5. Results and Discussion

5.1. Socioeconomic Status:

The purpose of the study was to evaluate the physical efficiency of the carpenters. Before doing that some associated factors were also investigated. Assessment of socioeconomic condition for a group of population is an essential characteristic in community based studies because it is a significant determinant of nutrition and health of an individual.

The socioeconomic status of the carpenters has been determined by three factors, e.g., occupation, education, and family income. The educational status of the carpenters has been shown in Table 5.1. Results showed that the educational level of the carpenters was average. Almost 16% of carpenters in this study were illiterate. The rest of them were literate but only 3.13% had above secondary level education.

Table 5.1: Frequency (f) percentage (%) of educational status of the carpenters (n= 256)

Parameters	Literate				Illiterate
	Primary	Upper primary level	Secondary level	Above secondary level	
f	105	67	34	8	42
%	41.01	26.17	13.28	3.13	16.41

The monetary condition of the carpenters has been shown in Table 5.2. From the results it was observed that the average monthly income of carpenters was only Rs. 4015/- . Results revealed that the monthly income of a large percentage (54%) of the carpenters was below Rs.4,000/- while 19.8% of the workers had a monthly family income of more than Rs. 5,000/-.

Table 5.2: Economic status of carpenters

Monthly family income (Rs.) Mean ± SD	Monthly family income (Rs)			
	< Rs. 3000/-	Rs. 3000-4000/-	Rs. 4000-5000/-	> Rs. 5000
4015.67± 165.73	3.46*****	54.32*****	22.46*****	19.76*****

(*value showing the percentage of total subjects)

From the composite socioeconomic score evaluated by the modified Kuppuswami Scale (Table 5.3) it was revealed that a notable percentage of the carpenters were within the lower middle category (27.73%) and a major parts of the carpenters (72.27%) were belonging to upper lower socioeconomic category.

Table 5.3: Socioeconomic status of carpenters according to the modified Kuppuswami Scale (Raj et al, 2015)

Total Score	Socioeconomic Status Scale	carpenters	
		n	%
26-29	Class I (Upper)	-	-
16-25	Class II (Upper middle)	-	-
11-15	Class III (Lower middle)	71	27.73
5-10	Class IV (Upper lower)	185	72.27
<5	Class V (Lower)	-	-

5.1.1. Discussion: The low literacy level of carpenters might be due to the lack of awareness regarding the advantage of education and also might be due to the limited family income of the subjects. The low socioeconomic status of the carpenters might influence their nutritional intake and health. The socioeconomic condition of the workers might affect the work related health problems. Thus poor socioeconomic status might be one of the concerns for the occurrence of work-related musculoskeletal disorders. Boyer et al., (2009) reported that the socio economic condition of the workers influenced the work-related musculoskeletal disorders.

5.2. Nutritional Assessment of the carpenters:

Nutritional status may be related to the health and efficiency of the workers. Malnutrition is a silent crisis and continues to be a major public health problem all over the world including India. Malnutrition arises either from deficiency or from excess of nutrients in the body. Malnutrition continues to be one of the major human development challenges in India.

According to Binagwaho et al., (2011) malnutrition is enormously linked with poverty and in India it has long been documented as a serious problem. Long term effect of malnutrition is connected with vital consequences in terms of work capacity, substantial growth, reproductive performances and risk of chronic diseases, viz., obesity, diabetes and hypertension (Singh et al., 2013).

In the present study nutritional level of the carpenters was assessed by anthropometric indices. The weight and height of carpenters were measured and from those measures BMI was calculated and the result has been shown in Table 5.4. The results exhibited that the average value of carpenter's BMI was 19.68±2.55 kg/m^2 and the range of BMI of carpenters was in between 15.56- 31.57 kg/m^2. The subjects of the present study had different levels of Chronic Energy Deficiency (CED) and they were classified into different groups according to the degree of severity of energy deficiency (Table 5.5). It was noticed that 41.02% of carpenters were within the underweight class and the percentage of overweight or obese subjects was negligible (Table 5.5) according to the WHO suggested classification (WHO, 1995).

5.2.1. Discussion: The BMI was advocated by the World Health Organization (WHO) as the most useful measurement for evaluating overall obesity as well as undernourishment (WHO, 2012; Kopelman, 2000). However, the BMI is a makeshift index, which is helpful in epidemiological and clinical studies. BMI is the economical, easy and also secure method (Pal et al., 2013; Banik, 2012) and the most first-rate indicator index for the assessment of nutritional status (Das and Bose 2010; Lee and Nieman 2003), predominantly in the field work situation where it is hard to carry out laboratory and experimental test (Ranasinghe et al., 2013; Vasudev et al., 2004). BMI and the status of the nutritional condition delivered as a well indicator of a society mainly for the adult people of developing countries (Venkatramana et al., 2005; Mosha, 2003). The condition of the health has been deteriorated in a graded manner when level of BMI moves low to high. (Kesavachandran et al., 2012).

The classification of BMI was done in different ways by different groups of researchers. One of the most popular BMI classifications was proposed by WHO. In this classification subdivision of the subjects was made into underweight or overweight /obese (WHO, 1995); another famous classification of BMI was suggested by Ferro-Luzzi et al., (1992) where classification was made into different grades of nutrition. These two different classifications were found to match in one point that was the point of cutoff for BMI value of 18.5 kg/m^2. The BMI value below this point was taken as the chronic energy deficiency (CED) or underweight. This classification was used in several previous studies (Bailey and Ferro-Luzzi, 1995; Khongsdier, 2005)

Table 5.4: The physical characteristics of the carpenters (n=256)

Variables	**Mean±SD**	**Range**
Age (years)	41.01±10.54	18-60
Stature (cm)	163.21±4.20	146.26-178.59
Body Weight (kg)	52.23±6.53	39.11-81.43
BMI (kg/m2)	19.68±2.55	15.56- 31.57

The BMI values of carpenters were represented in Table 5.5. It was observed that about 41.02% of carpenters were suffering from underweight (Table 5.5) and according to Ferro-Luzzi classification they had chronic energy deficiency (CED). The Table 5.5 pursued that a higher percentage (34.77%) of carpenters were the representatives of CED Grade I (Mild). About 18% of the carpenters were belonging to normal weight (BMI >18.5 - 20 kg/m^2) category.

Chronic energy deficiency (CED) has been ensured by the level of BMI < 18.5 kg/m2 which was an indicator for an individual who was suffering from loss of energy and as well as low body weight (Khongsdier, 2005).

World Health Organization, 1995 classified low BMI on the basis of worldwide adult population has been given below. Classification made through the population percentage of less than 18·5 kg/m^2 BMI.

- Very high that was higher than equal to 40% : critical situation
- High that was 20–39%: serious situation.
- Medium that was 10–19%: poor situation.
- Low that was 5–9% : warning sign, monitoring required

On the basis of the above the occurrences of CDE among the carpenters ware very high and were under the critical situation.

Table 5.5: Frequency (f) and percentage (%) of carpenters (n=256) showing different levels of Chronic Energy Deficiency (CED) according to BMI

BMI Value	**CED Classification[1]**	**Underweight/ Overweight Classification[2]**		**carpenters**	
		Classification	**Sub class**	**F**	%
<16.00	CED Grade III (Severe)	Under weight	Severe thinness	2	0.78
16.00 - 16.99	CED Grade II (Moderate)		Moderate thinness	14	5.47
17.00 - 18.49	CED Grade I (Mild)		Mild thinness	89	34.77
18.50 - 20.00	Low weight Normal	Normal range		47	18.36
20.01 - 24.99	Normal			102	39.84
25.00 - 29.99	Obese	Overweight		2	0.78
≥30.00		Obese		0	0

[1]Ferro-Luzzi Classification (Ferro-Luzzi et al. 1992); [2]WHO Classification (WHO, 1995)

The poor range of BMI of the carpenters might be the result of poor socioeconomic status (Table 5.3). BMI was proportionate to the monthly income of the family and also a positive correlation was found between family earnings and BMI (Chakraborty et al.,2007 and Bose et al.,2007) Results indicated that the higher number of carpenters was suffering from malnutrition which might be due to the inadequate amount of proper nutrient which also might be indirectly related to their poor economic status. Low BMI and high levels of under nutrition were a major public health problem, especially among rural under privileged adults in developing countries (WHO, 1995). One of the most crucial public health problems among the adults of developing county was malnutrition with low range of BMI (WHO, 1995). People of rural India also had CED with different grades (Bose et al., 2007; Pal et al., 2014a,b and Chakraborty et al., 2007). The carpenters also showed low levels of BMI which might be due to their tight schedule of physical work throughout the day. Strenuous physical activity might be one of the reasons of the low amount of fat in their body and that lead to low body weight. Some commonly known factors such as inequalities of socioeconomic status and also the life style of industrial workers played an important role for BMI (Wadden et al., 2012; Eckel et al., 2014). Distribution of fat in the upper part of the body and averting stoutness might be controlled by physical activity (Wadden et al., 2012; Lee et al., 2012). Levels of BMI are the good predictor for the work ability of the workers, more than normal range of BMI affect on work ability among the workers of advanced age (Linaker et al., 2020). Industrial workers of our country were poorly paid and that might be the cause for poor range of BMI (Khongsdier, 2005).

5.3. Body Composition:

The body composition of a person yields the information about the status of the body fatness and lean body mass. For the most part surplus body fat was assessed through BMI. Even though this indicator was helpful for medical and epidemiological practice - as it was a economic method, but for chronic diseases its extrapolative assessment had been questioned, more than ever it did not take any explanation about the body fat allocation, distribution of the extent of muscle and additional fibers which frame out the whole body weight of an individual, causes for irregularity found in person to person and also population to population (Pal et al., 2013; WHO, 2002). For that reason calculation lean body mass (LBM) and body fat percentage (BF%) were very much required.

From the skin fold measures the body composition of carpenters was evaluated and the result has been shown in Table 5.6. The mean body fat percentage of the carpenters was 14.14% which was within the normal limit (Kesavachandran et at., 2012)

Table 5.6: Mean ± SD of body composition Parameters of carpenters (n=256).

Variables	Mean ± SD (n=256)
Body density (gm/cc.)	1.06±0.02
Body fat percentage (BF %)	14.14±4.0
Total body fat (Kg)	7.6±2.9
Lean body mass (kg)	45.63±3.06

The body compositional parameters might be related to the BMI. The correlation coefficient (r) between different body compositional parameters and BMI has been shown in Table 5.7. A negative correlation was found between BMI and body density whereas a positive correlation was observed between BMI and other body compositional parameters, viz., body fat %, total body fat and lean body mass.

Table 5.7: Correlation coefficient (r) between BMI and other body composition parameters -body density, body fat%, total body fat and lean body mass

Variables	r	P
Body density (gm/cc.)	-0.904	0.001
Body fat percentage (BF %)	0.905	0.001
Total body fat (Kg)	0.911	0.001
Lean body mass (kg)	0.590	0.001

5.3.1. Discussion: Main body compositional parameters, viz., body density, body fat%, total body fat and lean body mass were analyzed in this study. The correlation between BMI and other body compositional parameters were computed in this study and it was clearly observed that there was a significant positive correlation between BMI and all parameters of body composition except with body density. It was well known that the body fat percentage was dependent upon many factors like, overall health, capacity of metabolism, amount of work activity etc and all those factors might also affect the range of BMI (Borga et al.2018). The lean body mass was calculated by subtracting the fat mass from the total mass of the body which indicated that the weight of the organs in the body were also associated with the BMI of the body (David et al., 2014).

