Abstract:

Introduction: Carpentry is one of the common small-scale industries which contribute to Indian economy. A cluster of carpentry workshop has been originated in different states of India such as, West Bengal, Assam, Orissa, Madhya Pradesh, Rajasthan, Karnataka, Kerala etc. Different districts of West Bengal, such as, Paschim Medinipur, Bankura, Purulia etc. are the virtuous standby bunch zone of carpenters.

Carpentry task is an assemblage exertion work in a firmly corresponding method by some carpenters. Every group is made up of2-3 numbers of varied workforces, executing diverse categories of carpentry work. The main responsibilities are – (i) cutting the raw wood by sawing, (ii) planning the wood for further preparation of furniture, (iii) designing and fine cutting of wood by the chisel. According to the responsibilities the carpenters were divided in to three major categories, viz. saw users, plane users and chisel users. They work in a group and some of them were habituated to perform all three tasks.

Carpenters, who had to execute their task by exercising physical effort, were exposed to some occupation associated health hazards and stresses. The significant contributing reasons might be an improper procedure of work, unusual posture, extreme job pressure, physical stresses, non-ergonomically designed workshop, and etc. The job associated strains might have certain effects on the health and performance of the carpenters.

Some difficult postures adopted by the workers like, bending, overstretching, squatting, crouching, twisting etc. at the time of executing the carpentry task. Those kinds of posture mostly lead to postural stress among the workers.

Some human factors related to the carpentry work were studied in this research work. Priority has been given to appraise the general health status, occupation related MSD, work posture, work-rest cycle, and physical variations of the carpenters. Carpenters had to execute their task in a workstation which must be suitable to them and their tasks. It was required to

assess the workstation from the ergonomics and human factors points of view. Ergonomic intervention was necessary to reduce the extent of mismatch between the workers and various components of the workstation. A number of hand operated tools were used by the carpenters in their workshop. Ergonomics evaluation of those tools as well as ergonomics modification of the hand tools might be required to ensure the better productivity and well being of the workers.

The followings were the objectives of the present research study –

i. To assess the socioeconomic and nutritional status of the carpenters.
ii. To evaluate musculoskeletal disorders and the discomfort level of the carpenters.
iii. To evaluate the postural stress of the carpenters
iv. Ergonomic intervention for redesigning the conventional workstation and hand tool (carpenters chisel) used by the carpenters.

Methods: To accomplish the said objectives the succeeding procedures were employed. The whole study was conducted in different carpenter's workshops of Paschim Medinipur districts of West Bengal state in India. For the execution of this research work 256 of male (18-60 years) carpenters were chosen arbitrarily. All those selected subjects volunteered to this study.

The carpenter's socio-economic position was estimated by modified Kuppuswami scale (Raj *et.al.* 2015). The workers educational status was appraised through questionnaire procedure and nutritional status of the workers was assessed by using anthropometric guides like, body mass index (BMI), body fat (BF%) etc. Anthropometric study (height, weight, BMI) was made through standard measurement method (as per WHO, 1986 guidelines). Modified 'Nordic' questionnaire technique was applied for determining the occupation related musculoskeletal disorder of carpenters. Discomfort or pain in different body parts of the workers was rated through10-point Borg's scale. By scheming the genuine work time and

break time of entire work shift, the work-rest cycle was assessed. It was detected through video-photography method from beginning to end of the work shift.

By using OWAS, RULA, REBA and QEC methods, the postural pattern of the carpenters was assessed. In addition, direct observation, video photographic technique was also employed. By determining of blood pressure and heart rate (HR) (during both resting and working situations) cardiovascular status of the carpenters was estimated and from the resting and mean working heart rate CSI (cardiovascular stress index) was calculated.

The whole body-center of gravity of the carpenters was determined by the segmental method. Different body joint angles of the carpenters was measured by a digital goniometer. the EMG study of different work posture of carpenters were evaluated by BioGraph Infiniti system (Pate-1). The Pulmonary function parameters of the carpenters were evaluated by using a digital spirometer. Different pulmonary parameters like, FVC $FEV_{1,}$ $FEF_{25\%-75\%}$, PEF and MVV-index were assessed. Furthermore, by using FEV_1/FVC value (minimum value <70%) the occurrence of COPD was determined.

Different hand tools were used by the carpenters for executing different tasks of carpentry work. Carpenter's chisel, which was one of the most frequent used tool of the carpenters, was redesigned with an emphasis to the man- tool interface. Some of the steps followed for redesigning the chisel were: (i) assessment of conventional chisel, (b) some concept of design was developed and prototypes were prepared (c) restructured the conventional chisel handle and (d) restructured chisel was evaluated by employing some methods such as subjective evaluation, joint angle study, heart rate study and productivity study.

