Original Article

A comparative ergonomic study of work-related upper extremity musculo skeletal disorder among the unskilled and skilled surgical blacksmiths in West Bengal, India

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Abstract

Objective: The main aim of the study was to determine the nature and extent of work-related upper extremity musculoskeletal disorders (MSDs) and physiological stress among the blacksmiths involved in surgical instrument industry. **Materials and Methods:** In the present investigation, 50 male blacksmiths of each skilled and unskilled groups of the forging section had been selected. For the symptom survey, a questionnaire on discomfort symptoms was performed. Repetitiveness of work and hand grip strength of both the groups were measured. **Results:** It was revealed that upper limb MSD was a major problem among both group of blacksmith, primarily involving the hand, wrist, fingers, and shoulder. From this study it was found that 66% (33) skilled and 80% (40) unskilled blacksmith workers are feeling discomfort. The most commonly affected regions among the skilled and unskilled blacksmith workers were lower back (skilled 65% and unskilled 80%), neck (skilled 60% and unskilled 80%), and hand (skilled 50% and unskilled).

Key words: Blacksmith, hand grip strength, musculoskeletal disorder, visual analogue scale

INTRODUCTION

Musculoskeletal disorders (MSDs) may be defined as injuries and disorders of the muscles, nerves, tendons, ligaments, joints, cartilage, and spinal disc. This may occur due to improper physical work activities or appalling workplace conditions. MSDs can be caused by heavy physical work, static work postures, frequent bending and twisting, lifting, pushing and pulling, repetitive work, vibration, and psychological and psychosocial stress.[1] MSDs are the most common self-reported work-related illness. They are the manifestations of the ergonomic hazards and are the leading causes of disability among the people during the working years. According to Levy and Wegman[2] occupationally caused or aggravated MSD rank first among the health problems in the frequency with which they affect the quality of life. MSD is commonly caused by overexertion, muscle strain, and repetitive strain. The risk of disorder is also directly related to the number and speed of movements and the amount of force exerted with each movement. A task with high repetition and poor postures may result in a significant number of complaints or injuries.[3] Awkward or extreme postures are less efficient than posture keep joints near the center of their range of motion. A person working from an extreme or awkward posture will have to use more force to accomplish the same amount of work compared to using a neutral posture, which in turn affects muscle loading and compressive forces on the internal vertebral disc.[4,5]

Work-related MSD continues to present a major challenge to workers and their employers in virtually every industry/work sectors. Most repetitive tasks require a continuation of both static and rhythmic muscle activity. The relationship between task demands, ergonomics, and MSD is of a probabilistic nature and is confounded by the fact that disorders can arise as a result of many activities of daily life, both at work and elsewhere. The disorders may present as co-conditions of other disease. Sartorio *et al.*[6] observed the incidence of work-related MSDs (WMSD) among the dental professionals in Italy and reported that the specific occupation and work organization may be the source of ergonomic hazards. It was also reported by Muggleton *et al.*[7] that the workers who were exposed to repetitive work for long time, the occurrence of MSD was found very high among them. Truchon *et al.*[8]

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found that Canadian workers are frequently going for sick leave due to recent occupational low back pain. Crouch[9] suggested that handgrip strength is a useful diagnostic tool to determine work-related upper extremity MSDs like Carpal Tunnel Syndrome (CTS). Decreased grip strength may make it difficult to form a fist, grasp small objects, or perform other manual tasks.

The manufacture of surgical instruments is one of the leading small-scale industrial sectors in West Bengal, India, with an enormous export potential. Manufacturers are now supplying surgical instruments to big dealers and exporters in Delhi, Mumbai, Jalandhar, and often directly to overseas clients. Manual forging in the local blacksmith units is the first step in the production chain. Blacksmiths forge the stainless steel components from rolled rounds, which are supplied by the instrument manufacturers. About 7500 persons are directly or indirectly involved in forging of surgical products in the Baruipur subdivision.[10] Blacksmiths are divided into two classes, owner of the hearth (locally called Kamarshal) and daily wage labour. The average monthly income of an owner is Rupees 4000 and for daily wage labourers is Rupees 1200. The daily wage labourers are engaged in rigorous unskilled work in the forging units and the owners are skilled workers performing precision activities to give final shape to the surgical instruments.

The main aim of the study was to determine the nature and extent of work-related upper extremity MSDs and physiological stress among the blacksmiths involved in surgical instrument industry.

MATERIALS AND METHODS

Selection of subjects

In the present investigation, 50 male blacksmiths of each skilled and unskilled groups of the forging section had been selected. To avoid selection bias, all the workers were selected randomly form the Baruipur subdivision of West Bengal. In our random selection, we did not find any worker who had less than 1-year experience.