5.4. Blood Pressure:

Auscultatory method was applied for the measurement of blood pressure of the subjects. Results have been represented in Table 5.8. It demonstrated that the mean values of blood pressure, both SBP and DBP of the carpenters were within the normal range.

Table 5.8: Mean ±SD of blood pressure of the carpenters (n=256)

Parameters	Blood pressure
SBP (mm Hg)	118.9±9.12
DBP (mm Hg)	72.76±8.0
MP (mm Hg)	88.32±7.57

SBP- Systolic blood pressure; DBP- Diastolic blood pressure, MP- Mean pressure

Table 5.9: Frequency (f) and percentage (%) of carpenters of different blood pressure categories

Blood pressure categories	Carpenters (n=256)	
	f	%
Hypotensive	39	15.24
Normotensive	211	82.42
Hypertensive	6	2.34

In this research study the participant carpenters were divided into three different categories (i.e. normotensive, hypotensive and hypertensive) according to cutoff value of blood pressure as mentioned in earlier section. From Table 5.9 it was observed that higher percentage (82.42%) of carpenters in this study was belonging to the normotensive category and a negligible percent of carpenters were in the category of hypertensive (2.34%).

5.4.1. Discussion:

In general the carpenters were normotensive in this present experiment. Some other study concluded that there was a rising tendency of blood pressure among other populace ('Santal') of Birbhum district in West Bengal (Roy, 2005). This variance might be caused for caste difference and variation in occupation, food habit and life style living.

5.5. Occupational Health Hazards

5.5.1. Musculoskeletal Disorder:

Musculoskeletal Disorders (MSD) is the most common work related health problems among the worker for their exhausting work culture and that may affect nerves, muscles, tendons and intervertebral discs (Summers et al., 2015). Work-related musculoskeletal disorders (WMSD) affect different part of body as well as produce a degenerative conditions like tenosynovitis, epicondylitis, bursitis etc (Russell et al., 2016).

In this study the prevalence of musculoskeletal disorders of the carpenters were assessed by Nordic questionnaire method (sec IV). Results of prevalence of WMSD of carpenters were presented in Table 5.10. The carpenters were categorized according to the tasks executed by them, viz., chiseling, planning, and sawing. Majority of workers were allotted for specific task of carpentry. The prevalence of MSD among carpenters has been represented separately for different tasks of carpenters.

Very high prevalence of MSD was found in different segments of the body among the carpenters. Among all segments, the prevalence of MSD was very high at lower back region (85.55%). A high percentage of carpenters reported pain in their wrist (78.52%) followed by the neck (61.72%), shoulder (69.14%) and knee (69.14%). It was observed that the prevalence of MSD was higher in case of both chiseling and planning at most of the body segments than that of sawing task.

Table 5.10: Frequency (f) and percentage (%) of musculoskeletal disorders (MSD) in the different body segments of the carpenters during performing different tasks

body segments	**Total no of carpenters** (n=256)	**Different task of carpenters**			Chi Square Value among three group ($\chi2$)
		Chiseling (n=82)	planning (n=108)	Sawing (n= 66)	
	f (%)	f (%)	f (%)	f (%)	
Neck	158 (61.72)	53 (65.09)	75 (69.02)	30 (45.37)	$10.413^{\#\#}$
Shoulder	177 (69.14)	48 (58.87)	83 $(76.67)^{*}$	46 (70.45)	$7.341^{\#}$
Elbow	88 (34.38)	28 (34.27)	40 (36.76)	20 (30.45)	0.826
Wrist	201 (78.52)	71 (86.58)	86 (79.62)	44 $(66.66)^{*}$	$8.738^{\#}$
Upper back	131 (51.17)	42 (51.23)	57 (52.66)	32 (48.30)	0.302
Lower Back	219 (85.55)	78 (95.12)	93 $(86.21)^{*}$	48 $(72.73)^{**}$	$14.881^{\#\#\#}$
Thigh	107 (41.80)	41 (49.67)	43 (39.57)	23 (35.30)	3.752
Knee	177 (69.14)	63 (76.83)	64 $(59.26)^{*}$	50 (75.75)	$8.569^{\#}$
Feet	43 (16.80)	13 (15.45)	18 (16.37)	12 (18.54)	0.144

w.r.t. (with respect to) Chiseling $^{*}p<0.05$, $^{**}p<0.01$
Overall: $^{\#}p<0.05$, $^{\#\#}$ $p<0.01$, $^{\#\#\#}$ $p<0.01$

Table 5.10 also represented that most of the carpenters doing sawing, chiseling and planning tasks reported discomfort and pain in their neck region. All the carpenters who were engaged in three different tasks reported pain at the neck region but the prevalence of occurrence of MSD was found higher in the workers who were engaged in chiseling (65%) and planning tasks (69%) than that of sawing.

Results also revealed that carpenters had high prevalence of MSD in the shoulder (69%). It was the highest in planning (76%) followed by sawing (70%), and chiseling (58%).

The prevalence of MSD in back muscle was also found among the workers who were doing different carpentry tasks (Table 5.10). High prevalence of MSD was noted in upper back (51%). It was the highest in case of planning (52%) followed by chiseling (51%) and sawing (48%). A high occurrence of MSD was expressed by the workers in lower back (85%). It was extremely predominant in chiseler (95%) then followed by plane operators (86%) and saw operators (72%). Numerous risk factors viz., adoption of awkward posture, work for prolonged time might be the causes of pain in lower back as well as the upper back portion of the carpenters.

Table 5.11: Frequency (f) and percentage (%) of musculoskeletal disorders (MSD) among three groups of the carpenters according to their work experience (Ex. I: experience =1 – 5 years; Ex. II: experience =6 – 10 years ; Ex. III: experience = > 10 years)

Body Segment	**Ex. I (n=53)**	**Ex. II (n=107)**	**Ex. III (n= 96)**	Chi Square Value among three Ex. Group ($\chi 2$)
	f (%)	f (%)	f (%)	
Neck	35 (65.49)	52 (48.60)	71 (73.62)$^{\#\#}$	14.302$^{\$\$\$}$
Shoulder	37 (69.38)	60 (56.07)	80 (83.51)$^{*\#\#\#}$	17.636$^{\$\$\$}$
Elbow	16 (30.49)	35 (32.71)	37 (38.32)	1.282
Wrist	43 (81.30)	76 (71.03)	82 (85.55)$^{\#}$	6.482$^{\$}$
Upper back	30 (56.08)	44 (41.12)	57 (59.26)$^{\#}$	7.537$^{\$}$
Lower back	50 (94.33)	82 (76.63)**	87 (91.00)$^{\#}$	12.189$^{\$\$}$
Thigh	37 (69.03)	23 (21.50)***	47 (49.40)$^{*\#\#}$	37.250$^{\$\$\$}$
Knee	45 (84.90)	60 (56.07)**	72 (75.06)$^{\#\#}$	16.280$^{\$\$\$}$
Feet	11 (21.29)	14 (13.08)	18 (18.34)	1.911

w.r.t. (with respect to) Ex. I $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$
w.r.t. (with respect to) Ex. II $^{\#}p<0.05$, $^{\#\#}p<0.01$, $^{\#\#\#}p<0.001$

Overall: $^{\$}p<0.05$, $^{\$\$}p<0.01$, $^{\$\$\$}$ $p<0.01$

The work experience may a factor influencing the prevalence of WMSD. In the present study it was evaluated among the groups of workers with different levels of work experience.

Results have been elaborated in Table 5.11. Depending on work experiences, the carpenters were divided into three groups, viz., Ex. I (work experience 1-5 years); Ex.II (work experience 6-10 years) and Ex.III (work experience ≥10years). It was noted that 20.70%, 41.79% and 37.5% of carpenters were belonging in Ex. I, Ex. II, and Ex.III respectively.

Results illustrated that the prevalence of musculoskeletal disorders were higher in carpenters with both lower and higher level of experiences than that of moderate level of experience in all the segments of the body. It might be due to the fact that workers of lower experienced group were less skilled than that of others experience groups. Middle and Higher experience groups gained better skill in their work as they work for much more time than that of lower experienced group. The higher experienced workers were more aged than that of other two groups which might be the reason for high prevalence of musculoskeletal disorders due to aging process (Eerd et at.,2016)).

It was observed from the post hoc analysis that the prevalence of MSD was significantly lower in middle experienced (Ex-II) group than that of lower experienced (Ex-I) group at the region of lower back ($p<0.01$), thigh ($p<0.001$), knee ($p<0.01$). The prevalence of MSD was almost the same in lower (Ex-I) and higher (Ex-III) experienced groups except in the regions of shoulder ($p<0.05$) and thigh ($p<0.05$). Significant difference was also found in middle (Ex-II) and higher (Ex-III) experienced group at neck ($p<0.01$), shoulder ($p<0.001$), wrist ($p<0.05$), upper back ($p<0.05$), lower back ($p<0.05$), thigh ($p<0.01$) and knee ($p<0.01$).

5.5.1.1. Discussion: Many investigators showed relationship between the socioeconomic status and occurrence of MSD. MSD was found to be significantly related with the level of education (Erick and Smith, 2014; Verma and Madhavi, 2017). In this study it was shown that carpenters were belonging to low socioeconomic condition and their level of educational were also very poor. This might be the one of the important reason for the occurrence of higher percentage of MSD. Van der Giessen et al. (2012) suggested that loss of productivity, work incapacity, high rise of product cost, sick leave were caused due to the pain in lower back region.

Work related injuries in developing countries were one of the major issues which were caused by excessive physical stress. Cheng et al. (2016) reported that lifting heavy weight, moving repeatedly and maintain work posture for prolonged time all are responsible for high work related musculoskeletal problems. Workers of unorganized sectors (viz., stone carving, jewelry making, craft work and pottery) were suffering from one most common occupational health problem that was the musculoskeletal problems (Mrunalini and Loeswari, 2015). Carpentry is the most popular unorganized occupational sector for developing countries. The prevalence of MSD was found to be high in the present study. During chiseling carpentry workers were required to lift heavy hammer repeatedly and the workers who were engaged in planning task, were required to operate metal plane in most of the cases. At the time of performing these tasks carpenters had to adapted bending posture which might impose static load on the muscle of shoulder and neck. Eckner et al. (2014) suggested that degenerative change in the spinal cord has been related with static lode on muscle.

Jain et al.(2017) observed that load related illness appeared if continued static load was applied on muscle. During lifting heavy weight on trapezius muscles played an important lead role. Illness in shoulder and neck muscles propagated due to static load in different levels on the neck mainly over the trapezius muscles (McNee et al., 2013). Although repeated movement of head and neck might be the reason for the disorder of neck. Kim et al.(2016) suggested that bending of neck less than 15^0 from the plumb line (i.e., mid-line) has been the causes of musculoskeletal disorders at the region of neck. During executing carpentry task the workers were found to bend their neck.

