

Design Science and Innovation

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Ergonomics for Improved Productivity

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Ergonomic Assessment of Work-Related Musculoskeletal Disorders and Comfort of Students in Mechanical Workshop



P. Saraswat, M. K. Sain, and M. L. Meena

Abstract A mechanical workshop is an integral part of any engineering institution. Improper design of workstations and hand tools in workshop can significantly affect student's comfort and concentration. Ergonomics science plays an essential role in improving working conditions, productivity, efficiency and reducing worker fatigue and musculoskeletal disorders (MSDs). Poor working postures, repetitive tasks and heavy workloads lead to increased risk of workplace injuries. An ergonomic assessment can identify these risk factors for further improvements. The objective of this paper is to find out comfort levels and work-related musculoskeletal disorders of engineering students working in mechanical workshops. A case study was conducted with a modified version of the Standard Nordic Questionnaire (SNQ) to collect the data regarding demography, MSDs and work comfort of students. The data were analyzed using Minitab 16.0 software. A total of 180 students (male and female) were asked to fill the questionnaire out of which 152 were found valid. According to the data analyzed, average comfort score was found to be 2.16 (1—Not comfortable at all, 2—Moderately comfortable, 3—Very comfortable). The minimum comfort score (1.78) was found in the fitting shop, closely followed by the carpentry shop (1.96). Results of the survey showed that 33.5% of students reported pain in shoulders, 32.2% in fingers and 29.6% in the wrist after working. The average rapid entire body assessment (REBA) score was found to be 8.5, indicating the high-risk level of tasks involved. From the study, it was concluded that un-ergonomically designed workstations and hand tools in mechanical workshops lead to reduction in the comfort level of students and further may even lead to MSDs. The study concludes that there is a large scope for ergonomic design of hand tools as well as workstations in mechanical workshops of engineering institutions. Well-directed research toward this end could result in substantial reductions in postural discomfort of students training in such workshops.

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Keywords Ergonomics · Mechanical workshop · Musculoskeletal disorders · Work comfort

1 Introduction

A major portion of the physical exertion of Mechanical engineering students is expended in the workshops of their respective institutes. Students do a lot of physical work there. Improper posture and hand tools may directly affect the students' postural comfort. Further, since the training provided in such institutes is generally the first experiential learning for most students, it becomes imperative that habit formation in working with un-ergonomic tools and postures be avoided at all costs; especially for those students who are training to improve their workmanship in engineering as a profession. Ergonomics is the scientific study of the man-machine interface at the workplace. The basic objective of ergonomics is to fit man and machine together to improve the worker's performance, reduce stresses and fatigue at work. Poor working postures, repetitive tasks and heavy workloads lead to increased risk of workplace injuries if work actions are not proper.

Moreover, improper design of workstations and tools leads to work fatigue and MSDs [10]. The forces exerted due to resistive motions, awkward postures and traditional designs of hand tools are mainly responsible for injuries [8] which can again result in MSDs in body parts. The key risk factors at workplace associated with the MSDs are bending, prolonged sitting or standing, repetitive tasks, manual handling and heavy lifting [1]. Exploration of occupational health problems is the first step toward designing work system ergonomically [11]. The musculoskeletal system of the human body enables the movement of body parts and is made up of soft tissues and bones. Damage to these tissues or injuries caused to the musculoskeletal system causes pain, and if prolonged without taking any corrective measure can result in MSDs [12].

Some factors were leading to musculoskeletal disorders such as loading heavy backpacks, sitting for several consecutive hours and adopting incorrect postures [7, 9]. Workplaces, and specifically workstations, must meet the basic requirements of safety and comfort when aiming for complete wellness of individuals [4]. Workstations and their environments which cause pain especially in wrists, arms, neck and back depending on the type of work performed and in which sufficient improvement activities have not carried out yet in terms of employee's health negatively affect employee productivity and create cost problems [5]. The various postural issues directly affect the spinal column are related to growth phase and body development, which generally coincide with the beginning of students' scholar phase [3, 6].

In this study, comfort levels and work-related musculoskeletal disorders of engineering students working in mechanical workshops were identified and discussed.