Assessment of physical parameters

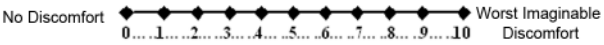
The height and weight of both groups of subjects were recorded by using an anthropometer and a weighing machine.

Questionnaire

A modified Nordic questionnaire[11] was applied which included a number of questions emphasizing individual details, type of work, upper extremity MSD symptoms, affected body parts, etc. to investigate the discomfort at work. After explaining the aim of the study in a layman's term, each subject was approached and the questionnaire was performed individually and collected on the spot on the same day. For the symptom survey, the subjects were enquired to know whether they suffered from tenderness, swelling and warmth in the wrist and from pain, numbness, and tingling in the hands.

Visual Analogue Scale

The Visual Analog or Analogue Scale (VAS)[12] is designed to present to the respondent a rating scale with minimum constraints. Respondents mark the location on the 10-cm line corresponding to the amount of pain they experienced. This gives them the greatest freedom to choose their pain's exact intensity. It also gives the maximum opportunity for each respondent to express a personal response style. The VAS frame measures exactly 10 cm. The distances from zero to the markings in cm are result indicators to be processed as continuous variables for statistical analysis.



Repetitiveness of Work

A study on repetitiveness was performed through the analysis of time and motion of work in both the groups. The total time period for a particular job was recorded by video photography. Different activities constituting that particular job and the time taken for the completion of each activity were recorded with stopwatch by viewing the video clips. Repetitive activity was considered to be that activity which occupied more than 50% of the total time period for that particular job. The result will confirm the repetitiveness of the work.

Grip Strength

A physical examination was performed by handgrip dynamometer (Make: Rolex, India) to measure the handgrip strength of the experimental group and the comparison group. The handgrip strength was measured following the standard method where in the handle of the dynamometer is adjusted at which the second joint of the index finger is bent at nearly a right angle. The body must be straight without side bending, both feet and arms in natural positions and the dynamometer should be gripped with full force.[13] The dynamometer should not come in contact with the body or clothing and should not be swung around. The measurement was done among workers at 90° elbow flexion and 180° elbow extension as because it has been observed that the highest and lowest values of grip strength vary in accordance with the elbow positions.[14]

Physiological Parameters

A stop watch was used to measure the heart rate. Heart rates were measured before and just after work by 10 beats method from the carotid pulse.[15] The blood pressure was measured before and just after work by the help of sphygmomanometer and stethoscope.

Statistical Analysis

Student "t" test was performed to find out whether there is any significant difference in between the parameters of the groups. A two-tail Chi square test of independence was applied

to determine whether there is any significant association between the parameters measured. The computed χ^2 was next compared with the critical χ^2 value for the chosen level of significance ($P < 0.05$). Statistical analysis was performed using the statistical package PRIMER OF BIOSTATISTICS (Primer of Biostatistics 5.0.msi, Msi Version = 1.20.1827.0, Primer for Windows, Mc-Graw-Hill).

RESULTS

The mean values of age and physical parameters (height, weight) of skilled and unskilled blacksmith subjects are shown in Table 1. The mean age of the skilled and unskilled was 40.4 ± 6.38 years and 37.6 ± 5.21, respectively. The body height of the skilled and unskilled was 168.16 ± 11.23 and 166.32 ± 10.13, respectively. The body weight of the skilled and unskilled was 59.9 ± 9.90 and 57.9 ± 8.70, respectively.

The daily work scheduled including the mean duration of work per day and rest as well as the number of working days in a week and number of absent days in a week is mainly present in Table 2. It was observed that both the group of blacksmith (skilled and unskilled) works 6 days in a week. But the subjects of skilled blacksmith worked 10.0 ± 2.38 h per day and got 1.5 ± 1.0 h rest per day. However, the subjects of the unskilled blacksmith worked 10.0 ± 2.14 h per day and got 1.5 ± 1.0 h rest per day. The number of working days in a week among both skilled and unskilled blacksmith were 6 days in a week.

Table 3 shows the association between with discomfort and without discomfort feeling among the skilled and unskilled blacksmith workers. It was found that 66% (33) skilled and 80% (40) unskilled blacksmith workers are feeling discomfort. In this case, a significant association was observed between with discomfort and without discomfort feeling among the skilled and unskilled blacksmith workers.

Table 1: General physical information of the workers

Variables	Skilled blacksmith	Unskilled blacksmith
	Mean (SD)	Mean (SD)
Age (years)	40.4 (± 6.38)	37.6 (± 5.21)
Height (cm)	168.16 (± 11.23)	166.32 (± 10.13)
Weight (kg)	59.9 (± 9.90)	57.9 (± 8.70)

Table 3: Associations of with discomfort and without discomfort feeling between skilled and unskilled blacksmith workers

Study groups	Subjects without discomfort feeling	Subjects with discomfort feeling	χ^2 values	Remarks
Skilled blacksmith	17	33	1.826	Significant
Unskilled blacksmith	10	40		

Intensity of pain among the skilled and unskilled blacksmith workers were measured by VAS rating. The Kruskal Wallis Test was performed to identify the deference of intensity of pain among the both group. By the statistical analysis of these data it was found that there is a significant difference of intensity of pain among the skilled and unskilled blacksmith workers [Table 4].

