools are the traditional basic tools used by workers in Bell Metal Industry. The current research was undertaken to study the occupational problems related to the hand tools used by these workers from the districts of Assam. A descriptive survey was conducted on 30 male artisans involved in forging activity using an interview and questionnaire tool; in order to know the hand tool design related problems. The intervention study was carried out for five parameters of the tool-hammer for redesigning: rough finish, weight of tool, contact point stress, handle length, and force exerted while using the tool. Based on the design problems in the existing hammer, 2 prototypes were developed and tested. The McNemar test further supported that the new prototype design I and II were better and significantly reduced the problems associated with the existing hammer design.

Keywords: Hand Tools, Bell Metal Industry, Forging, Polishing, Hammer.

1.INTRODUCTION

In a large number of industrial occupations, hand tools are primary tools **(Motamedzade et al., 2007)**. Different hand tools are being used by people over a million of years but the design of the hand tools remains almost the same as in the past **(Haapalainen et al., 2000 cited Sharma et al., 2016)**. Today there are two general classes of hand tools: human powered (manual) and externally powered **(Aghazadeh & Mital, 1987).** Over the years, much effort and research has been developed to the exploration and understanding of the interrelationship between human capability performance and hand tool design in order to ensure that hand tools are used more effectively, accurately, comfortably and safely **(Kumar et al., 2014)**. Knowledge about pressure perception is important when designing hand tools. Discomfort or pain in the hand could lead to decreased precision, concentration and motivation **(Johansson et al., 2014).** The use of hand tools (like screwdrivers, pliers and scrapers) frequently leads to feeling of discomfort during work **(Evers et al., 2004).** In the same study it was cited that there is reduction in job satisfaction and efficiency of the workers. **(Fellows & Freivalds, 1991 cited in Evers et al., 2004)**. On a longer term, the use of hand tools can cause musculoskeletal disorders. **(Aghazadeh et al., 1987., Chao et al., 2000 & Evers et al., 2004)**. Since the shape of the tool handle will affect the posture used to hold it, the shape of the handle is a primary factor which can be used to reduce or eliminate fatigue in the user. **(Winston & Narayan., 1993 cited in Motamedzade et al., 2007)**. Proper grip size and diameter of the hand tools improves the efficiency of work **(Vink et al., 2005 & Haque, 2018)**. Extensive uses of hand tools lead to pains and aches of muscles. Injuries during work are one of the most important but preventable and modifiable occupational safety and health issues. **(Nakata et al., 2006 cited in Bharwana et al., 2015).** Previous studies have shown that in many occupations, some of the major causes of work-related disorders and diseases are linked to the use of hand tools **(Motamedzade et al., 2007)**. Ergonomic design hand tools reduce the risk of occupational disorder in upper limbs **(Haque, 2018).** Functionality, reliability, quality and comfortability are needed to be considered while designing hand tools; as any type of discomfort when using hand tools for a longer period of time may lead to musculoskeletal disorders thereby decreasing worker's productivity.

Bell metal industries in Assam is one such industry where still traditional hand tools are used to make traditional utensils and decorative articles manually. The hand tools used by the artisans are traditional hammer in different sizes, tongs and chisels. The tools are used for activities like forging, polishing, shearing, welding and cleaning. All these activities are carried out manually in sitting posture. Few studies have been reported but still the problems related to tool design and comfort persists. Hence, the present research investigates the problem related to hand tools ie., Hammer which is widely used in forging activity for giving shape to the articles and utensils in the Bell Metal Industry. Secondly aim of the study was to conduct an intervention program for 2 prototypes of long handled hand held hammer used in forging activity.

2.METHODS

2.1 Study Design: The study is a descriptive investigative study. It was conducted in Barpeta district of Assam. The reason for carrying out the research in this area was that the majority of men from this village were engaged in making bell metal articles and utensils.

2.2 Participants: A total of 30 male artisans engaged in forging activity, aged 22-50 years participated in study from Barpeta district of Assam. The participants had working experience for 2-37 years. The workers worked for 8–10 hours per day for seven days a week. These artisans were involved in only forging activity where they give shapes to the utensils or decorative articles after heating with a hammer. They worked in unhygienic, small areas outside their home with traditional tools purchased from the local market for years together.

There are in all five activities carried out by the bell metal workers; forging, polishing, shearing, welding and cleaning. But for the current study only forging activities and hand tools (long hammer) used for forging were studied.