2 Materials and Methods

A case study was carried out at the mechanical workshop of an engineering institution of first-year students. The study started with direct observation during laboratory working in the four shops of the workshop namely fitting, carpentry, welding and machine shops. It was observed that some students experienced postural discomfort while using hand tools. Questionnaire survey methodology was used to find various health-related issues and the comfort level of students. The modified version of the Standard Nordic Questionnaire was used to collect the data. A total of 180 students (male and female) were involved in the study out of which 152 were found to be valid candidates. The work actions of students in all the shops were recorded using interviews, questionnaires and photography. Microsoft excel software was used to analyze the data. The data were found to be normalized in normality test.

3 Data Analysis

3.1 Percentage Analysis

Students' data pertaining to their age, gender and other physical characteristics in percentages are shown in Table 1. Being first-year engineering students, most of them were in the age group of 17–19. Among the observed students, 73.68% were male.

3.2 Analysis of Musculoskeletal Disorders (MSDs)

From the survey, it was apparent that most of the students reported some health problems or discomfort. The most commonly affected body parts are shoulders, upper arm, wrists, fingers and lower back. Figure 1 shows the percentage of students that reported having MSD symptoms. Overall 72% of students reported MSDs in the workshop. It was found that the most reported MSDs were in the shoulder, as around 33.5% of students reported shoulder pain. The percentage of MSDs in other body parts was also found to be significantly high. 32.24% of the students were found having MSDs in the fingers. About 29.61% of students were found suffering from wrist problems which usually arise due to repetitive working in awkward postures, particularly in filing and carpentry tasks. MSDs in the neck and upper arm regions were found to be 19.74% and 17.76%, respectively. The average rapid entire body assessment (REBA) score was found to be 8.5, indicating the high-risk level of tasks involved.

Figure 2 shows the working actions and postures of the students. The tasks are repetitive and require physical work.

Table 1 Percentage characteristics of students

S. No	Characteristics	No. of Students (N = 152)	Percentage
1	Age		
	17 Years	62	40.79
	18 Years	71	46.71
	19 Years	18	11.84
	>19 Years	1	0.66
2	Gender		
	Male	112	73.68
	Female	40	26.32
3	Weight	29	19.08
	?50	69	45.39
	51–60	41	26.97
	>7	13	8.55
4	Workshops		
	Fitting Shop	42	27.63
	Carpentry Shop	38	25.00
	Welding Shop	34	22.37
	Machine Shop	38	25.00
5	Height (cm)		
	<=160	31	20.39
	161–170	56	36.84
	>170	65	42.76

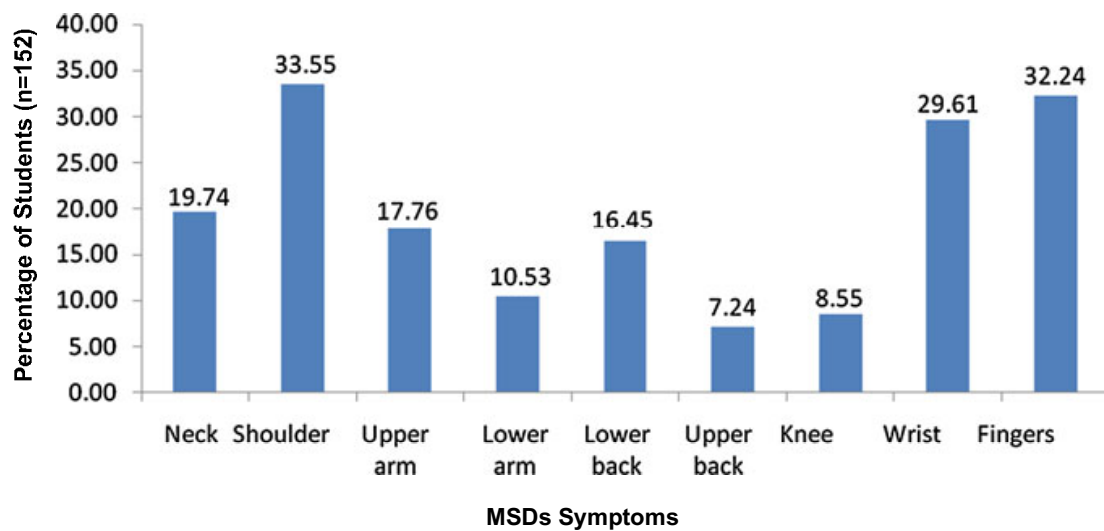
**Fig. 1** Various MSD symptoms among students