The feeling of discomfort in different body parts in each group (skilled and unskilled) of workers is shown in Table 5. From this study it was observed that feeling of discomfort in different body parts varied among the skilled and unskilled blacksmith workers. From Table 5, the most commonly affected regions among the skilled and unskilled blacksmith workers were lower back (skilled 65% and unskilled 80%), neck skilled 60% and unskilled 80%), hand (skilled 50% and unskilled 64%), wrist (skilled 20% and unskilled 50%), and shoulder (skilled 30 % and unskilled 36%).

In the surgical blacksmith, the repetitiveness of the main activity, i.e. hammering is shown in Table 6. It is observed that during a single cycle of 129.5 s (± 0.31) work, the main activity (hammering) was performed for 71.5 s by skilled surgical blacksmith and 117.5 s by unskilled surgical blacksmith. So it has been show that the main activity performed by the surgical blacksmith was more than 50% of the work cycle. This indicates that both group of surgical blacksmith performs repetitive activities in their daily work schedule [Table 6].

The Table 7 shows the difference in general work nature among skilled and unskilled blacksmith. It observed that the unskilled blacksmith are using significantly higher weight of hammer (2.5 kg) with a higher frequency (120 hammering/min) than the skilled blacksmith in their daily life.

From Table 8 it is observed that there exists a significance difference in handgrip strength measured at 180° elbow

Table 2: Mean duration of work and rest per day with average number of working days in a week

Workers	Duration of work per day (in hour)	Duration of rest per day (in hour)	Number of absent in a week (in days)	Number of working days in a week
Skilled blacksmith	10(± 2.38)	1.5 (± 1.0)	2.1 (± 1.08)	6
Unskilled blacksmith	10(± 2.14)	1.5 (± 1.0)	3.2 (± 2.18)	6

Table 4: Comparison of VAS rating among skilled and unskilled blacksmith workers

Study groups	VAS rating	R value	Kruskal Wallis test
Skilled (G_1) blacksmith	6.84 ± 1.35	(R_1)	$H = 6.450$ $P < 0.05$
Unskilled (G_2) blacksmith	7.56 ± 1.46	(R_2)	

VAS: Visual Analogue Scale

Table 5: Discomfort feeling (pain) at different body parts among skilled and unskilled blacksmith workers.

Number of affected workers	Different body parts				
	Neck	Shoulder	Wrist	Hand	Low back
Skilled	30 (60%)	15 (30%)	10 (20%)	25 (50%)	33 (65%)
Unskilled	40 (80%)	18 (36%)	25 (50%)	32 (64%)	40 (80%)

Table 6: Average repetitiveness of work activities among skilled and unskilled blacksmith.

Group	Main activity	Time taken for main activity (in sec)	Total time taken for one work cycle (in sec)	Repetitive / non-repetitive
		Mean (SD)	Mean (SD)	
Skilled	Hammering	71.5 (± 0.36)	129.5 (± 0.31)	Repetitive
Unskilled		117.5 (± 0.41)		Repetitive

Table 7: General work nature among skilled and unskilled blacksmith.

Workers	Skilled	Unskilled	"t" value	Remarks
Number of hammering/min	99.3 (± 3.25)	120 (± 4.38)	26.061	Significant ($P < 0.001$)
Hammer weight (kg)	0.9 (± 0.88)	2.5 (± 1.22)	7.517	Significant ($P < 0.001$)

Table 8: Relation between hand grip strength (in kg) of the skilled and unskilled blacksmith workers.

Hand grip strength	At 90° elbow flexion	At 180° elbow flexion
Skilled blacksmith	43 (± 2.65)	42 (± 3.02)
Unskilled blacksmith	41 (±2.34)	38 (± 2.75)
t test	Significant ($P < 0.001$)	Significant ($P < 0.001$)

Table 9: Comparative study of physiological stress (heart rate) among skilled and unskilled blacksmith.

Activity	Average just after work heart rate (beats/min)			t value	*P* value
	Skilled blacksmith (n = 50)	Unskilled blacksmith (n = 50)	Difference		
Hammering	122.7 (± 9.0)	131.1 (± 8.2)	8.40 (±10.7)	4.86	$P < 0.001$

extension between the subjects of both the groups. The skilled blacksmith had significantly higher handgrip strength than the unskilled blacksmith. Table 9 showed that there is a significant change in heart rate in between skilled and unskilled blacksmith.