For optimizing the height of workstation for the plane users, some synchronized steps were applied. In the beginning, the disadvantages or problems of the design of the conventional workstation was evaluated by cross-examining the users, assessing BPD and determining joint angles of the users and assessing the postural stress at the time of using the

conventional workstation by study of EMG. Ultimate design of the workstation was executed by a psychophysical study, and by study of productivity.

Results and Discussion: The results of the present research work represented that most of the carpenters were belonging to lower socioeconomic category according to the modified Kuppuswami scale. They had a poor nutritional status. Depending to Chronic Energy Deficiency (CED) categorization (WHO, 1995) it was found that a distinguished proportion of carpenters were within the range of under nourished (<18.50 kg/m2) category. Around82% of the carpenters were belongings to normotensive category and nearly15% of the workers were within the hypotensive range.

The findings of occupation related musculoskeletal disorders exhibited that nearly all of the body parts were affected during execution of carpentry tasks. Maximum pretentious body segments were lower back (85.55%) and waist (78.52%), knee (69.14%), shoulder (69.14%) and neck (61.72%) of carpenters in view of all tasks together. Significantly higher prevalence of MSD was observed in some of the body parts of the carpenters. In all kinds of carpentry tasks musculoskeletal problems were found in the lower back, wrist and knee portion of the body, but problem was enormously predominant during chiseling and planning task. Saw operators were extremely affected by knee problems. Problems in lower back of the body were highly prevalent for chisel users (95.12%) and plane users (86.21%). The prevalence of MSD was also observed very high in higher and lower experience groups of carpenters than that of middle experience group workers.

The results of body part discomfort rating (BPD) exposed that the workers involved in various carpentry tasks had different degrees of BPD. During chisel and plane operations, severe pain (BPD>7) was found in shoulder and lower back of the body. Moderate level of pain (BPD>4 to 7) was detected in neck and hand arm system among the workers involved in all kinds of carpentry tasks. According to the work experience the of BPD rating was

found to be greater in higher and lower experience group than that of middle experience group. This ache or discomfort might be related to inappropriate working posture, poor work environment along with high work load in the work place.

The most important factor in the job-related stress was the total duration of a work shift. The work-rest cycle exhibited that the overall working time was around 8 to 9 hours including rest pauses. The total time of work shift was the maximum in chisel operation followed by the plane and saw operation.

The cardiovascular stress index (CSI) was high in different tasks of carpenters. The CSI and work-rest period was found to be closely related. It was recommended that within the work shift the carpenters might take more frequent short breaks instead of a long duration break.

As per the results of different posture analysis procedures, the work postures adopted by the carpenters had 'moderate' 'to 'very high' levels of risk in different tasks of carpentry. The workers were suffering from occupation associated health hazards, feasibly for extended working periods along with assuming awkward postures. In this study it was observed that three different postures were predominant for three different tasks of carpenters. Most of the time the chisel users adopted forward bending posture while sitting with folded legs. The plane users had to work in forward bending posture understanding condition. The predominant posture of the saw users was the forward bending with one leg folded at upper position. Prolonged squatting and bending postures were the main reasons for the occurrence of MSD in the lower part of the body. From the results of postural assessment it was found that the tasks of carpenters had a great risk and needed immediate corrective measures.

Results of the center of gravity showed that the location of CG was deviated from that of reference position under normal erect posture. In EMG study there are vast deviation was found in different muscle for different body posture which and also significant difference

was found among in three different task of carpentry. The RMS values of EMG for fore arm muscle was highest in stressed during chisel operation and for the biceps and triceps muscles that RMS values was highest during plane operating task.

Further vital aspects of posture related stress was higher occurrence of job related musculoskeletal disorders and rigorousness of discomfort rating. At the time of executing different task of carpentry, the workers had to assume numerous types of difficult postures. In different task of carpentry, the workers had to adopt different work posture. For chiseler they had to adopt sitting with folded legs for about 85.50% of the total work time where wise plane users and saw users had to adopted erect with forward bending and erect with one leg folded at upper position (forward Bending) respectively for maximum time of the work period.

The evaluation of blood pressure (BP) of carpenters indicated that approximately 82% of workers were in normotensive category. The study of heart rate revealed that mean working heart rate of the carpenters was120.86±9.90 and peak working heart rate was 129.04±8.77. Depending on mean working heart rate, the work load of tasks of the workers was categorized as light to heavy. The chiseling and sawing tasks were within the range of moderate category.