2.3 Descriptions of forging activity and tools used: In forging activity, the artisans used different types of hammers for beating and shaping metal sheets to produce objects or utensils. This percussive tool has two parts: a weighted fixed head and a handle. Materials used for the hammer were iron for the head and bamboo for the handle.

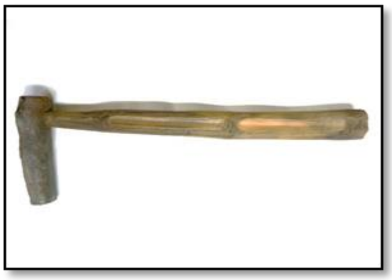
Tools used in Forging Activities		
		
A. Large Size Hammer	B. Medium Size Hammer	C. Small Size Hammer
Posture adopted to shape the utensils		
		
A. Hammering heated metal sheet to give shape	B. Hammering heated metal bowl to give shape	C. Finishing by using small hammer

Figure 1. Forging activities carried out using hammer

2.4 Data Collection: The data was collected in two phases as described below:

Phase-I: It included the survey of the area and getting permission from the Ministry of Labour, Assam. Then the artisans were selected using convenient sampling from Barpeta district and their consent to participate in study was taken. First stage of data collection included observation of workers followed by their Interview.

Observation and Structured Interview:

An observation was done to study their conditions of work environment, work activities performed, tools used and their work posture while carrying out forging activity for bell metal articles and utensils. Videos and photographs were taken to get the details of activities carried out during one complete cycle of forging activity using various tools and techniques and posture adopted.

Structured interviews were conducted to gather general cum work related information of the workers like types and number of work activities carried throughout the day; problems associated with hand tools; tools requiring redesigning, etc.

Phase-II: Survey using Questionnaire

Questionnaire: Based on the phase 1 data obtained, a questionnaire was developed to get information from the artisans. Questionnaire had two sections:

a. General and Personal Information – Here the information related to age, educational qualification, marital status, years of experience, personal habits were included
b. Hand tools and problems related to their usage- this section included questions on types of hand tools used while performing different activities, problems associated with the hand tools (feel and fit of tool) and design suggestions for tools and handles.

Phase-III: Intervention Study

The intervention programme was carried out for long hammer design as it had maximum problems and workers wanted change in the existing design. For this purpose, two prototypes of long hammer were designed and tested. Five parameters of the tool considered for redesigning the hammer were: rough finish, weight of tool, contact point stress, handle length, and force exerted while using the tool.

- **Prototype Design**

Dimensions of Existing Round Shaped Hammer: The shape of the existing hammer was round shape with handle made from bamboo. Weight of Hammer: 2.0 kg, Handle length: 58 cm, diameter of handle: 4.2 cm. Hammer (head) length: 14.5 cm and diameter: 4.5 cm.

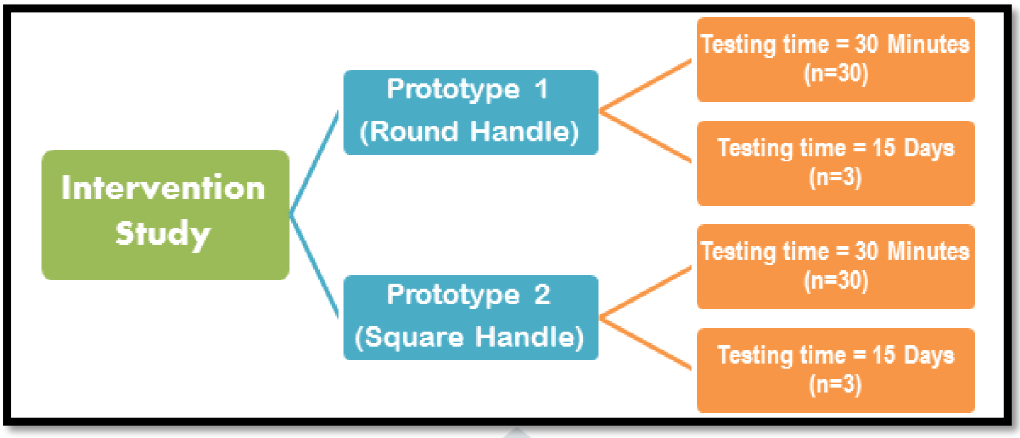
Based on the problems faced in the present design, the prototype was designed considering the workers suggestion, that their tools need to have less rough finish, should be light in weight, should have no contact point stress, handle length should be slightly reduced, and less force should be exerted while using the tool.