DISCUSSION

The results of this study revealed that the surgical blacksmiths are engaged in rigorous hand intensive jobs, so naturally they suffer from various MSDs primarily affecting the upper extremity.

It can be observed from the present study that work-related incidents affect different body parts of the blacksmiths. This has also lead to a high rate of workday loss. Previously, it has been observed that unskilled blacksmiths fail to keep their commitments because of absenteeism.[16] In the case of unskilled blacksmiths, the added disadvantage is low control over the task in an unhygienic working environment.[16]

The blacksmiths perform repetitive hammering jobs[17] that give shape to the surgical instruments. This type of job not only requires skill but is also time consuming. Hammering jobs are responsible for most of the incidents. The significant correlation between the total number of incidents and total workdays lost in a year is an indicator of the fact that frequent incidents result in lost workdays.

From the statistical analysis it is evident that there is a significant association between positive and negative responses of discomfort feeling among the skilled and unskilled blacksmith workers. This suggests that the unskilled blacksmith workers engaged in hand intensive activities have to perform strenuous tasks repeatedly throughout the day, suffered the most, where as the skilled blacksmith workers suffered less.

It is also evident from the results that the unskilled blacksmith suffered from discomfort in the upper extremities in more number than the skilled blacksmith. Most commonly affected regions among the skilled and unskilled blacksmith workers were lower back (skilled 65% and unskilled 80%), neck skilled 60% and unskilled 80%), hand (skilled 50% and unskilled 64%), wrist (skilled 20% and unskilled 50%), and shoulder (skilled 30% and unskilled 36%).

It is found that the unskilled blacksmith workers had significantly higher intensity of pain feeling than the in the skilled blacksmith workers. Thus, it can be assumed that the job done by the unskilled blacksmith workers are extremely intense.

This finding can be supported further by the fact that the tasks performed by the unskilled blacksmith workers involve repetitive acceleration of hands with heavy hammer over sustained period of time. According to Silverstein *et al.*,[18] an activity is said to be repetitive if 50% of the work cycle involves similar motion patterns. This criterion of repetitiveness was satisfied in this study wherein the hammering activity covers 90.7% of the work cycle of unskilled blacksmith workers and 55.2% of the work cycle of skilled blacksmith workers. Thus,

high repetitiveness may be regarded as a causative factor for the development of MSD in upper limbs of the of the unskilled blacksmith workers predominantly

This type of job not only requires skill but is also time-consuming. Hammering jobs are responsible for most of the incidents. The significant correlation between the total number of incidents and total workdays lost in a year is an indicator of the fact that frequent incidents result in lost workdays. Gangopadhyay *et al*.[19] also found that there is a significant difference in the total number of injuries occurring between the skilled and unskilled surgical blacksmiths. Thus, it can be said that the unskilled blacksmiths are more affected than the skilled ones. Among them, incidents are very predominant, the unskilled ones involved in the highest number of incidents.

The handgrip strength of the workers of both groups was measured at 90^0 elbow flexion and 180° elbow extension. A significant difference in handgrip strength at both positions was observed between the subjects of both the groups. The skilled ones had significantly higher handgrip strength than the unskilled ones.

Therefore, all the results when aggregated together provide a fairly clear indication of the fact that the unskilled blacksmiths are more liable to suffer from MSD of the upper limb than the skilled ones.

From this study it can be concluded that the surgical blacksmiths are constantly engaged in highly repetitive hand intensive jobs and by performing such strenuous jobs for several years, they suffer from discomfort feeling at the upper extremities like the hands, wrists, fingers and shoulder region. The feeling gets aggravated with prolonged work, injuries followed by a decrease in the handgrip strength, and inability in grasping objects. The finger is the most affected portion of the body, followed by the hand, wrist, eye, face, leg and back. In both skilled and unskilled blacksmiths, the primary types of injuries are burns or scalds and scratches or abrasions. All these factors consequently may lead to the development of MSD at the upper limbs of the surgical blacksmiths.

CONCLUSION

The present investigation reveals that surgical blacksmiths are highly affected by upper extremity disorder. As a consequence, they suffer from injuries affecting different body parts. Furthermore, these injuries contribute to a high rate of lost workdays. It also proved that the unskilled blacksmiths are more sufferer than the skilled blacksmiths. The demand–control model of Karasek[20] suggests that persons involved in highly skilled occupations, such as assembly fitters or call operators, can handle this type of situation. Difficulties in withstanding this kind of physical and mental strain may be the cause of uncontrollable absenteeism. Thus, it can be concluded that the unskilled blacksmiths are highly stressed in their occupation due to the work nature, which also affects their health, productivity and overall work performance.

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