The Cardiovascular stress index (CSI) of the woodworkers uncovered that they were imposed to cardiovascular stress during performing out their diverse carpentry assignments. There was a little variety in CSI among chisel users (CSI values 30.24) and plane users (CSI esteem 33.07). Both of the work had high cardiovascular pressure. Be that as it may, CSI estimation of saw activity (25.18) was beneath than other two tasks. The term of working activity was discovered which was identified with the cardiovascular stress. The work-rest pattern of various classes of woodworkers has been examined and its outcomes were contrasted with the CSI values. The similar outcomes uncovered that more prominent the

level of work time, more noteworthy was the CSI level and the other way around.

The results of the pulmonary function tests showed that all the pulmonary variables (FVC, FEV_1, FVC/FEV_1, $EF_{25\%-75\%}$, PEF, and MVV-index) were below the normal range. The average FVC, FEV_1, FVC/FEV_1, PEF, $EF_{25\%-75\%}$, and MVV-index were 3.21±0.41 litters, 3.04±0.56 litters, 82.12±9.43%, 6.65±1.07 litters/minute, 3.78±1.21 litters/minute and 84.16±13.0 litters/minute respectively. There was prevalence of COPD and other pulmonary dysfunctions among the laborers. The diminished estimations of these pneumonic factors may The lower score the pulmonary function variables might be because of long time exposure of the wooden dust in the workstation. These problems were aggravated among the workers those who were addicted to smoking.

Two ergonomic interventions were employed to lessen the work related health problems of the carpenters.

In the first intervention the chisel, a commonly used hand tool, was evaluated and modified the design of the tool from ergonomic point of view. The carpenters needed to hold the chisel firmly using one of their hands during performing the work. During holding and applying intense force, the chisel user felt distress at the various parts of the body, viz., fingers, palm, wrist and shoulder. An endeavor has been made to redesign the chisel handle considering the human factors. The problems using the conventional handle interface was assessed. Some design ideations were initiated to eliminate the drawbacks. As per proposed ideations the size, shape and texture of the handle were modified and according to that four prototype models were made. In such concepts hand dimensions of the carpenters were incorporated. The psychophysical evaluation of the prototypes was made by means of paired comparison test.

Following adjustments were made to renovate the handle of the chisel.

i. The length of the handles was expanded for proper holding of the tool by considering

the hand length of the users and the results of the paired comparison test.

ii. The diameter of the handles was modified according to the inner hand grip of the users as well as the finding of the paired comparison test.

iii. The shape of the handle was selected from the best scores of the Paired comparison test so that the slippage of the palm could be prevented.

iv. A rubber grip was incorporated at the gripping area of the handle for firm gripping during working.

v. A safety guard made of thick rubber plate was fitted above the holding area of handle for preventing mishit of the hammer.

The overhauled chisel was assessed by a few boundaries, The renovated chisel was examined by some parameters, viz., prevalence of MSD, joint angle study, working pulse rate and productivity study. The consequences of these investigations showed that the redesigned chisel was more efficient, easy to operate and less stressful.

The second ergonomic intervention was the optimization of the height of the workstation for performing various tasks of the carpenters, especially for the plane operators. The existing height of the work surface of the plane operators was varied from one place to another. The average height of the same was about 60.3 cm. Such conventional workstation produced various musculoskeletal problems during doing the work. To find optimum height of the workstation some prototype models of the workstation were made with varied heights,viz.,65 cm, 70cm and 75 cm. Those prototypes were tested by paired comparison test. The prototype which yielded the best score was selected for optimization of the height. In addition to the 5^{th} percentile value of the standing height of the users was also taken into account. Further, EMG studies were conducted on shoulder and back muscles and found that least myoelectric activities were noted. All the experimental studies revealed that the best height of the workstation was 70.0cm. The optimized workstation was tested with by

computing body joint angles, prevalence of MSD and body part discomfort rating. All results were in favour of redesigned workstation. Moreover, productivity study was also supported these findings.

Conclusion: From the above discussion, it could be inferred that the prevalence of work related musculoskeletal issues (WRMSD) was observed among the woodworkers. They were experiencing various WRMSD. The major affected body parts were the lower back, wrist, shoulder, neck, and knee. The magnitude of pain or discomfort rating was also high in those body sections.

The postural stress was high among the workers because of adopting awkward working posture for a long time. The higher pervasiveness of MSD and occurrence of pain or discomfort rate was related with the postural stress. The work related health hazards alongside postural stress could be diminished by adjusting the work-rest cycle.

Proper usage of redesigned chisel and optimized workstation might relieve the carpenters from work associated health hazards and enable them to achieve better productivity. Thus the results of the study might provide well being of the carpenters.