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Ergonomic design of hammer handle to reduce musculoskeletal disorders of carpenters

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Abstract
The musculoskeletal disorders (MSDs) are the most common work-related health problems in Bangladesh, affecting thousands of carpenters. Typically, musculoskeletal disorders affect the elbow, neck, shoulders and wrist pain during wooden work. The aim of this paper is to focus on certain important aspects of hammer use in occupational work situations, with an emphasis on comfort or discomfort in using hammer according to users. The study concluded that it was necessary to redesign the hammer to reduce the musculoskeletal disorders. Anthropometric data of 300 male carpenters (age: 45.23±11.65 years) in South-Western districts of Bangladesh were measured. The ergonomically designed multipurpose hammer reduces the musculoskeletal disorders mainly wrist pain 87% to 72%.

Keywords: hand tools, anthropomentry, musculoskeletal disorders, handle and power grip

1. Introduction

A hammer is a simple force amplifier that works by converting mechanical work into kinetic energy and back [1]. Existing non-powered traditional hammer contains a head and a handle, which can be fixed together by a special wedge or by glue, or both. This construction is often used to combine a compressed metallic striking head with a non-metallic shock absorbing handle to reduce user fatigue from repeated strikes [2-4]. Hammer is one kind of the best hand tool which todays used for various function of household, machinery and industrial works [5]. Hammer is one of the most important hand tool used in carpentry. But an improper designed hammer may cause significant musculoskeletal disorders (MSDs) [6]. Musculoskeletal disorders (MSDs) are currently most critical problems faced by the ergonomists in the workplace [7]. Workplace injuries are extremely severe in these types of industries. Poor working conditions and the absence of workers have resulted in a very high incidence of MSDs [8]. Ergonomically designed hand tools reduce the risk of occupational disorders of the upper limbs. They also provide comfortable work for the workers and give high production rate [9]. Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, Principles, data and methods to design in order to optimize human well-being and overall system performance [10]. Several researchers designed some non-powered tools such as shovel, hammer, screw driver etc. In that case they were focused on the comfort and discomfort issues based on some parameter [11-17]. Grip size and diameter is important parameter to design a hand tool. Proper gripping improves the efficiency of the wooden work [18]. This study was focused on hammer handle related injuries in traditional carpentry or wooden work and controlling the rate of injury through ergonomic study and designing new multi-purpose hammer. In this study authors are trying to prevent the ergonomic discomforts and injuries mainly wrist pain which occurs most of the time using traditional hammer.

2. Methodology

A. Material and Methods

The study was conducted during 20th August 2017 to 20th October 2017 in different areas of Bangladesh. In this study, there were 300 carpenter's respondents. All of them were willing to participate in this study. A survey was conducted on the types of hammers were used in Carpentry work. Following figures-1 & 2 shows the design of hammers available in south-western areas of Bangladesh [18-20].

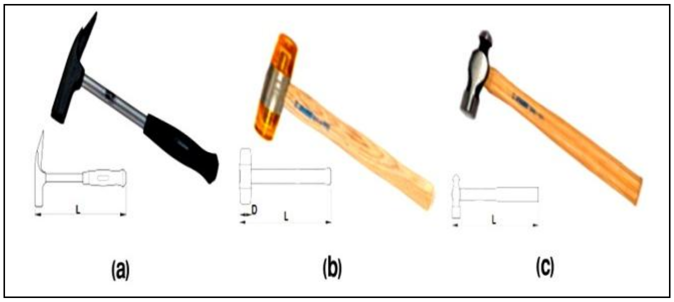

Fig 1: (a) Carpenters hammer, (b) Bumping hammer, (c) Ball- peen hammer

Carpenters hammer is a hammer with a cleft at one end for pulling nails. Its broadly uses in carpenter industry. Bumping hammer is a power-driven hammer with two broad flat faces on a narrow head. It is used in bumping sheet metal. It is a hammer have a rounded, hence "ball", peen which used for shaping metal closing rivets and rounding edges off metal pins and fasteners. It is also used for hitting chisels and punches during carpenter work.