Fig. 2 Working postures of students in the workshop

3.3 Comfort Level Analysis

Comfort levels are scores or indices used to quantify the level of comfort felt during a job or while handling various equipment. A comfort level scale 1 to 3 (1: Not comfortable, 2: Moderately comfortable, 3: Very comfortable) was selected to assess the comfort level of students while using hand tools and working at any workstation. Some hand tools like file, hacksaw, saw and jackplane were selected for analysis by their grip quality and handle size. Table height in carpentry and fitting shop and machines height were also considered for comfort analysis.

Table 2 shows comfort level scores for various parameters identified for the workshop. The average comfort score is 2.16, which is above moderate. The minimum comfort score of 1.78 was found in the fitting shop for grip quality of file tool. Other areas of concern have handled the size of saw and grip quality of saw with comfort level scores of 1.83 and 1.98, respectively. On the whole, results show that improvements are required in areas where the score is less than 2.

4 Results and Discussion

A case study of students working in a workshop of an engineering institute was conducted to investigate MSDs and other discomforts. The survey data was analyzed, and it was found that it has been observed that 72% of students reported musculoskeletal disorders related problems while working in the workshop. The most MSDs were found in the shoulder and finger part of the students. This is due to the repetitive use of the hand tool and improper postures and un-ergonomically designed workstations. The comfort scores for various parameters of hand tools were also calculated. The average comfort score was 2.16, which is above moderate. The two parameters handle the size of saw and grip quality of saw with comfort level scores of 1.83 and 1.98, respectively, also required improvement in hand tool design.

Table 2 Comfort level scores

S. No	Parameter	Average comfort score
1	Grip quality of the file	1.78
2	Handle size of the file	2.07
3	Handle size of hacksaw	2.19
4	Grip quality of hacksaw	2.16
5	Work table height of fitting shop	2.24
6	Grip quality of the saw	1.98
7	Handle size of the saw	1.83
8	Grip quality of jackplane	2.16
9	Handle size of jackplane	2.15
10	Work table height of carpentry shop	2.18
11	Work table height of the welding shop	2.45
12	Breathing in the welding shop	2.21
13	Lathe machine height	2.37
14	Shaper machine height	2.42

5 Recommendations

After the analysis of musculoskeletal disorders (MSDs) and comfort score, there are some recommendations which are given below, to improve the working environment in the workshop.

- The lot of improvement is needed to redesign the worktable. The repetitive nature of work is increasing the MSDs to students. Work table should be designed according to anthropometric measurements. The height of the table should be adjustable.
- Working postures of the students should be according to the direction of the task, i.e., backward or forward.
- The texture of hand tools must be nonslip; it should provide proper grip.
- The average comfort score indicates the need to redesign of small hand tools. The design of handle size and grip quality of file and hacksaw, file and saw should be redesigned ergonomically.

6 Conclusion

A mechanical workshop is a place where students can get hands-on practice in improving their workmanship and engineering skills. However, incorrect postures and un-ergonomically designed hand tools can lead to the cultivation of harmful

practices which would result in severe MSDs in future if not in the immediate present. The significant improvements are needed in the tools as well as the workstations to achieve the desired ergonomic level for students. The reasons for low comfort levels were identified as un-ergonomically designed hand tools and workstations. In particular, comfort scores indicated that sizes of handles, as well as grip quality of various hand tools, require significant modifications. The results are quite similar to that of the findings of Bandyopadhyay and Sen [2] and other studies. The present study has helped in identifying various areas for improvements in hand tool design and workstation design in such institutional workshops. The results of the survey have given some basic guidelines as to which parameters need the most attention from the viewpoint of ergonomic improvement. A standardized ergonomic approach would indeed go a long way in preventing work-related musculoskeletal symptoms among students. Use of ergonomic principles and ergonomically redesigned hand tools can improve the work life and would result in reduced MSDs.

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