Prototype - I (Round Shaped Hammer): The round shaped hammerhead has been designed keeping in mind the design of the sledge hammer. Weight of Hammer: 1.35kg, Handle length: 55cm, diameter of handle: 3.4cm. Hammer (head) length: 10.9 cm and diameter: 3.7cm.

Prototype - II (Square Shaped Hammer): The square shaped hammer has been designed keeping in mind the design of the locksmith hammer. Weight of Hammer: 1.27 kg, Handle length: 55cm and diameter of handle: 3.1 cm. Hammer (head) length: 14 cm Head (square) length: 3.5cm and breadth: 3.2 cm.

Existing Tool (Large Hammer)	Prototype 1 (Round Head Hammer)	Prototype 2 (Square Head Hammer)
		

2.5 Sample : All workers were given both the Prototype of hammer for testing for half an hour (30 minutes) respectively. Further both the Prototype was given to 3 workers each to test it for 15 days. Statistical analysis has been done for Prototype I and II of hammer.



2.6 Data Analysis

The data was analysed using the Descriptive statistics method. The data was analysed for frequency, percentages and standard deviation. The tables and graphs were made. SPSS Version 20.0 was used for pre and post intervention testing of 2 prototypes of long hammer design I (Round Head) and II (Square Head).

1. Pre- and Post- measures are workers experience with respect to each quality of the tool - (With Two levels : Yes, No)
2. Sample : Non Probability (Judgment Sampling)
3. Significance level (α): This was set at 0.05. That is the result will be treated as significant if the obtained p-value is <0.05.
4. McNemar Test is the most appropriate test to judge the significance in the difference of Pre and Post responses.

3. RESULTS AND DISCUSSIONS

Table 3.1. shows the personal characteristics of male artisans doing forging activity. The mean age of the artisans was 36.27 years; average height was 163.57 cms; average weight was 65.67 kg and mean years of experience was 15 years respectively. 56.67% had primary education, 20% were SSC, and 23.33% were HSC pass. With respect to personal habits; 46.67% of artisans were involved in smoking, 40% in tobacco chewing and 10% in consumption of alcohol.

Table 3.1: Personal Characteristics of the artisans doing Forging activity (n= 30)

Demographic Parameters	Mean ± SD	Range
Age (Years)	36.27 ± 8.66	22 - 50
Heights (Cm)	163.57 ± 4.88	153.4 - 172.7
Weight (Kg)	65.67 ± 9.30	49 - 93
Years of Experience (Years)	15 ± 8.86	02 - 37

General and MSD Problems among the Workers

The majority of forging activity workers experienced general health problems like muscle cramp (76.67%), numbness in fingers (33.33%) and cuts/bruises, sore muscles, swelling in wrist (30.00%); 23.3% reported tingling, knee bursitis, cumulative trauma disorder and few had hardening of palm and inflamed skin.

The results of MSD problems showed that the majority of them felt maximal discomfort in the lower back 76.67%, upper back 66.67% and neck 36.67%. 46.67% reported severe discomfort in shoulder and elbow 40.00%. Moderate discomfort in neck and elbow 36.67% in the upper extremity and minimal discomfort in calf 43.33%, thighs/hips and knees 36.67% was reported by majority of workers.

Thus, as there were problems with hand tools there was a need to modify the hand tool using ergonomics principles that will improve efficiency in productivity and reduction in MSD problems.

Comparison of responses of 30 workers using existing hammer design and prototype I & II for the duration of 30 minutes

Table 2 shows the responses of the 30 workers (using the existing hammer and using the newly designed prototype (I & II) for 30 minutes each.

Results of the existing long handled hammer used for forging indicated that only 37% workers responded that more force was needed to be exerted while using the hammer.

Whereas, around 50-60% workers felt that the hammer 'handle diameter was not comfortable', 'finger grip uncomfortable', 'needed more pressure to operate', 'fit in hand was not good', 'size of the handle was not comfortable' and 'handle too hard'.

Approximately, 67-73 % of workers reported the 'shape of the handle not good', 'contact point stress created at handle' and 'tool is heavy in weight'.

Lastly, more than 80 % of the workers complained that the existing Handle Length was long and the handle finish was rough.