Frequent repetitive movement are required for all type of carpentry tasks but the frequency of movement was high for planning and sawing than that of chiseling. During performing planning and sawing carpenters had to move their both hands in forward backward motion repeatedly. So in planning and sawing tasks the movement of upper portion of the arm was much frequent. This might be the causes for the occurrence of MSD in shoulder of the carpenters. During chiseling the workers used their right hand to hit on chisel by a hammer repeatedly. Both hands of the carpenters played equal role for performing different tasks of carpentry which might be the causes for pain / discomfort in hand arm system.

Vigorous physical work pressure and repetitive movement of muscle can cause pain and dis-function of soft tissue (Burton et al., 2008; Peters and Johnston 2017). Eenergy of vibration has been catch by the human body due to simultaneous use of hand tool (Pari and Dhara, 2015). In upper part of the body vibration of hand tool affects the tendons of the shoulder (Singh et al., 2014).

Maity and Dhara,(2015) suggested that continuous use of particular muscle, tissue and tendons caused tenderness of tissue and fatigue in muscles as well as in tissue which may lead to physiological exertion. Gallagher et al. (2013) reported repetition of work and duration of exposure to work both was proportional to the amount of tissue impairment. Repetitive movement of arm related with arousal of tenderness in trapezius muscles followed by the shoulder pain (Suh et al.,2015). Trapezius muscle is one of the important muscles in the shoulder mainly in upper arm of the body which plays a role in different types of movement of arm. So, load on the trapezius muscle could refer to as the pointer of shoulder stress. The shoulder muscle injury was also related with repetitive position charge of the arms. Not only repetitive motion of the hand, but also adoption of unusual postures could also be harmful during tissues moves outside the normal range of motion, instigating stress or tear. That Movement of shoulder joint more than 60^0 with awkward posture related to chronic regional disease. This is due to higher level of muscle strain in shoulder (Bron et al., 2012). In all carpentry tasks, the carpenters had to elevate their hand to some extent and this may a cause for tenderness and fatigue-ness of shoulder muscle. Brandt et al. (2014) also stated the similar conclusions. The pain in elbow and wrist joint was also reported by the carpenters. There were repeated movements of wrist joint during the handling of chisel , plane and saw.

Frequent movement of wrist joint of workers especially the workers who were engaged in industrial work lead to discomfort and tenderness in wrist joint (Nunes et al.,2012; Gasibat et al.,2017). During doing all type of tasks the carpenters had to move both wrists (extension/ flexion) frequently. Nag et al. (2009) and Gonçalves et al. (2017) reported that with the frequent movement of wrist the fingers also move repeatedly that rise the ulnar-deviation which related to the contradiction between flexor tendon and carpal tendon. Instability of the movement of hand was related to inflammation, dysfunction of wrist joint (Kozak et al., 2015). Problems in spinal disc may appear from the pain in back muscle. A strong association between physical load and back disorder was suggested by the National Academic of Sciences (Barondess et al., 2001). Pain in back lead to erosion in spinal disk which causes for the distresses between nerve and vertebrae (Manchikanti et al., 2013; Hooten et al., 2015). Forward bending posture increased the pressure of inter-disc causing spinal disc damage (Dimberg et al., 2015; Hartmann et al., 2016). Imposition of extra load on spinal tissue caused damage more rapidly (Kamradt et al., 2017).

In this study prevalence of MSD was high in lower and higher experience group which might be due to lack of training and skill of the workers belonging to lower experience group. On the other hand, higher age group workers had higher level of experience. The workers of middle experience group were more skilled or trained that might be one of the causes for lower prevalence of MSD than others experience group. Most of the previous study concluded that the age was the most vital factors for muscle strength (Holmström and Engelhardt, 2013). Prevalence of MSD was proportionate with increasing age (Bodhare et al.,2016) Cheng et al., (2016) and it was noted in their studies that the duration of work and age had steady association with the WMSD.

5.5.2. Discomfort Rating:

Occupational health status of carpenters was also evaluated by a unique technique that is the body part discomfort rating (BPD). For the measurement of BPD a 10 point subjective scale was used. It was graded “0” (no pain) to “10” (very severe pain) as mentioned in (sec IV). The extent of pain and discomfort was divided into three different categories by a10-point scale (Dutta and Dhara, (2012), as pointed out below:

a) Grade 1 to 4.   : Mild pain
b) Grade >4 to 7 : Moderate pain
c) Grade >7 to 10 : Severe pain

A different rate of body part discomfort was reported by the carpenters involved in different tasks. Shoulder and lower back of the carpenters had high BPD as presented in Table 5.12. Severe degree of pain (severe >7) was found only a few cases among the carpenters. However, moderate degree (>4 to 7) of pain and discomfort was found in shoulder, lower arm, lower back of the body. Chisel operators reported sever discomfort/ pain at shoulder (7.18) and lower back (7.20) and moderate discomfort was noted at neck (6.21) and lower arm (4.79). Severe pain was observed at shoulder (7.10) and lower back (7.28) of the plane user and moderate degree of pain was noticed at lower arm (4.98) and leg (4.01) of the plane user. On the other hand, no pain at any region was found in saw user. Saw user reported moderate level of pain at neck (4.59), shoulder (6.21) and lower back (5.61) regions of the body. Significant difference was observed almost all segments of the body among the three different task performers.

Table 5.12: The Body part discomfort (BPD) rating (Mean ±SD) in different body segments of the carpenters during performing different carpentry tasks (in a 10 point scale).

Body segments		**All carpenters in the study** (n=256)	**Different task of carpenters**			F value among three groups of carpenters
			Chiseling (n=82)	planning (n=108)	Sawing (n= 66)	
Neck		4.72±1.63	6.21±2.21	3.23±3.04***	4.59±2.04$^{***\#\#}$	31.66$^{\$\$\$}$
Shoulder	Right	6.79±1.60	7.18±2.33	7.10±3.32	6.21±1.88	2.88$^{\$}$
	Left	6.27±1.79	5.77±2.36	7.05±3.34**	5.72±1.92$^{\#\#}$	7.13$^{\$\$\$}$
Upper-arm	Right	3.15±2.21	3.28±1.85	3.29±2.12	2.61±1.8	2.92$^{\$}$
	Left	2.90±1.89	3.12±2.09	3.11±2.04	2.56±1.66	1.95
Lower-arm	Right	4.10±1.79	4.79±2.28	4.29±2.11	3.14±2.26$^{***\#\#}$	10.61$^{\$\$\$}$
	Left	4.14±2.12	4.49±1.19	4.98±2.16	3.16±2.01$^{***\#\#\#}$	18.92$^{\$\$\$}$
Upper-Back		2.29±1.88	3.21±2.16	1.99±2.15***	1.62±1.58***	13.29$^{\$\$\$}$
Mid-back		1.03±1.32	1.09±2.01	0.93±1.66	0.89±1.48	0.29
Lower-Back		6.73±2.68	7.20±3.77	7.28±3.1	5.61±2.36$^{**\#\#}$	6.53$^{\$\$\$}$
Buttock		1.01±1.46	0.96±1.58	0.78±1.32	0.86±1.65	0.33
Thigh	Right	2.98±1.74	2.57±2.3	3.58±2.43**	2.41±2.20$^{\#\#}$	6.80$^{\$\$\$}$
	Left	2.83±1.69	2.43±2.24	3.54±2.53**	2.21±2.25$^{\#\#\#}$	8.27$^{\$\$\$}$
Leg	Right	3.41±1.51	2.35 ±2.38	4.01±2.01***	2.92±2.44$^{\#\#}$	13.38$^{\$\$\$}$
	Left	3.10±1.49	2.35±2.32	3.98±2.18***	2.63±2.13$^{\#\#\#}$	14.72$^{\$\$\$}$
Ankle	Right	2.98±1.99	3.57±2.34	2.44±2.06***	2.22±2.03***	19.12$^{\$\$\$}$
	Left	2.87±2.09	3.05±2.22	1.85±1.82***	2.18±2.13	8.30$^{\$\$\$}$
Overall PRD of the body		3.79±2.24	3.83±0.84	3.71±1.54	3.03±0.73$^{***\#\#\#}$	9.84$^{\$\$\$}$

w.r.t. (with respect to) Chiseling $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$
w.r.t. (with respect to) planning $^{\#}p<0.05$, $^{\#\#}p<0.01$, $^{\#\#\#}p<0.001$
Overall: $^{\$}p<0.05$, $^{\$\$}p<0.01$, $^{\$\$\$}$ $p<0.01$

Table 5.13: The Mean ±SD of Body part discomfort (BPD) rating (in a 10 point scale) in different segments of the body of three groups of the carpenters according to their work experience (Ex. I: experience =1 – 5 years; Ex. II: experience =6 – 10 years; Ex. III: experience = > 10 years)

Body Region		**Ex. I (n=53)**	**Ex. II (n=107)**	**Ex. III (n= 96)**	**F value** among three Ex. Groups
Neck		4.56±1.54	3.78±2.11 *	5.64±1.57 $^{***\#\#\#}$	25.27 $^{\$\$\$}$
Shoulder	**R**	4.63±2.01	3.63±2.18 **	5.14±1.99 $^{\#\#\#}$	13.76 $^{\$\$\$}$
	L	4.36±2.03	3.32±2.01 ***	4.85±2.04 $^{\#\#\#}$	14.39 $^{\$\$\$}$
Upper arm	**R**	2.42±2.07	2.37±1.96	2.32±2.13	0.19
	L	2.33±1.81	2.09±1.99	2.69±2.11	2.28
Lower arm	**R**	2.23±1.75	1.70±1.50	1.92±1.13	2.45
	L	2.13±1.77	1.82±1.64	2.15±1.46	1.26
Upper back		3.89±2.61	2.79±2.21 **	4.88±2.03 $^{\#\#\#}$	22.18 $^{\$\$\$}$
Middle back		4.47±1.76	3.08±1.94 ***	4.92±1.79 $^{\#\#\#}$	26.73 $^{\$\$\$}$
Lower Back		5.21±1.58	3.45±1.66 ***	5.34±1.96 $^{\#\#\#}$	34.12 $^{\$\$\$}$
Buttock		3.43±2.07	2.57±1.84 *	3.27±2.62	3.74
Thigh	**R**	1.94±1.80	1.72±1.66	1.77±1.77	0.29
	L	1.68±1.60	1.70±1.67	1.73±1.71	0.01
Cuff	**R**	3.81±1.80	3.62±1.88	4.23±1.92 $^{\#}$	2.72
	L	3.77±1.77	3.59±1.90	4.15±1.57	2.62
Feet	**R**	2.81±1.62	1.20±1.50 ***	2.92±1.60 $^{\#\#\#}$	36.09 $^{\$\$\$}$
	L	2.40±1.48	1.25±1.53 ***	2.54±1.73 $^{\#\#\#}$	18.87 $^{\$\$\$}$
overall body discomfort		3.21±1.82	2.43±2.01	3.36±1.87 $^{\#\#\#}$	6.59 $^{\$\$\$}$

w.r.t. (with respect to) Ex. I $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$
w.r.t. (with respect to) Ex. II $^{\#}p<0.05$, $^{\#\#}p<0.01$, $^{\#\#\#}p<0.001$
Overall: $^{\$}p<0.05$, $^{\$\$}p<0.01$, $^{\$\$\$}$ $p<0.01$

According to duration of work experience of carpenters the body part discomfort was evaluated and the results have been shown in Table 5.13. Significant difference (p<0.05 or less) of BPD was observed among three experience groups of carpenters in most of the body segment apart from upper arm, lower arm, thigh, cuff, and buttock. Results described that the rate of BPD was low in middle experienced group in comparison with lower and higher experience group as illustrate in observations of prevalence of MSD. The post-hoc analysis of BPD was done between the groups and results showed that the BPD of middle experience group (Ex-II) was significantly lower ($p<0.05$ or less) than that of lower experience (Ex-I) groups in neck, shoulder, upper back, lower back, buttock and feet of body. In addition, the mean BPD in moderate experienced group (Ex-II) was also significantly lower ($p<0.05$ or less) in neck, shoulder, upper back, mid back, cuff, feet in comparison with that of high experienced groups (Ex-III).