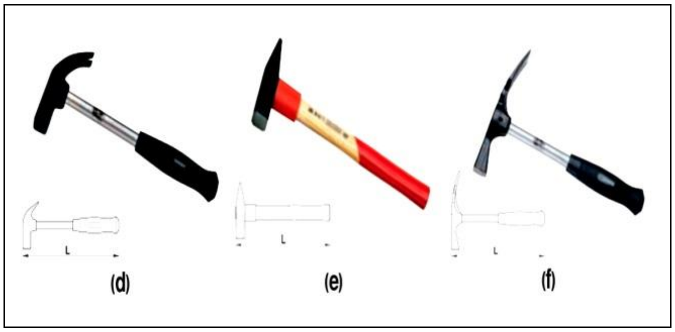

Fig 2: (d) Claw hammer, (e) Locksmiths hammer, (f) Masons hammer

Claw hammer is a hammer with a heavy rigid head and a handle. It is basically used to deliver an impulsive force by striking. Locksmiths hammer is a German pattern hammer with colored end of handle and basically handle made of wood. Basically used to create high pressure & force. Mansions hammer is a hammer with a moderately heavy head sharpened at one end to a chisel edge. This types of hammer specially used for removing pin from wood.

B. Measurement of existing hammers

The hammers are widely used in the carpentry and wooden work in Bangladesh. Many existing hammers are not ergonomically designed because they require a lot of wrist bending and twisting during use. In this survey work researchers took the measurement (Handle diameter, Grip Size) of the different existing hammers shows in figure-3.

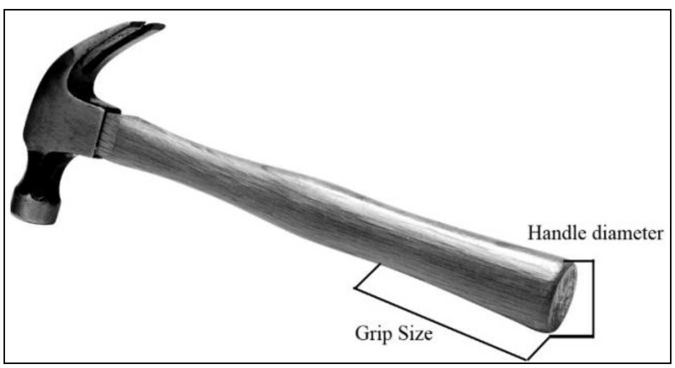

Fig 3: Measurements of hammers

C. Anthropometric measurements of hand

Hand length (HL): The length of the hand as measured between the wrist crease and the tip of the longest finger on the hand, usually thumb finger.

Hand breadth (HB): The length of the palm of the hand, measured perpendicular to hand length.

Finger length (FL): The length of the thumb finger as measured between the palmar digital and the tip of the middle finger.

Hand breadth at metacarpal (HBM): The maximum breadth across the hand where the fingers join the palm. The right hand is extended straight and stiff with the fingers held together.

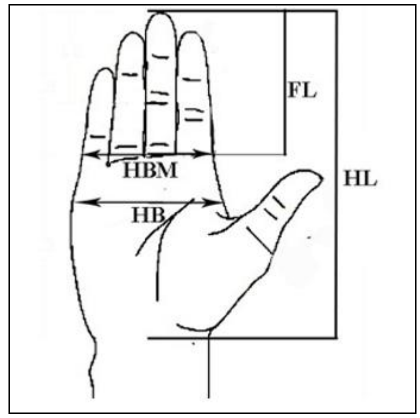

Fig 4: Hand anthropometry

D. Determination of an optimal cylindrical handle diameter for power grip

In this study researchers use following equations to determine the general grip, power grip diameter and grip size [21-29]:

$$Dopt|1,2 = \frac{Opt|1,2}{\pi} = \frac{Dgrip|1,2\cdot\pi - \left(\frac{L|1,2+LF|T}{2}\right)}{\pi} \quad [1]$$

$$Power\ grip\ diameter = HL\ or\ HS\ x\ 20\% \quad [2]$$

$$Grip\ size = Grip\ diameter * \pi \quad [3]$$

E. Skewness test

According to Fan and Gencay (1995) [30], Hamilton (1989) [30-31] following equations is used to calculate the skewness:

$$Skewness = \frac{(3*(Mean - Median))}{Standard\ deviaion} \quad [4]$$

If the skewness is between the -0.5 and 0.5, the data are approximately symmetric.