Results of the long-handled hammer prototype (I and II) used for forging revealed that more than 80 % of the workers rated that 'Less Force exerted from tool' 'Handle diameter comfortable', 'Finger grip comfortable', 'Need less pressure to operate', 'Good fit in hand', 'Comfortable size of the Handle', 'Good shape of the handle', 'No Contact point stress at handle' and 'Tool is Light in Weight'. Very importantly, less than 15% of workers only reported problems with 'Big Handle Length', 'rough Finish Handle' and 'Handle too hard'. Thus clearly indicating that the new prototype design I and II were overall better and were successful in reducing the problems associated with the existing hammer design.

Table 3.2. Responses of artisans using existing hammer and the newly designed Prototype I & II (Testing time - 30 minutes each)

Design and Function aspect of Tool (n=30)	Existing Hammer				Prototype 1 (Round Head Hammer)		Prototype 2 (Square Head Hammer)	
	Frequency for Yes	%	Frequency for No	%	Frequency for Yes	%	Frequency for Yes	%
Positive aspects of the tools - needs to be maintained or increased								
Less Force exerted from tool	19	63.3	11	36.7	28	93.3	25	83.3

Handle diameter comfortable	15	50.0	15	50.0	27	90.0	26	86.7
Finger grip comfortable	13	43.3	17	56.7	25	83.3	26	86.7
Need less pressure to operate	13	43.3	17	56.7	26	86.7	26	86.7
Good fit in hand	12	40.0	18	**60.0**	27	90.0	28	93.3
Comfortable size of the Handle	12	40.0	18	**60.0**	26	86.7	26	86.7
Good shape of the handle	9	30.0	21	**70.0**	25	83.3	25	83.3
No Contact point stress at handle	9	30.0	21	**70.0**	27	90.0	27	90.0
Tool is Light in Weight	8	26.7	22	**73.3**	28	93.3	29	96.7
Negative aspects of Hammer - needs to be modified or reduced								
Big Handle Length	25	**83.3**	5	16.7	4	13.3	4	13.3
Rough Finish Handle	24	**80.0**	6	20.0	1	3.3	1	3.3
Handle too hard	17	**56.7**	13	43.3	4	13.3	4	13.3
Friction between hand and handle	9	30.0	21	70.0	2	6.7	2	6.7
Sharp edges of the handle	8	26.7	22	73.3	1	3.3	1	3.3

Comparison of existing hammer design with prototype I & II on five tool design parameters using McNemar test (Table 3.3)

The McNemar test results associated with the binomial cross-table are statistically significant (Exact p-value (2-sided) < 0.05) for Rough Finish of Handle, Tool Light Weight, No Contact Point Stress and Big Handle Length. Thus indicating that the distribution of percentage of workers in pre-tool for rough finish of handle, tool light weight, no contact point stress and big handle length differs significantly from that on the post-tool perception with the workers feeling more comfortable in handling the new hammer (prototype 1 and 2) since roughness of the handle, tool weight, contact point stress and big handle length is reduced. In general, the present study supported the fact that the use of round or squared shape hammer head relieved workers from the problem of "rough finish" "tool weight", "contact point stress" and "big handle length".

With respect to 'Force Exerted', the round shape hammer head relieved workers from the problem, but the experience of workers with respect to less force exerted from the square hammer head was not significant. Hence, further improvement is required in prototype 2 for this parameter.

Table 3.3. P-values of pre post intervention study using McNemar test results associated with the binomial cross-table

Comparison of existing design with Prototype on following parameters	p-value obtained from Pre & Post Test		Remark
	Prototype-I Round Head	Prototype-II Square Head	
Rough Finish handle	.000*	.000*	Results are significantly different as p<0.05, indicating that new prototype was able to relieve workers with problems associated to rough handle
Tool Light Weight	.000*	.000*	Results are significantly different as p<0.05, indicating that new prototype was able to relieve workers with heavy weight of the tool
No Contact Point Stress	.000*	.000*	Results are significantly different as p<0.05, indicating that new prototype was able to relieve workers with problems associated to Contact Point Stress
Big Handle Length	.000*	.000*	Results are significantly different as p<0.05, indicating that new prototype was able to relieve workers with problems associated with long handle length
Less Force Exerted	.012*	.109	Results for the round shape head was significant, but for square shape handle it was not significantly different as p>0.05, indicating that square shape head hammer was not able to relieve workers with problems associated with force exertion while hammering.

*** Indicates that the values are statistically significant with p<0.05. Level of significance was set at 0.05.**

Table 3.4. Subjective responses of 3 workers on Prototype I & II of long handle Hammer after using it for 15 days each for forging activity.