5.5.2.1. Discussion: From the results it has been revealed that the carpenters had different levels of body part discomfort during executing different tasks. Array of task might be responsible for the high rate of discomfort at neck shoulder and lower back of the body. Adoption of bending posture by the carpenters was very common in all tasks of carpentry. Van Hoof et al (2012) and Vijendren et al., (2016) suggested that bending posture was more stressful work posture than the straight back postures. A factor that was originating discomfort was the bending posture during work (Chaffin et al., 2006).

Severe discomfort was found in the shoulder of chisel and plane users which might be due to frequent movement of hand and recurrent hitting the hammer. Some previous studies expressed that several factors had proportional relation with rate of discomfort. Those factors are: complicated postures (Heneweer et al., 2011), high biomechanical load (Hallman et al., 2016), stressful physical work (Widanarko et al., 2015), lifting of heavy weight frequently (Linaker et al., 2015), and work for a long duration (Hallman et al., 2016).

Severe discomfort was found in shoulder and lower back region of the chisel and plane user. However moderate rate of discomfort in shoulder and lower back was reported by the saw user. Static load for using heavy hammer and plane might the reason for the shoulder and lower back pain (Lee et al., 2012).

High degree of body part discomfort was reported in different work groups by different investigators. In industrial workers body part discomfort was sturdily associated with duration of work experiences (Lee and Nussbaum et al., 2012). Same pattern of results in both the study of MSD and BPD was observed among the workers. Therefore, both the studies proved that the incidence of discomfort / pain in different segments of the body varied with the skill of work and working postures of carpenters

Fulmer et al., (2017) found the relation between work experience and pain/ discomfort of the body segments among the constructional workers. They observed that the pain of the body segment was increased with increasing experiences. They noted that 33% of constructional workers feeling pain discomfort with experience of 5 years or less whereas 40% of workers feeling pain with experience range of 6- 10 years. Further, 84% of workers was effected when the year of experience increased to 30.

In the present study highest rate of pain and discomfort was reported in higher experience group (Ex-III) having greater than 10 years of experience than that of moderate experience group (Ex-II) having year of experience in between 6 to 10 years (Table- 5.13). Muscle strength and muscle endurance was reduced with age that might be the reason for the higher rate of BPD in higher experienced workers (Williams et al 2015). Various previous researchers also reported that the age was the most effective factor for the occurrence of BPD (Wandner et al., 2012). The experienced workers habitually old in age had discomfort in the back, hands and legs. Ageing was the most important factor for the occurrence of different physiological problems and that also caused impairment of nervous system. (Helme and Gibson, 2001; Riley et al., 2014). It may be summarized that the stated discomfort of the carpenters in the present study might be due to bad work posture, bad circumstances at place of work together with extended period of work time and overworking.

5.5.3. Work Rest Cycle in carpentry task:

The entire work shift of the carpenters was divided into the time period for work and rest. The work rest cycle of the carpenters doing different types of tasks has been presented in Table 5.14. In most of the cases the workers would join their work at 6 am and work for 4 hours continuously. Generally they would take one hour as food break. After taking food break workers rejoined in their work and continued their work for about another four hours. Mostly, these types of work and rest pattern were maintained by the carpenters in three carpentry tasks.

In different carpentry tasks the work time was found to vary in between 74.8% to 79.19% of total time of work shift whereas the time of the rest time was noted from 20.81% to 22.68% of the total work shift. Results illustrated that the highest time (79.19%) of work was devoted by the chisel operators which was followed by plane users (77.58%) and then saw users (74.8%). The highest time of rest was taken by saw users (25.2%) and this was followed by plane users (22.42%) and by the chisel operators (20.81%).

Once work was done by the worker, recovery is necessary for that individual which was achieved by taking rest. Fatigue and recovery are the factors which were dependent to each other. One (Fatigue) is the degenerative process and other one (recovery) is the regenerative process. So the fatigue is the transitory and revocable. The effect of fatigue may be reduced by taking rest after the work (Geurts, 2014). Even though, in certain environments the process of recovery might be unsatisfactory or poor and that might be the reason for transformation of short-term fatigue into adversarial and more long-lasting health problems (viz, sustained fatigue, prolonged tension and sleep deficiency) (Coffeng et al., 2015, Tuomivaara et al., 2017) and finally form illness or disease (Hülsheger et al., 2014, Thun et al., 2016).

A particular work was related to particular muscle or body part of workers which was used for repeated times (Stanton et al., 2004; Karwowski, 2012). Petreanu et al (2017) suggested that such an uses of specific muscle repeated times tended to form soft tissue damage and finally grow MSD in specific body segment. Therefore, it is necessary to take recurrent rest to recharge the affected muscles. This was a useful procedure for enhancing muscle strength or decreasing fatigue related with the task. Breaks during the work or between the tasks were very much important not only for the fatigue of muscles but also for the nervous systems which equally worked with those muscles (Kroemer and Grandjean, 2001; Kroemer, 2017). Work and rest are cyclical process consist of energy deposition and energy store in the body that was an essential process for regeneration of muscles.

Table 5.14: Mean ± SD of work time and rest time (minute) of workers in different carpentry tasks

Different carpentry job	Total time of work (minute)	Total time of rest (minute)	Total duration of work shift (minute)
Chiseling (N=82)	415.19±21.39 (79.19%)	109.12±8.32 (20.81%)	524.31±23.84 (100%)
planning (N=108)	407.15±25.6 (77.58%)	117.69±10.27* (22.42%)	524.84±21.04 (100%)
Sawing (N= 66)	385.18±26.7$^{*\#\#}$ (74.8%)	129.9±10.2$^{*\#\#}$ (25.2%)	515.08±21.79$^{\#}$ (100%)
All tasks (N=256)	409.54±31.38 (77.32%)	120.15±11.84 (22.68%)	529.69±29.16 (100%)

w.r.t Chiseling * p<0.001
w.r.t planning $^{\#}$ p<0.01, $^{\#\#}$ p<0.001

In this study, the average time taken for rest was 22% of total work shift by the carpenters. But the time for rest was utilized or enjoyed by the carpenters non-appropriately. That's why an appropriate scheming of work rest-cycle is important for retrieval of work-energy of those carpenters.

In the present study, in spite of taking rest the workers showed high value of Cardio Vascular Stress Index (CSI) (sec IV; 4.9.2.) that indicated the improper scheduling of rest time. It was noted that cardiovascular stress was directly or indirectly related with the rest period (Table5.14.).

Table 5.15: Mean ± SD, percentage (%) of different categories of rest pauses (in minute) in different carpentry tasks

Different carpentry job	**Work associated rest**			**Recommended rest (diet break)**				**Total rest time**
	Sitting idle	**Standing idle**	**Total**	**Tiffin**	**Tea**	**Lunch**	**Total**	
Chiseling (N=82)	23.58 ±7.12 (21.6%)	21.58 ±7.40 (19.8%)	45.16 ±7.41 (41.4%)	21.07 ±4.35 (19.3%)	17.75 ±2.51 (16.3%)	25.14 ±4.66 (23%)	63.96 ±4.02 (58.6%)	109.12± 8.32
planning (N=108)	24.26 ±6.91 (20.6%)	23.06 ±7.34 (19.6%)	47.32 ±7.01 (40.2%)	22.93 ±3.76 (19.5%)	21.98 ±4.91 (18.7%)	25.46 ±4.56 (21.6%)	70.37 ±5.14 (59.8%)	117.69± 10.27
Sawing (N= 66)	28.16 ±8.47 (21.7%)	28.59 ±9.51 (22%)	56.75 ±9.52 (43.7%)	24.64 ±3.12 (19%)	21.15 ±4.83 (16.3%)	27.36 ±3.39 (21%)	73.15 ±4.24 (56.3%)	129.9±10.2
All tasks (N=256)	25.73 ±7.31 (21.4%)	25.32 ±8.12 (21.1%)	51.05 ±8.29 (42.5%)	23.12 ±3.81 (19.2%)	18.88 ±5.23 (15.7%)	27.10 ±3.87 (22.6%)	69.1 ±6.76 (57.5%)	120.15± 11.84

Therefore, it might be suggested that the rest schedule of the carpenters was obligatory to modify and should be set as long as of adequate recovery time. The work rest schedule was further studied and the results have been shown in Table 5.15. The total rest period was divided into two parts viz., the work associated rest and the recommended or prescribed rest. The recommended rest was only for the food break which was obvious regular in nature. But the work associated rests were irregular by nature. Results showed that highest percentage of rest taken by the saw users (43.7%) followed by the chiseler (41.4%) and by the plane users

(40.2%). It was also observed that the highest percentage of recommended or prescribed rest was taken by the plane user (59.8%) which was followed by chiseler (58.6%) and the saw users (56.3%).

5.5.3.1. Discussion: Chiseling required high energy during performing the task due to hitting of hammer on the chisel frequently and also the plane users required higher energy for movement of upper limbs with heavy plane. Avlund, (2013) and Theou et al., (2008) told that demanding task might lead with deficiency of energy and ultimately cause body fatigue.

As the work associated rest was not adequate for recovery of fatigued muscle, a 'standard time' break was necessary for recharging the working muscles. (Armstrong, 2009). In the present study chiselers took shorter duration of work associated rest than plane user and saw users. It might be due to fact that the chiselers had to perform more attentive work which needed much concentration and so they could not take rest frequently during work. The Plane and saw operators took rest in between the gap of work but it was not sufficient for the recovery of muscle activity as they had to use their upper limbs more frequently and vigorously. Apart from all those task carpenters had to perform others carpentry tasks like , cleaning of the wood mass which was created out of the task, packaging of the wooden stuff which was manufactured, fitting the wooden stuff at proper position of the product and all those tasks created additional stress among the carpenters.

It is suggested that the carpenters should not take a longer rest rather it might be more effective when a long duration single rest time is replaced with the numbers of rest time with short duration. Powell, (2017) also opined that in a working day numerous numbers of short breaks were healthier than a single long break. Sadeghniiat-Haghighi and Yazdi (2015) stated that numerous short breaks could prevent extremity of fatigue in muscles as well as muscle injury which could not protect by a long or less recurrent break. Therefore, the appropriate design of scheming of work-rest cycle for the carpenters might be advantageous.