- If the skewness is between -1 and -0.5 or between 0.5 and 1, the data are moderately skewed.
- If the skewness is less than -1 or greater than 1, the data are highly skewed.

3. Results

A. Ergonomic selection of musculoskeletal disorders

The Figure-5 and Table-1 presents the prevalence of musculoskeletal disorders in different body regions of carpenters. As Figure-5 shows, the most commonly affected parts are wrist, shoulder and elbow.

Table 1: Frequencies of ergonomic discomforts and injuries

Musculoskeletal Disorders	No. of Workers	Percentage of Workers (%)
Headache	150	50
Shoulder pain	195	65
Wrist pain	260	87
Stiffness in finger	215	72
Soreness in elbow	183	61

In this study the prevalence of musculoskeletal disorders among carpenters were 87% for the wrist pain due to improper ergonomically designed hammer. Other musculoskeletal disorders among workers were 72% for the stiffness in finger and 75% for shoulder pain [32, 33].

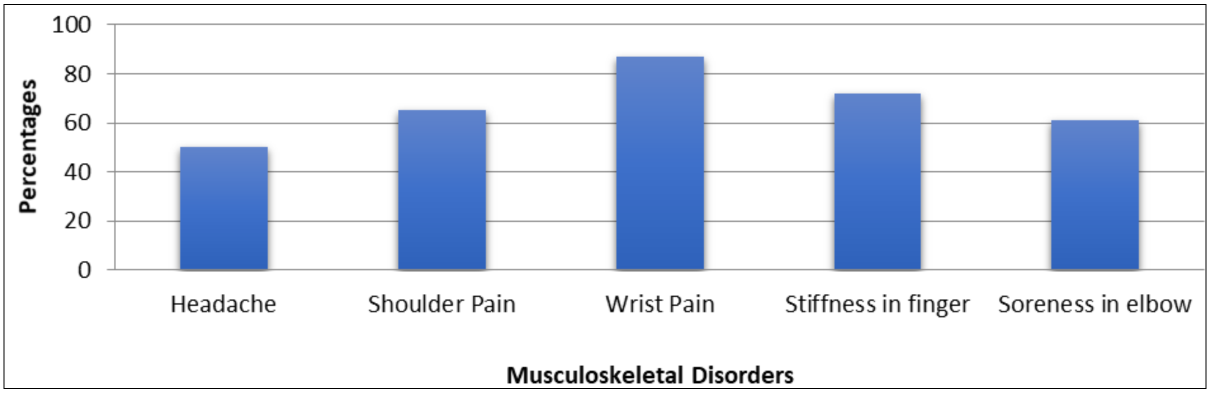

Fig 5: Frequencies vs. Musculoskeletal Disorders (After using existing hammer)

Survey results shows that 69% carpenters want to improve in working conditions, other result shows that more than 55% of carpenters do not satisfied with their working environments. 47% workers want to redesign the hammer because of they are not comfortable with exiting hammer. Most of carpenters suffer from various musculoskeletal disorders which are not good for long time, so that they want to improve the design of their hammer [34-38].

B. Overall dimensions of hammers available in different areas of Bangladesh

The overall dimensions of existing hammers were recorded from different areas of Bangladesh show in following table.