Design Parameter	Design Consideration	Design Solutions (Prototype -I and II)	Remarks
Positive aspects of the tools - Maintained or increased with new Prototype design			
Less Force exerted	Around 37% of workers said that more force needed to be exerted from the tool.	As the new prototypes weight was reduced, therefore force exerted was reduced considerably.	Prototype-I: All subjects felt force exerted was reduced. Prototype-II: One of the subjects felt no reduction in force exerted because of the square shape of the hammer head. Other two subjects felt force exertion was reduced.

No Contact point stress	70% of workers said that there was contact point stress of handle	In the new prototype's contact point stress was reduced by smoothing the handle and to have good grip groves were given at regular intervals of one inch till 30cms of handle.	All subjects felt no stress after reduction
Light Weight of Tool	73% of workers said that tool was not light in weight. The standardised tool weight is unavailable. and Existing Long handle hammer weight is 2.0 kg on an average	In the new prototypes the weight of the large hammer was reduced. The weight of iron head of large hammer was reduced to 1 kg and weight of wooden handle was approximately half kg Prototype -1: 1.35 kg approx. Prototype -2: 1.27 kg approx.	All subjects were comfortable with the new weight of a large hammer and they felt that weight was reduced.
Negative aspects of Hammer - Modified or reduced with new Prototype design			
Long Handle length	83.33% workers said that the handle length of the existing hammer was long. Average length of handle: 58 cm.	In new prototype's the length of the handle was reduced to 55 cm. Reduction of handle was difficult because a certain amount of length they need for the task and they don't have proper standards which can be considered while designing.	All subjects were comfortable with new length.
Rough finish of handle	80.00% workers said the finish of the existing large hammer was rough.	In the new prototypes roughness of handle was reduced by smoothing handle and replacement of cane or bamboo handle by wood.	All subjects were comfortable with the new design.
Overall, Tool Rating			
Overall Design of long handle Hammer tool	Overall view of design was subjective.	All the changed features in prototype's were rated good by the workers.	Prototype-I: All subjects said good design. Prototype-II: One subject rated average and other two said good design.

Table 3.4 shows the responses of the workers with respect to new prototypes designed after testing for 15 days with both the designs. The workers reported reduction in weight of the tool and force required, they were comfortable with length of the handle as it reduced the contact point stress. Overall, all the 3 subjects rated new design as good and comfortable for prototype-I; whereas one subject felt prototype -II as average design. But these responses are based on subjective responses of three workers only; the results may differ when tested on larger number of subjects.