Work related MSD would be intervened by the recovery rest (Faucett et al., 2007 and Chakrabarty et al., 2016). The word intervention related with the differences in productivity. It was concluded that more frequent rest during work reduce as well as recover the injuries related to work place and increases the productivity (Gallis et al., 2013). Samani et al., (2009) and Luger et al., (2015) suggested that active rest during work also useful to more flexible muscle action which might have obligatory faction for WMSD

5.5.4.Postural Analysis:

Work posture is highly related to the productivity as well as work related musculoskeletal problems. Several studies pointed out that implementation of ergonomic principle in most of the working area caused an increase in productivity and reduce work related MSD (Gangopadhyay et al., 2014; Abareshi et al., 2015). Working posture adopted by different carpentry tasks was evaluated. Carpenters had to adopt different complicated postures to fulfill their task, viz., erect, bending, squat sitting, and twisting etc.

Different researcher used different methods for postural analysis according to posture adopted by the workers (Mc-Atamney and Corlett, 1993). Among several methods, direct observation method was more effective method when there was a condition of movement of the total body parts. In other hand, direct observation method is easier and more economic method for postural analysis.

In this study direct observation method was implicated by using video photographic technique for analysis of postural stress. The benefit of video recording method was that the researchers would get adequate time to examine the work posture. In addition, this technique was also very helpful to researcher for remembering the work posture by viewing the video (Ismail et al., 2009; Pari and Dhara, 2015). Analysis of postural stress of carpenters has been discussed in this part.

Carpenters had to take up different inappropriate working posture during performing the task (Table 5.16). Results showed that carpenters had to adopt many awkward postures, viz, sitting with folded legs (forward bending), erect with forward bending, erect with one leg folded at upper position (forward bending) throughout their working shift. Forward bending in erect condition was the more dominant posture for the carpentry task. For instance, during using the chisel the carpenters used to adopt sitting posture with one leg folded under forward bending condition for most of the time (85.50% of total work time). This kind of posture also adopted by plane user but for period of comparatively shorter duration (25.6% of total work time) than that of chisel operators. Plane users were habituated to work with forward bending posture (74.4% of total work time). Forward bending posture was the one of the common posture in carpentry which was used by the plane user (74.4%) and the saw users (13.62%).

Table 5.16: Percentage (%) and Mean ±SD of work time for different work posture adopted by carpenters

Working postures	**Different carpentry task**		
	Chiseling (n=82)	planning (n=108)	Sawing (n= 66)
Sitting with folded legs (forward Bending)	355.04±39.17 (85.50%)	104.25±30.60* (25.6%)	-
Erect with forward Bending	60.15±25.71 (14.5%)	302.9±22.59* (74.4%)	52.46±11.48# (13.62%)
Erect with one leg folded at upper position (forward Bending)	-	-	332.72±24.39 (86.38%)
Total working period	415.19±21.39 (100%)	407.15±25.6 (100%)	385.18±26.7 (100%)

w.r.t. chiseler *$p<0.001$; w.r.t. plane user $^{\#}p<0.001$

5.5.4.1. Discussion: Forward bending was one of the common postures for all kind of tasks performed by the carpenters. They were found to adopt forward bending posture for a long time which was very stressful for the workers and that might be the cause of occurrence of low back pain. Long term taking up of bending posture might impose the tension in the disk and finally tends to back pain. Most of the time carpenters required to have forward bent under erect condition or sometimes to work with squat sitting posture. This kind of postures was very strenuous and continued for a long time.

Researchers (Mukhopadhyay and Khan, 2015) also suggested that some factors like, awkward postures, frequent doing of the same task, and handling of load could create work related MSD among the workers. Awkward postures with long period of time also the reason for high rate of pain and discomfort (Chung et al., 2005; Rao et al., 2012). During performing the task for a long period of time, the workers used to change their posture unconsciously. So, it was observed that they were exposed to some stressors and uncomfortable posture which required high energy consumption. During performing stressful tasks a proper work posture was necessary for the workers. Appropriate posture for the task was the stress reducing factors for health and it could increase the productivity also. (Pejčić et al., 2016). It was necessary to aware the workers about their bad work posture and their bad effect and on the other hand the beneficial effect of adoption of appropriate work posture (Williamson, 2000; Gallagher, 2005).

Carpenters had also to adopt twisted posture as stated earlier. Other investigators (Dul and Weerdmeester, 2008 ; Thatcher, 2013) suggested that body discomfort and pain occurred due to the most common factor that was the twisted posture of workers. It was observed that it was difficult to hold the load under the difficulties found during forward bending posture with static load (De and Bhasin 1991). This might be one of the explanations for back problem in carpenters. This also might the causes for disk pressure which might lead to back and shoulder problems. Static muscular load commonly in trunk region was created by the long duration bending posture. Therefore, postures adopted by the carpenters were very harmful for the vertebra as well as for musculoskeletal system also. From previous study it was obtained that twisted and bended back created maximum postural stress than that of straight back postures (Montgomery et al., 2011; Fleisig et al., 2013).

It was found from the study of BPD (sec IV; 4.6.2) and MSD (sec IV;4.6.1) that the carpenters who carried out different carpentry tasks stated pain and discomfort at lower back, shoulder and knee joint which might be caused due to adopting those postural patterns.

Significant association was found between awkward twisted back posture with the occurrence of low back pain (Goswami et al., 2016; Kanyenyeri et al., 2017) and both were judged by workers to be the most causative job factors of pain and injury. Soft tissue were decreased with long time flexion which caused for shortening of back muscle strength, physical inability and muscle injury (O‟Sullivan et al., 2006; Claeys et al., 2011).

5.5.5. Analysis of Posture by OWAS, RULA, REBA and QEC Methods:

Patterns of posture adopted by the carpenter during performing different tasks were analyzed. In the present study postural analysis was done on 30 randomly selected carpenters from all task groups of formerly selected 256 carpenters. Alphabetical order was followed to select the subsamples in this study.

Depending upon the type of work and requirement of tools for performing a specific task as well as the frequency and duration of work cycle, the workers had to adopt various types of postures in their work place. For assessing work posture as the risk factor for musculoskeletal damage, the postural analysis can be an acceptable technique (Kee and Karwowski, 2007). The work related pain / discomfort in different body segments can be pointed out by the assessment of work postures through ergonomic methods. A number of methods have been suggested by the researcher for assessing the work posture and also for finding the ergonomic risk factors of workers. Depending on postural types there are several observational methods for the assessment of postural stress, e.g., OWAS (Heinsalmi, 1986), LUBA (Kee and Karwowski, 2001), RULA (Mc-Atamney and Corlet, 1993), REBA (Hignett and Mc-Atamney, 2000), QEC (Li and Buckle, 1999) etc. From those techniques, OWAS, RULA, and REBA are the most used techniques for postural assessment of workers. From more than 30 years OWAS (Ovako Working Posture Analysis System) has been used for estimating the risk level of MSDs (Karhu et al. 1977). Injury tendency at different industries was estimated by effective technique of OWAS (Grecchi et al. 2006). As the versatile postural pattern was present in OWAS technique, so this method was widely used.

Different tasks of carpentry were dynamic in nature and involved entire body parts. The OWAS postural analyses have been worked out on a wide range of postures of workers involved in different jobs like, brick kilns workers (Sahu and Sett, 2010) , nurses (Goswami et al. 2013) and the workers in different small and large scale industries (Kee and Karwowski, 2007) but the results can be poor in detail because some of the body parts were not included in the analysis (Hignett and Mc-Atamney, 2000, Pal et al. 2015a). Hignett and McAtamney (2000) stated that RULA is generally used if the person is sitting, standing still or in an otherwise sedentary position, and mainly using the upper body and arms to work. Quick Exposure Checklist (QEC) is an observational method is used for the assessment of exposure of upper body and limb for static and dynamic tasks. For all other tasks REBA should be used. Researchers (Sahu and Sett, 2010; Mukhopadhyay and Srivastava, 2010) used several posture analysis methods viz. OWAS, RULA, REBA etc. simultaneously for posture analysis. In the present study all the four methods ware applied for posture to get additional information about the postural stress during performing carpentry tasks. In carpentry both static and dynamic activities are involved and moreover, both upper and lower parts of body are engaged in executing the tasks. That was the reasons for employing different posture analysis methods.

Tables 5.17 to Table 5.19 represented the results of the posture analysis by employing OWAS, RULA, REBA and QEC methods for three major tasks of carpentry.

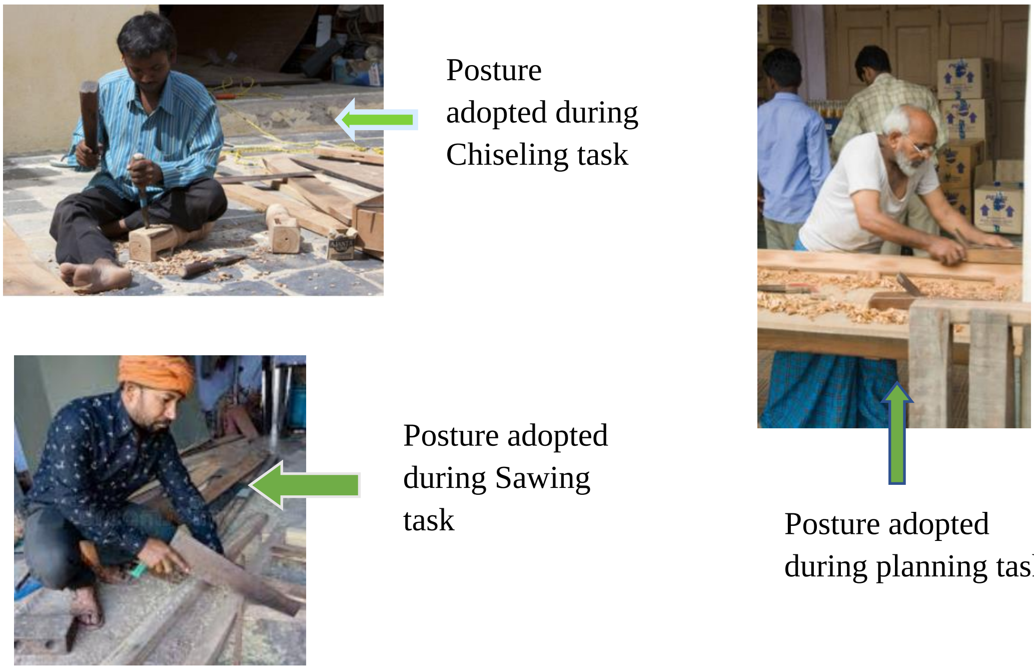

Fig 5.1: Different type of posture in carpentry task

5.5.5.1 Chiseling:

It has previously been stated that the dominant postures taken up by the workers during chiseling were the forward bending posture and sitting on the floor with one leg folded. According to the outcome of postural analysis by OWAS method, it was noted that the forward bending posture or other posture adopted by chisel users required corrective measure as early as possible. Similarly, results of the postural study by RULA and REBA methods revealed that both forward bending and sitting with one leg folded postures were considered as high risk and it was necessary to investigate and to alter instantaneously. The study of chiseling tasks by QEC method quantified the risk level of specific body segments including the neck, shoulder/arm, back and wrist/hand (Table 5.19).

If the postural risk of chiselers was observed separately we could see that in workers the risk level was high in back and neck and moderate in wrist/hand, shoulder/arm while adopting forward bending posture as well as sitting posture with folded leg.