Table 2: Dimensions of existing hammers

Parameter	Handle length(cm)	Handle diameter(cm)
Average	32.35	2.95
SD	0.516	0.06
Max	33	3.1
Min	31	2.89
5th Percentile	31.6	2.896
50th Percentile	32.5	2.95
95th Percentile	33	3.04

C. Anthropometric measurements of the Carpenter

Table 3: Anthropometric measurements

Man	Age	MFL	TL	IGB	HBM	HB	HL	MFL
Average	45.2	7.87	3.01	4.16	7.63	8.48	18.69	7.87
SD	11.7	0.487	0.34	0.47	0.49	0.45	1.18	0.487
Max	75	9.7	3.9	5.1	8.9	9.6	23.4	9.7
Min	23	6	2.3	3.4	6.4	7	16.4	6
5th %le	26	7.2	2.5	3.5	6.9	7.8	17.1	7.2
50th %le	45	7.9	3	4.1	7.6	8.5	18.5	7.9
95th %le	65	8.695	3.69	4.8	8.495	9.2	21	8.695

D. Skewness test of existing hammer

Table 4: Skewness test

Statistic	Handle length (cm)	Handle diameter (cm)
Mean	32.35	2.95
SD	0.516	0.06
Median	32.28	2.98
Skewness	0.41	-1.5
Evaluation	Approximately symmetric	Highly Skewed

E. Proposed dimensions and design of ergonomically designed hammer

Table 5: Proposed dimensions

Features	Dimensions (cm)	Used Equations
Optimal grip diameter	3.368	[1]
Power grip diameter	3.739	[2]
Grip size	11.747	[3]

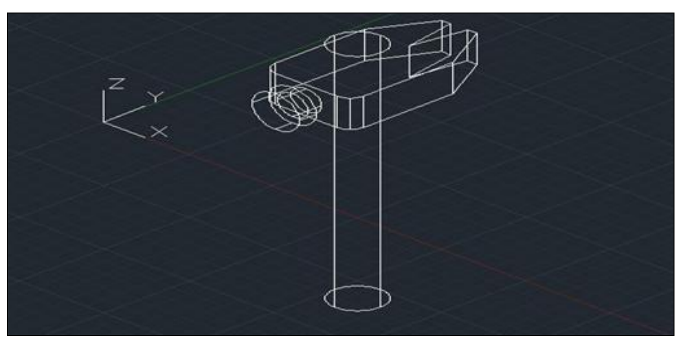

Fig 6: CAD Design (Isometric View)

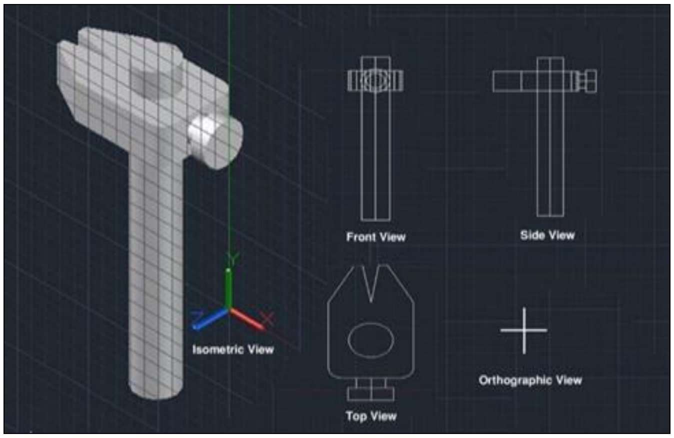

Fig 7: CAD Design (2D Drawing)