4. DISCUSSION

In the Bell Metal Industry, the artisans make articles and utensils using processes like Shearing, Forging, Soldering, Polishing and Cleaning; where several hand tools like Hammers, Tongs, Chisel's and Scissors were used. For the present study a long-handled hammer used in the forging process was studied and evaluated by designing 2 prototypes for intervention. These hammers have handles mostly made from wooden materials, bamboo, cane or iron. The most influencing design criteria in hammer design for forging activity was too much stress at contact point of hand and handle, rough finish of handle, handle too hard and uncomfortable handle diameter. **Haque (2018**) conducted a similar study on ergonomic design of hammer handle to reduce musculoskeletal disorders of carpenters in different areas of Bangladesh. They focused on certain important aspects of hammer used in occupational work situations with emphasis on comfort or discomfort in using hammer according to users. 47% carpenters wanted redesigning of the existing hammer as they were not comfortable. A new multipurpose hammer was designed which was found to be comfortable. A similar study on ergonomic design of hand tools - screwdriver for Indian workers using a comfort predictor was conducted where the handle of the screwdriver was modified by giving more torque than conventional handle and found higher working efficiency. (**Arunesh and Pankaj, 2011). Parvez and Shahriar (2018)** conducted a study on agricultural farm-related injuries in Bangladesh and Convenient Design of working hand tools. It was found that 67% of agricultural injuries occurred due to hand tools and most significant injuries being cuts on the limbs, blisters on palm skin due to high stress on hand, tools slippage from hand and so on. Improper handle dimensions lead to high stress and injury at work and sometimes resulted in workers' physical disability. It was recommended that to achieve better productivity along with better safety, tools must be redesigned and suitable for the workers. In another study **Chang (1998)** analysed the ergonomic evaluation on three different handles of garden tools made of wood, solid fiber-glass and hollow fiberglass. The hollow fiberglass handle was 12% more efficient than either the wood handle or the solid fiberglass handle. The hollow fiberglass handle was half smooth and the other half ribbed. This ribbed surface increased the control of the tool as it prevented the hand from slipping during work. Further, the garden tools with novel fiberglass handles instead of traditional wood handles were tested to evaluate the effects of handle types on ergonomic effectiveness, user satisfaction and subjective judgement of tactile feel and control. Similarly, **Kim (2012)** studied the effect of ergonomic design changes in hand tools on physiological cost and subjective ratings on four types of hand hacksaws. The results showed that before the tests, ergonomically reconfigured hacksaws received better rating scores than original hacksaws; however, there were no differences in subjective ratings of the hacksaws after the tests. **Eikhout (2001)** evaluated a new scraper and results showed that the new scraper, in comparison with the traditional one has strong positive effects on physical load, wrist flexion, extension, radial deviation and force are reduced. **Motamedzade et al., (2007)** designed and redesigned the weaving comb, knife and scissors as the most common tools in carpet weaving operation. Three prototypes of the hand tools were made and a usability test was conducted to assess comfort and applicability of the designed hand tools and weavers' perceptions. The new ergonomically designed weaving hand tools were found to be applicable and acceptable for the carpet weavers, however the author felt that further appropriate revisions to the ergonomically designed tools based on quantitative measures of musculoskeletal loading should be considered. **Meena, Dangayach and Bhardwaj (2015)** in the textile printing handicraft industry found most of the workers working with existing hand block tools were not comfortable. To provide a comfortable rounded handle of the hand block tool in particular, the profile was recommended. The handle of the existing tool was flat, causing wrists strain due to bending and twisting of wrist. The new block tool improved comfort level by 42.69% and production rate by 29.62% and RULA scores for arm and wrist improved from 5 to 3. **Chakrabarti and Bhattachheriya (2012)** in intervention strategy for work tools development for women agro-based workers in northeast India found that mostly workers themselves manage work tools of their own with available local resources. **Sengupta and Latta (2012)** studied the Grip Design for Manual Hammer Stapling Tool. Experimental design was conducted on 16 male students. The grip design features of hammer stapling tools available in the retail market were evaluated in terms of grip comfort, safety, usability, wrist angle and muscle activity. Three tool models with distinctly different grip design were selected for the evaluation and found that smooth and rounded shaped grip would improve grip comfort than hard, serrated less rounded shaped grip. Slight change in bent of the handle, compressible foam rubber grip made the tool comfortable. **Kuijt-Evers et al., (2004)** studied the underlying factors of comfort and discomfort in using hand tools with respect to the user. Two studies were carried out; first pre-study where all possible descriptors of comfort and discomfort were collected and in second study the relationship between the descriptors and comfort using hand tools was studied. The author suggested optimization of the functionality and physical interaction to reduce discomfort in using hand tools. The author has concluded that the same descriptors were related to comfort and discomfort in using hand tools, descriptors of functionality are most related to comfort in using hand tools followed by descriptors of physical interaction and descriptors of appearance become secondary in comfort in using hand tools. A case study was also conducted on Surgeons for precision tools where the palm measurement was measured. (**González. et al., 2018)**. **Gangopadhyay et al., (2006)** in a study on MSD problems among brass metal workers in West

Bengal, India found that most of them felt pain, followed by tingling, numbness in their hands, swelling, warmth and tenderness in their wrists. They concluded that the main reason for MSD in the upper limb could be the repetitive nature of the job, less handgrip strength and long working hours. **Bharwana et al., (2015)** in a study on work related injuries in small scale metal press industries of Shahdrah town, Lahore, Pakistan, showed that the one of the major causes of the occupational injuries includes lack of knowledge, poor tools and equipment, poor maintenance and mismanagement. **Shah and Patel, 2017** found that 80% of people face problems due to less education, inability to use advanced machines and equipment and lack of information about exports.

5. CONCLUSIONS

In the present study, the two prototypes of long hammer for forging activity were designed and tested; were found comfortable for the workers with improvement in design, finish, weight and length of the handle. Prototype of improved and modified design, good quality and better finished hand tools instead of traditional tools should be designed and tested for functionality with respect to comfort and discomfort. Hence, using an ergonomics approach in designing hand tools, the functions like sizes, weight, force needed, length and grip needs to be considered along with aesthetic appeal of the tools is also essential. Further work is needed for the development of tools with detailed procedure of design and test on a larger number of workers for better comfort and productivity.

LIMITATIONS OF THE STUDY

Due to time constraint the intervention could be conducted only on 3 subjects for 15 days with each prototype I and II. Therefore, this needs to be further tested on more workers for a substantial period for better results.

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