Table 5.17.: Action and risk levels of postural analysis of all carpentry tasks by different methods

Tasks	OWAS		REBA		RULA	
	Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Chiseling (n=30)	3	Corrective measures as soon as possible	10	High risk, investigate & implement change	7	Investigate and change immediately
planning (n=30)	3	Corrective measures as soon as possible	12	Very high risk, implement change	7	Investigate and change immediately
Sawing (n= 30)	3	Corrective measures as soon as possible	11	Very high risk, implement change	7	Investigate and change immediately

5.5.5.2. Planning:

In case of planning task in carpentry, the results of postural assessment by OWAS method indicated that the posture needed corrective measure as soon as possible. Similarly from the results of postural assessment by RULA and REBA methods, it was found that the posture adopted during planning task was of very high risk and needed the change of posture immediately. The results of the posture analysis by QEC method revealed that the risk level was high in back, shoulder/arm and neck and moderate in wrist/hand while performing planning task.

5.5.5.3. Sawing:

The analysis of postures adopted by the workers during sawing task in carpentry showed that the posture needed corrective measure as soon as possible (OWAS method). According to the analysis done by REBA and RULA methods the postures adopted by the workers during sawing operation was categorized as very high risk and needed change in the posture soon. The results of the posture analysis by QEC method indicated that the risk levels were high at back and neck and moderate at the shoulder/arm, wrist/hand, while performing sawing task in forward bending posture.

Table 5.18: Percentage of carpenters belonging to different action categories (AC) in different tasks according to three methods

Experience group	Different methods	AC 1	AC 2	AC 3	AC 4	AC 5
Chiseling (n=30)	OWAS	_	19%	78%	3%	_
	REBA	_	_	_	11%	89%
	RULA	_	_	4	96%	_
planning (n=30)	OWAS		17%	79%	4%	
	REBA	_	_	_	9%	91%
	RULA	_	_	_	100%	_
Sawing (n= 30)	OWAS	_	20%	78%	2%	_
	REBA	_	_	_	13%	87%
	RULA	_	_	4	96%	_

Table 5.19: Postural analysis by QEC method: scores and risk levels in different carpentry tasks

Body parts / Stress	**Score / Risk level**	**Tasks**		
		Chiseling (n=30)	planning (n=30)	Sawing (n= 30)
Back	score	34	40	32
	Risk level	High	High	High
Shoulder/ arm	score	30	32	28
	Risk level	Moderate	High	Moderate
Wrist/ Hand	score	30	30	30
	Risk level	Moderate	Moderate	Moderate
Neck	score	14	14	14
	Risk level	High	High	High
Vibration	score	4	4	4
	Risk level	Moderate	Moderate	Moderate
Work pace	score	4	4	4
	Risk level	Moderate	Moderate	Moderate
Stress level	score	9	9	9
	Risk level	High	High	High

If we go for a comparative analysis for three tasks of carpentry, it was observed that the carpentry task was very stressful. From the results of QEC it was noted that most of the body segments were under high risk and the stress level was also high when performing carpentry task. If we consider the risk level of different body segments (QEC results), it was revealed that the back and neck were exposed to high risk level in all carpentry tasks (Tables 5.19).

Studies of MSDs and discomfort rating revealed that during performing different carpentry tasks the workers reported to be suffered from the pain/ discomforted in different body segments which might due to their postural pattern as well as long duration of work in awkward postures. The results of the posture analysis supported the results of MSD studied by different groups of investigators. Das, (2014) and McNee et al. (2013) noted that MSDs in different segments of the body was highly prevalent among the workers. They also stated that the most common MSDs in workers were at the lower back followed by the upper back and then at lower extremities of the body. O'Sullivan et al. (2006) reported that musculoskeletal pain was more common among the workers when they worked in squatting position. Long term adoption of bend and twist postures was associated with postural stress. Several researchers (Gallagher et al. 2005; Kim et al. 2016) reported that the major work-related risk factors which were associated with lower back pain, were identified as awkward work postures, viz., forward bending and twisting movements, lifting. Awkward working posture always occurred when the workers performed the job with their body parts deviating significantly from the natural posture. In case of performing job in awkward working posture, a high force was applied in the skeletal system and might lead to acute overloading and damage of skeletal structures (Kozak et al. 2015). Kozak et al. (2015) also reported that prolonged performance of tasks with inclined trunk might create WMSDs associated with lower back pain especially in the lumbar region. Van Herp et al. (2000) showed that repetitive movements and activities, prolonged static positioning, forceful exertions and non-neutral body postures have been identified as key risk factors for MSDs.

From different posture analysis methods it may be summarized that the postures adopted by the workers had risk levels from 'medium' to 'very high' in different tasks of carpentry. The workers suffered from health problems, perhaps because of prolonged working hours, awkward posture and used less safety measures while working. Moreover, ergonomic interventions such as redesigning the hand tools, working with appropriate posture and modifying work-rest schedule would improve the conditions and reduce their MSDs. From this study it has been recommended that workers should avoid awkward work postures as far as possible and take adequate rest during their work for reducing job related health hazards.

5.5.6. Evaluation of Center of Gravity

Every human being possesses a center of gravity (CG) which has an important participation during any type of movement of the human body. The position of CG in the body is a determining parameter for the equilibrium of the body.

As mentioned earlier, three different posture were adopted by the carpenters for performing different tasks , e.g. sitting with folded leg along with forward bending during chiseling, erect with forward bending during planning. The CG of the carpenters was determined during normal standing as well as during performing the carpentry tasks. The CG of the former position was taken as reference in this study. Changing the location of the CG from reference point denoted as deviation of CG. Results of the of the CG studies of carpenters performing different tasks have been presented in Table.5.20

The vertical location of CG of the carpenters became significantly ($p<0.001$) lowered from that of the reference location of CG during performing chiseling work and on the other hand the value of vertical CG were significantly higher for the posture which were adopted during planning and sawing task from that of the reference posture (Table 5.20). Results revealed that there was a highly significant ($p<0.001$) difference in the position of vertical CG among three different tasks ,e.g. , chisel operating task (41.92±1.18), plane operating task (72.86±8.90) and saw operating task (70.42±5.31).

Table 5.20: Centre of gravity (expressed as % of the length of the body) of the carpenters in different carpentry tasks

Postures	Vertical CG		Horizontal CG	
	Location of CG (Mean ±SD)	Deviation from reference posture	Location of CG (Mean ±SD)	Deviation from reference posture
Normal standing (Reference posture)	60.34±2.47	-	39.61±4.29	-
Chiseling (n=30) (Sitting with folded leg under forward bending)	41.92±1.18 $	18.42	84.79±6.70 $	-45.18
planning (n=30) (Erect with forward bending)	72.86±8.90 *$	12.52	48.50±8.55 *$	-8.89
Sawing (n= 30) (Erect with one leg folded at upper position under forward bending)	70.42±5.31 *$	10.08	49.03±6.65 *$	-9.42

w.r,t Chiseling *p<0.001; w.r.t reference posture $ p<0.001

From the results it was observed that the maximum shift of the location of CG towards the base of the body was taken place during sitting on the ground in comparison to that of erect posture (Table-5.20). As a consequence the body became more stable while workers performed their work by sitting on the floor.

In case of horizontal CG the deviation of the same from the reference posture was the highest in case of chiseling performed by sitting on the floor. There was also significant deviation of horizontal CG while sawing and the deviation was the least in case of planning task.

5.5.6.1. Discussion: The location of vertical CG was found to be lowered in chisel operating work postures of carpentry task in comparison to the reference posture. This might be caused by adoption of sitting posture during performing this carpentry work. The vertical CG of the workers was found to be shifted to upward direction during plane and saw operating tasks. It might be due the bending posture taken up by the workers during those tasks. Changes in the length of the body center of gravity sifted from reference position and it was also sifted with handling lode by the muscle and also by the joints (Dubey et al., 2019). The variation in vertical CG in different work might be related to variety of posture adopted by carpenters as well as the position of the body segments also change in relation with the task variation (Maity et al., 2014). Partial movement of body or changing position of the body is related to common changes in center of gravity. With raised or dropped arm above the head the center of gravity becomes higher and lower respectively within the human being. As well as during stretching of arm with forward or backward movement, the center of gravity sifts anterior or posterior direction within the body. During forward bending posture the trunk is flexed in forward direction and that position helps CG to shift outside the body (Schafer, 1997). Stability of body becomes lower with greater shifting of CG from the reference position of CG (Virmavirta and Isolehto, 2014). Common association between the squatting posture and center of gravity was explained by Mastalerz and Palczewska, (2010) and it was suggested that they have linear, dimensionless functions. According to CG analysis, if the shifting of CG towards upper side of body it was meant that the body stability is less and imposes postural load. Therefore, high deviation of CG from that of the reference posture pointed out the unsteady posture adopted by the workers that might be cause for musculoskeletal problems among the carpenters. A notable shifting of vertical CG towards the base was observed during chiseling than that of planning and a least deviation in horizontal CG was found in case of planning operation.

5.5.7. Study of EMG voltage:

By means of electromyographic (EMG) study, the information regarding comparative quantity of muscular involvement in an exercise along with the optimum positioning for the exercising muscle could be identified (Motamedzade et al., 2014). In the present investigation different muscles, e.g., forearms, biceps, triceps, shoulder (Trapezius) and back muscles (Lattisimus dorsi) in three different carpentry tasks, e.g., chiseling, planning and sawing were selected for EMG studies. The EMG record in normal standing condition was marked as reference and the deviation of EMG voltage in working conditions from that of reference posture was calculated.

Table 5.21.A: Mean and standard deviation EMG RMS values (μV) of different arm muscles of carpenters in normal standing and three different working conditions (n=30)

Postures	Fore arm		Biceps		Triceps	
	RMS-R	RMS-L	RMS-R	RMS-L	RMS-R	RMS-L
	Value (μV)	Value (μV)	Value (μV)	Value (μV)	Value (μV)	Value (μV)
Normal standing (resting)	7.5 ±5.69	9.6 ±5.35	4.4 ±2.56	22.8 ±16.57	6.3 ±5.36	5.2 ±2.28
Chiseling(n=10)	243.8 ±61.53	213.9 ±44.31	135.4 ±29.46	110.6 ±24.16	143.2 ±38.19	112.8 ±26.73
Deviation from normal	236.3	204.3	131	87.8	136.9	107.6
planning(n=10)	206.0 ±43.78	136.4 ±34.64	142.4 ±59.10	101.6 ±52.19	163.8 ±21.73	149.2 ±58.32
Deviation from normal	198.5	126.8	138	78.8	157.5	144
Sawing(n=10)	200.4 ±54.42	198.7 ±38.16	140.1 ±25.12	129.3 ±28.10	158.4 ±27.35	167.6 ±31.26
Deviation from normal	192.9	189.1	135.7	106.5	152.1	162.4
F-value	1.93	10.95**	0.07	1.46	1.27	4.58*

*p<0.01; **p<0.001

Table 5.21. A and Table 5.21.B represents the RMS values of EMG signal of five different muscles of carpenters. To find out the significant variation of absolute EMG voltages and RMS values during performing three different carpentry tasks, the analysis of variance (ANOVA) was employed. The results illustrated that EMG RMS values of forearm, triceps, shoulder muscle and back muscles were significantly different ($p<0.01$ or lesser) in different carpentry tasks. Results also illustrated that the value of RMS for the fore arm muscle was the maximum for the chisel operating task and for the biceps and triceps muscles the said value was the highest for the plane operating task. The result of the ANOVA test revealed that there were significant ($p<0.01$; $p<0.001$) differences among the tasks for the fore arm and triceps muscles.