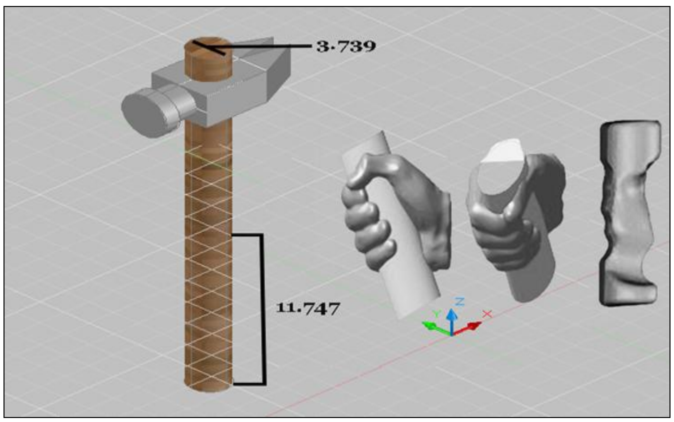

Fig 8: CAD design of newly designed hammer

F. Flexibility Analysis

Table 6: Ergonomically designed hammer vs. Existing hammer

Comfort factors	Ergonomically designed hammer	Existing Hammer
Quality of the hammer handle	Good	Good
Surface Finish of hammer handle	Good	Good
Compatibility for the type of grip	Excellent	Normal
Overall Comfort at first look	Excellent	Normal
Fits the hand	Excellent	Bad
Effect of hammer use on hand/arm	Good	Worst

G. Experimentation for ergonomically designed hammer handle

Table 7: Experimentation for optimal diameter

Evaluation	Description
Grip size is too small	The two middle fingers are digging into the heel portion of the operator palm.
Grip size is correct	The two middle fingers are slightly gapped to touching the heel portion of the operator palm.
Grip size is too large	The two middle fingers have too much gap to the heel portion of the operator palm.

The authors have found that the Grip size is correct and the compatibility of grip is excellent. It fits with hand comfortably.

I. Validation and Testing

The Figure-9 presents the prevalence of musculoskeletal disorders in different body regions of workers after using new designed multi-purpose hammer.

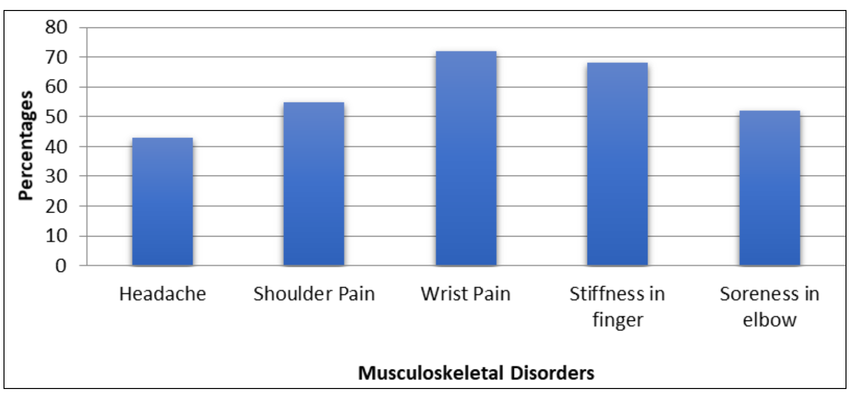

Fig 9: Frequencies vs. Musculoskeletal Disorders (After using new designed hammer)

4. Discussion

In this study, the authors survey different areas in Bangladesh. Here the authors have found that the carpenters were facing high level of wrist pain after carpentry or wooden work. For this reason, the authors were recorded some significant anthropometric measurements for purpose of designing ergonomically correct hammer handle to prevent the wrist pain.

5. Conclusion

The purpose of this study has been fulfilled; a hammer handle for power grip operation has been developed and implemented. However the workers found that their working postures with new multipurpose hammer is good and reported comfort. Results shows that wrist pain was the big of musculoskeletal disorder of carpenters which have been reduced to 72% from 87%.

6. Future Scope

In this study, anthropometric data were collected from 300 male carpenters of South-Western districts in Bangladesh. As the scenario of wooden working condition in most of the districts in Bangladesh is almost the same, the provided injury and discomfort related data can be a great resource for the administration and for social workers to understand the working condition in carpentry industries of Bangladesh. In this study, research could not perform dynamic simulation of hammer operation for lack of facility. It will be makes the proposed hammer model more validate.

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8. Conflicts of Interest

The authors declare that they have no conflicts of interest.

9. Ethical Statement

The authors declare that they have followed ethical responsibilities.

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