Table 5.21.B: Mean and standard deviation EMG RMS values (μV) of shoulder and back muscles of carpenters in normal standing and three different working conditions (n=30)

Postures	Shoulder muscle (Trapezius)		back muscle (Lattisimus dorsi)	
	RMS-R	RMS-L	RMS-R	RMS-L
	Value (μV)	Value (μV)	Value (μV)	Value (μV)
Normal standing (resting)	14.0±10.36	17.6±8.35	10.3±6.10	9.8±4.97
Chiseling(n=10)	198.2±53.13	102.5±28.18	210.5±34.12	209.4±29.88
Deviation from normal	184.2	84.9	200.2	199.6
Planning (n=10)	193.0±52.70	126.8±88.49	211.6±24.83	206.7±22.49
Deviation from normal	179	109.2	201.3	196.9
Sawing (n=10)	221.5±32.64	232.1±22.84	245.5±27.7	219.4±29.41
Deviation from normal	207.5	214.5	235.2	209.6
F-value	1.03	15.56**	4.65*	0.59

*p<0.01; **p<0.001

Table 5.21.B represented the RMS values of back and shoulder muscles of carpenters involving three different tasks and this table illustrated that the RMS values of the back muscle and shoulder muscles were the highest for the saw operating workers. The RMS

values of those two muscles were significantly ($p<0.01$; $p<0.001$) varied among different tasks.

Fig I: Recording of EMG (normal standing of four arm)

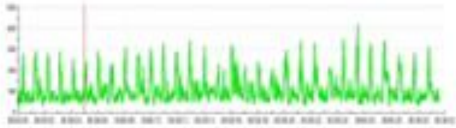

Fig II: Recording of EMG (working condition of four arm)

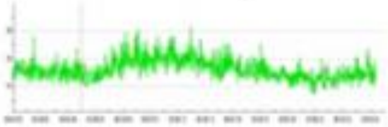

Fig III: Recording of EMG (normal standing of biceps)

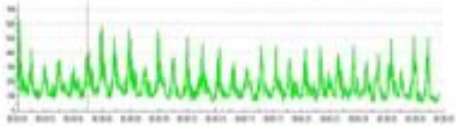

Fig IV: Recording of EMG (working condition of biceps)

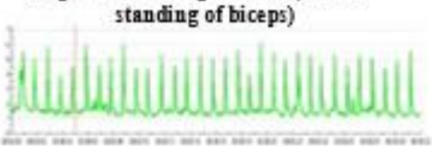

Fig V: Recording of EMG (normal standing of triceps)

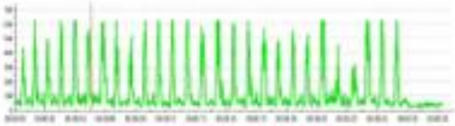

Fig VI: Recording of EMG (working condition of triceps)

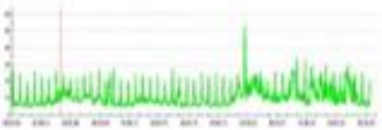

Fig VII: Recording of EMG (normal standing of trapezius)

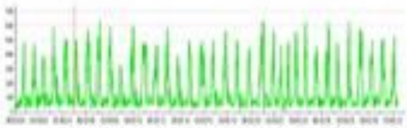

Fig VIII: Recording of EMG (working condition trapezius)

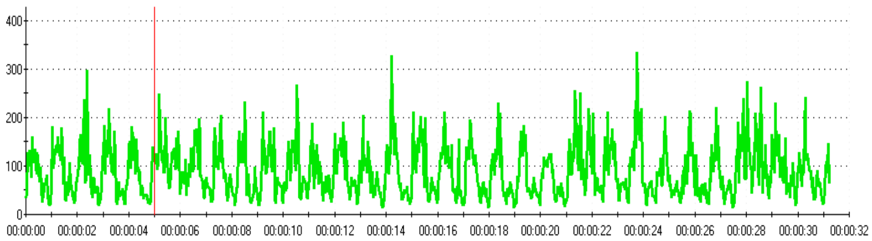

Fig IX: Recording of EMG (Back muscle)

Fig 5.2: EMG records of different muscle

5.5.7.1. Discussion:

The RMS value of EMG represented the response of muscle or nerve-muscle activity during the work. In the present study the EMG voltages of arms, shoulder and back muscles in three tasks of carpentry were analyzed and it was noted that the values of different hand muscles showed differences in different work activities. It might be due to the activity of specific muscle for the specific task with differential involvement of muscle fibers. The values of EMG were the higher in the forearm muscle of the workers during chiseling than that of other two tasks. It might be due to the their amount of load imposed on the forearm during chiseling which might be higher than that of other two activities as during chiseling the carpenter had to hit forcefully on the chisel by the hammer. The muscle contraction during doing carpentry tasks was the isotonic type of contraction as all these tasks required to handle load. It was suggested that during the handgrip task with load, the hand arm muscle produced isotonic contractions, so that muscles produced tension with altering length of muscle (Cao et al., 2017; Widmaier et al., 2010). In isotonic contraction energy of the muscle as well as the signal of the EMG was fluctuated (Nazmi et al.,2016).

5.5.8. Evaluation of Cardiovascular Status:

Two main basic parameters to assess the cardiovascular status of workers were the heart rate and blood pressure of those subjects. Most of the epidemiological reviews have shown that growths in the daily occurrence of cardiovascular mortality and illness linked with the upsurge of air particulate matter in each and every day (Du et al., 2016) and also related to the stress of work (Steptoe and Kivimäki, 2013). Many studies also stated that excessive job pressure or stress was related to the occurrence of stroke (Inoue et al., 2016) and also caused job associated cardiovascular diseases (Lazaridis et al., 2017). Both physiological parameters – Heart rate (HR) and Blood Pressure (Systolic BP and Diastolic BP) were assessed for evaluation of cardiovascular status of the carpenters.

5.5.8.1 Heart Rate:

The study of heart rate (HR) was one of the best ways to find out the physiological strain of the carpenters. To define the energetic load of the workers, measuring the heart rate frequency appeared to be the most beneficial technique. In resting and different working conditions the heart rates (HR) of carpenters were measured. Table 5.22 explains the average age, resting and working heart rates (mean and peak) of workers performing different carpentry tasks. Increased HR was noted during the onset of work in different carpentry tasks. The mean working HR was 120.86±9.90 beats/ minute while mean peak working HR was 129.4±8.77 beats/ minute. Among the three working groups of the carpenters the highest mean working HR was observed in the planning task. The mean working HR of plane users was 126.31±9.36 beats/minute.

Table 5.22: Categorization of work level on the basis of mean working heart rate (Sari et al., 2016)

Work level	Heart rate (beats/minute)
Very light	<60
Light	60-100
Moderate	100-125
Heavy	125-150
Very heavy	150-175
Unduly heavy	>175

According to the work category classification (Sari et al. (2016), as shown in Table 5.22, the mean working HR of chisel users and saw users were graded as moderate work category whereas plane users was graded as heavy work category. No significant difference was found in working HR among different groups of carpenters. The working HR in chisel and saw operators was 116.03±8.0 beats/minute and 110.38±9.74 beats/minute respectively. Results indicated that the plane operators had a greater degree of physiological load than that of the chisel and saw operators. It was revealed that physical strain in different carpentry tasks was different. The working HR was noted to be raised significantly ($p < 0.001$) from that of the resting state of the workers. Linear rising of HR was observed with the increase of oxygen consumption for both skilled and unskilled workers (Ghosh et al., 2014). Consequently, the physical strain was raised with the beginning and progress of task of the carpenters. Similar findings were also found in the experiment of Miyamoto et al., (2014).

Table 5.23 : Resting and working heart rates in three different carpentry tasks

Parameters	Chiseling (n=82)	planning (n=108)	Sawing (n= 66)	**All categories (n=256)**
Age (years)	43.16 ±8.99	33.88 ±9.104	39.68 ±10.73	41.01 ±10.54
Resting heart rate (beats/minute)	73.71 ±4.6	72.58 ±5.07	73.29 ±4.26	72.41 ±5.81
Mean working heart rate (beats/minute)	116.03 $\pm 8.0^{\$}$	126.31 $\pm 9.36^{*\$}$	110.38 $\pm 9.74^{*\#\$}$	120.86 $\pm 9.90^{\$}$
Peak working heart rate (beats/minute)	127.24 $\pm 7.89^{\$\%}$	139.28 $\pm 8.83^{*\$\%}$	124.14 $\pm 9.63^{\#\$\%}$	129.04 $\pm 8.77^{\$\%}$

w.r,t Chiseling $^{*}p<0.001$; w.r.t planning # $p<0.001$; w.r.t Resting heart rate $^{\$}$ $p<0.001$**;** w.r.t Mean working heart $^{\%}$ $p<0.001$

Some experimental studies proved that the increased HR during work affect the cardiovascular system which might be responsible for physical, psychosocial strain (Huang et al., 2013) and also for occupation associated stress (Tonello et al., 2014). At the period of execution of task, increased heart rate of the workers might due to all the above factors. Acceleration of heart rate was the key cardiac factor to fulfill the requirement of oxygen for performing physical work, over and above that was essential at the period of rest. According to Ghosh et al., (2014) raising work load or intensity had linear relationship with increasing heart rate and oxygen consumption.

5.5.8.2. Cardiovascular Stress Index:

During execution of tasks, the carpenters were exposed to cardiac stress. In the present investigation, computation of cardiovascular stress index (CSI) was made from the resting HR, working HR and age predicted HRmax of the subjects and the computed results have been displayed in Table 5.24.The cardiovascular stress was graded depending on the cut-off values of CSI as presented in Table 5.25. The findings of the results of cardiovascular stress index revealed that the tasks of carpenters were physiologically stressful. The CSI value was the maximum in planning (33.07±8.57) followed by chiseling (30.24±9.20) and sawing (25.18±8.91). It might be related to the work load and duration of performing the task (Ilies et al., 2015). It was observed that the duration of work time was greater in plane and chisel user than that of the saw operators, as noted from work-rest cycle (Table 5.26). Extended time of work might be one of the reasons for greater CSI of the carpenters (Kim et 2017).

The magnitude of CSI differs with the sternness of the task and it might also be used to estimate the task severity instead of consumption of oxygen (Lee et al., 2016). The period of work might be associated to the CSI (Sahu et al., 2013). The work-rest cycle of different tasks of carpenters have been studied and compared to the results of CSI (Table 5.26). From the results it was noted that the value of CSI was increased while the percentage of work time was increased within the work shift.

Table 5.24.: Classification of cardiovascular stress index (CSI) by Brant, (2009)

Stress Categories	CSI value
Very high stress	CSI:>80%
High stress	CSI: 50-80%
Stressful	CSI: 25-50%
Ideal, No stress	CSI: <25%

Table 5.25: Mean ± SD of Cardiovascular Stress Index (CSI) of carpenters during different carpentry tasks

Worker Group	CSI	Stress Category
Chiseling (n=82)	30.24±9.20	Stressful
planning (n=108)	33.07±8.57	Stressful
Sawing (n= 66)	25.18±8.91	Stressful
All category(n=256)	29.03±8.37	Stressful

The CSI values of carpenters were compared with that of other manufacturing employees (Table 5.26). It was noted that the cardiac stress was comparatively much higher among the carpenters than that of the workers associated with car assembly factory (Goldsmith et al., 1978) and slightly higher than that of the workers of steel factory (Vitalis et al., 1994) and china clay mine (Pari and Dhara, 2015). Such difference in CSI among different occupational groups of workers might be due to difference in the severity of the task and period of activity. The environmental condition was also an important factor (Dey et al., 2007).

Table 5.26: Mean ± SD of CSI and % of work and rest periods of total work shift in different carpentry tasks.

Job categories	CSI	% of actual work time (min.)	Percentage of rest period (min.)		
			Prescribe rest	Job related rest	Total rest
Chiseling (n=82)	30.24±9.20	415.19±21.39 (79.19%)	63.96 ±4.02 (58.6%)	45.16 ±7.41 (41.4%)	109.12±8.32
planning (n=108)	33.07±8.57	407.15±25.6 (77.58%)	70.37 ±5.14 (59.8%)	47.32 ±7.01 (40.2%)	117.69±10.27
Sawing (n= 66)	25.18±8.91	385.18±26.7 (74.8%)	73.15 ±4.24 (56.3%)	56.75 ±9.52 (43.7%)	129.9±10.2
All categories (n=256)	29.03±8.37	409.54±31.38 (77.32%)	69.1 ±6.76 (57.5%)	51.05 ±8.29 (42.5%)	120.15±11.84

Table 5.27: Comparison of CSI between workers of present study and workers of other study

Carpernters[1] (n=256)	**China clay mine workers**[2] (n=185)	**Steel Workers**[3] (n=12)	**Car assembly Workers**[4] (n=20)
29.03±8.37	26.20±8.35*	25.0±14.0	20.0±7.0**

[1]Present study; [2]Pari and Dhara, (2015); [3]Vitalis et al., (1994); [4]Goldsmith et al., (1978)

w.r,t present study $^{*}p<0.01$, $^{**}p<0.001$

5.5.9. Evaluation of Pulmonary Functions

In carpentry workshop wooden dust is most common air contaminants. Air dusts are the most commonly known substance which is related with usual widespread job-related respiratory syndromes. Some of the diseases are pneumoconiosis, systemic intoxications etc. But, now a days, it was noted that other air dust associated diseases, such as allergic alveolitis, asthma, irritation in throat and cancer.

Chronic obstructive pulmonary disease (COPD) is lung syndrome that causes chronic inflammation in lungs and creates obstruction of airflow through the lungs. Industrial workplace is one of the most common risk factors for the occurrence of COPD (Hnizdo et al., 2002). Other most common risk factor which may influence the occurrence of COPD is smoking habits of the individuals (Bhairahawa, 2013). The workers who are involved in industrial or any construction related occupation are often exposed to harmful dust that distresses the normal function of the lungs and causes for occurrence of COPD. In carpentry workshop several types of wooden stuff manufacturing tasks were performed that produced a lot of dust particles and workers would perform their tasks without using any type of protective mask or other device that caused obstruction of lungs.

In the present study the pulmonary function parameters were studied on carpenters as well as on a group of age matched control subjects. The results have been presented in Table 5.28. The results represented that the average FVC of the carpenters was 3.21±0.41 liters which was significantly ($p<0.001$) lower than that of control subjects (3.79±1.09). The normal range value of this parameter was 3.5 to 4.5 litters, as stated by Pari and Dhara (2016). Hence, the present investigation revealed that the FVC value of the carpenters were lower than normal range as stated by Pari and Dhara, 2016.

The FEV1 is the volume of air which an individual can exhale forcefully from the lungs in one second. From the results it was observed that the value of FEV1of control group was 3.31±1.52 litters. This research work indicated that FEV1 of carpenters was 3.04±0.56 litter which was significantly ($p<0.01$) lesser than that of control value of FEV1. It was also observed that FEV1/FVC (%), PEF (litter/min), and MVV-Index (litter/min) values of the carpenters were significantly ($p<0.001$) lower than that of the control subjects and the value of FEF25%-75% (litter/sec) of the carpenters was also significantly ($p<0.05$) lower than that of the respective control value.

Table 5.28: Mean ± SD and range of pulmonary function parameters of carpenters

Variables	Control subjects (n=100)		carpenters (n=256)	
	Mean ± SD	Range	Mean ± SD	Range
FVC (litter)	3.79±1.09	1.73-6.09	3.21±0.41**	1.86-5.09
FEV_1 (litter)	3.31±1.52	1.83-4.13	3.04±0.56*	0.9-5.01
FER or FEV_1/FVC (%)	89.79±6.34	62.0-100.7	82.12±9.43**	60.82-99.7
PEF (litter/min)	7.32±1.84	3.17-10.5	6.65±1.07**	1.87-10.00
$FEF_{25\%-75\%}$ (litter/min)	4.83±3.51	1.79-8.32	3.78±1.21**	0.45-6.6 5
MVV-Index (litter/min)	92.07±15.04	40.36-136.22	84.16±13.0**	36.95-129.45

w.r.t control group *p<0.01; **p<0.001

Table 5.29: Pulmonary function parameters of three groups of the carpenters according to their work experience (Ex. I: experience =1 – 5 years; Ex. II: experience =6 - 10 years; Ex. III: experience = > 10 years)

Pulmonary parameters	Duration of exposure (years)			F ratio
	Ex. I (n=53)	Ex. II (n=107)	Ex. III (n= 96)	
FVC (litter)	3.34 ±0.78	3.05 ±0.67	3.00 ±0.64*	4.56$
FEV_1 (litter)	3.06 ±0.55	2.9 ±0.49	2.03 ±0.52**#	98.4$$
FEV_1/FVC (%)	92.83 ±5.62	85.14 ±8.3**	73.51 ±6.35**#	139.16$$
PEF (litter/minute)	7.61 ±1.89	6.12 ±2.19**	5.7 ±1.4**	18.50$$
FEF 25%-75% (litter/minute)	4.45 ±1.0	3.72 ±1.23**	2.85 ±0.83**#	42.34$$
MVV-Index (litter/minute)	92.01 ±16.63	82.14 ±20.23*	73.23 ±15.05**#	19.71$$

w.r.t. Ex.I *p<0.01;**p<0.001
w.r.t. Ex.II #p<0.001
F ratio: $ p<0.01; $$ p<0.001

Table 5.29 presents that the pulmonary parameters of carpenters were changed with variation of the duration of exposure to the working environment (indicated by years of experience). With the increase in the duration of exposure there was a regular decline in the mean values of all the pulmonary variables. The FVC in Ex I group (duration of 1 to 5 years) was found to be significantly reduced (p<0.01) progressively as period of exposure was enhanced.

Similarly, FEV1, FEV1/FVC, PEF, FEF25%-75% and MVV-Index were also found to be reduced significantly (p<0.001) as the duration of exposure (or experience of work) was increased.

Table 5.30: Comparison of pulmonary functions (Mean ± SD) between smoker and non-smoker carpenters (n=256)

Pulmonary parameters	Smoker	Non-smoker
	(n=121)	(n=135)
FVC (litter)	3.12±0.74	3.24±0.71
FEV_1 (litter)	2.47±0.67	2.59±0.69
FEV_1/FVC (%)	78.66±11.36	83.67±10.54**
PEF (litter/minute)	6.05±1.98	6.37±1.89
$FEF_{25\%-75\%}$ (litter/minute)	3.1±1.18	3.41±1.17*
MVV-Index (litter/minute)	80.99±19.36	82.26±19.4

*p<0.05; **p<0.001

The mean values pulmonary function parameters of smoker and non-smoker carpenters have been presented Table 5.30. About 47% of the carpenters were habituated to smoking of ‘beeri’ (a handmade cigarette) or cigarette. The results indicated that all the pulmonary variables of the carpenters with smoking habit had lesser mean values in comparison to that of non-smokers carpenters. Significantly lesser values in FEV1/FVC (p<0.001) and FEF25%-75% (p<0.05) were observed in smokers than that of non-smokers. Therefore, the smoking was a vital factor which generally stated to harm lung function. Smoking and period of exposure was considerably related to the respiratory capacity, once age was a covariate which was comprised of the reversion that no longer became substantial (Das et al., 2017).

The pulmonary function parameters of the carpenters were compared with that of other groups of workers (Table 5.31). The results revealed that different pulmonary function variables were significantly different (p<0.001) among different occupational groups. The FVC and FEV1 were significantly lower than that of office worker who was treated as control group as they have no exposure of dust. However, the China clay mine workers had the lowest values in all the variables which might be due to greater exposure of dusts than other two groups of workers.

Table 5.31: Comparison of pulmonary functional variables (Mean ± SD) of carpenters with other workers

Parameters	carpenters (n=236)	Office workers[1] (n=41)	China clay mine workers[2] (n=185)
FVC (litter)	3.21±0.41	4.99±0.57*	2.58±0.44*
FEV_1(litter)	3.04±0.56	4.07±0.51*	2.00±0.40*
FEV_1/FVC (%)	82.12±9.43	81.6±10.4	77.59±7.89*

w.r.t. carpenters, *p<0.001,
[1] Milanowski et al., (2002); [2] Pari and Dhara, (2012)

Table 5.32: Severity of COPD in workers according to their work experience (n=60) (Ex. I: experience =1 – 5 years; Ex. II: experience =6 - 10 years; Ex. III: experience = > 10 years)

	Ex. I (n=50)		**Ex. II** (n=50)		**Ex. III** (n=50)	
	Frequency	**Percentage (%)**	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
Total no of COPD	**5**	**10.00**	**10**	**20**	**13**	**26**

Table 5.32 illustrates the prevalence of COPD of three experience groups of carpenter. It was observed from this table that 10% carpenter of lower experience group, 20% of workers middle experience group and 26% of higher experience group were suffering from COPD. Thus results indicated that the occurrence of COPD increased with the duration of exposure as more experienced group had greater cumulative duration of exposure.

5.5.9.1. Discussion:

The lesser values of pulmonary function variables in carpenters might be due to exposure of wood dust, smoke etc in polluted work place (Ribeiro et al., 2006; Hamzah et al., 2014). The investigation of Jayawardana et al., (1997) expressed that exposure to wood dust, and smokes was related with pulmonary efficiency as measured by FVC, FEV1, FEV1/FVC, PEF etc among industrial workers in Sri Lanka. According to the Aghilinejad et al.(2016) exposure to hazardous workplace had a significant role in the occurrence of respiratory symptoms. Deformed lungs function was more prevalent for the lower body weight people and body weight of the workers were another important factor (Das et al. 2017).

The results of the present research work was supported by the results of others studies which also stated that pulmonary function variables, such as FVC, FEV1 and PEF were reduced due to exposure to various types of dust and the severity of malfunction of lungs increased with increasing period of exposure (Jani et al., 2019). From the outcome of the present study it was noted that the pulmonary function variables exhibited significant variation in different age groups and the variables were gradually reduced with progression of age. The same findings were observed by the Khan et al., 2017. Significant alterations in the values of pulmonary function variables in compare to that of control group (as they have no exposure of dust) among industrial workers like, wood workers (Milanowski et al., 2002), china clay mine (Pari and Dhara, 2012) workers were observed.