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Work Related Musculoskeletal Disorders in Defence Personnel Involved in Heavy Engineering Maintenance

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Abstract

Background: Work-related Musculoskeletal disorder (WMSDs) are multifactorial occupational disorders, having high morbidity and economic cost. Heavy engineering maintenance personnel involved in manual material handling, physical load with awkward posture poses high risk of WMSDs. **Objectives:** This study investigates the prevalence of work-related Musculoskeletal disorder (WMSD) among Indian defence personnel involved in heavy engineering maintenance work. **Setting and Design:** A cross-sectional survey was conducted with participant consents. **Materials and Methods**: 379 defence personnel involved in heavy engineering maintenance task were assessed for WMSDs, using NMQ. The effect of risk factors such as age, working hours, BMI, smoking and type of job on WMSDs was analysed. **Statistical Analysis:** Data analysis was done using using logistic regression with SPSS version 14. **Results**: 67.54 % personnel (N=379) reported WMSDs with total of 704 WMSDs. 51.45% reported multiple WMSDs and 16.09% had single WMSDs. Highest WMSDs were reported in low back (44.85%), followed by knee (28.23%), elbow/forearm (15.83%), ankle/foot (22.95%), shoulder (18.46%), upper back (18.46%), neck (15.83%) and wrist/fingers (12.92%). Long working hours (p=0. 000; OR=1.83, 1.58-2.12) and smoking habits (p=0.000; OR=5.52, 3.43-8.48) are significantly correlated with WMSDs. Automobile me chanics (p=.045; OR=2.64, 95% CI=1.04-6.72) and welders (p= 0.034; OR =2.32, 95% CI = 1.21 – 4.36) are at higher risk of WMSDs. **Conclusion:** There is a high prevalence of WMSDs among Indian defence mechanics. It is suggested that ergonomics training is required for maintenance workers. The detrimental effect of smoking is also noted with the prevalence of WMSDs.

Keywords: Defence, Heavy Engineering, Maintenance, Mechanics, Work Related Musculoskeletal Disorders

1. Introduction

MSDs are multifactorial disorders, which cause damage to muscles, ligaments, cartilages, tendons, soft tissues and nerves[1]. MSDs are characterized by varying severity of pain, restricted range of motion and limitation of functions[2]. Maintenance and repair jobs pose a high risk of MSDs, due to heavy physical work or manual material handling, awkward posture and high job demand[3]. MSDs that are occupational health hazards are termed as work related musculoskeletal disorders.

Work Related Musculoskeletal Disorders (WMSDs) have high morbidity and economic costs[4]. WMSDs negatively affects the workers' health, thereby lowers productivity, increases absenteeism and work day loss and is associated with substantial financial cost[5]. The economic cost of work-related injury and illness was estimated to be 4% of the GDP of developing countries[6]. In the case of developed countries, indirect cost for MSDs amounts to 40% of total annual costs of accidents[7]. Unfortunately, WMSDs are under reported in developing countries and indirect cost of occupational musculoskeletal disorder (non-fatal) in 2007 was 1.5 and 1.1 billion dollars, respectively due to lack of standardized statistics recording and notification system[8].

Defence forces are equipment intensive and have a large number of personnel employed for maintenance and repair of heavy engineering system[9]. These personnel provide close support to combat units and most equipment are maintained and repaired in-situ, under field conditions with bare minimum infrastructure. This entails risk factors such as manual material handling, excessive load, repetitive task, work pressure, wrong postures causing WMSDs[10].

Musculoskeletal injuries and disorders are main reason for morbidity and temporary disability in military population[11,12]. Health clinic visit rates are approximately equal for injuries and illness in military environment but the morbidity associated with injuries is over five times greater than that associated with illness[13,14]. MSDs are second highest reason for premature discharge from military services[15]. Combat environment and geographical topography are responsible for MSDs in US military[16]. Large number of musculoskeletal injuries is seen

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in defence services, but studies identifying the cause and risk factors of these musculoskeletal injuries/disorders are sparse[17]. The literature so far lacks any insight about the WMSDs in defence personnel, involved in maintenance and repair operation along with combat duties.

This highlights the significant role of defence personnel involved in maintenance and repair operation.

2. Objective

The study aims to investigate the prevalence of WMSDs in defence personnel involved in maintenance and repair operation.

3. Materials and Methods

This cross-sectional study focuses on defence personnel involved in heavy engineering repair and maintenance operation. These defence personnel work as automobile mechanics, crane operators, welders and hydraulic system mechanics. A survey research was done at seven different geographic locations from three different terrains in India: (i) Plains and coastal region (ii) High Altitude and Hilly (North-Eastern region) (iii) Semi-desert (North-Western region).

A total of 423 defence personnel involved in variety of maintenance tasks were enrolled for the study, after an informed consent. 379 personnel correctly responded, making a response rate of 89.5%. 44 personnel were excluded due to incomplete information. They were divided into two groups, based on their experience. Group 1 (G1) - personnel having minimum 15 year of service and did more of supervision, guiding and coordination of maintenance task (n= 120). The Group 2 (G2) - personnel with less than 15 year of service and were involved in executing maintenance and repair task (n=303).

Respondents filled a self-reported questionnaire, having Part A as personal information and Part B as Nordic Musculoskeletal Questionnaire (NMQ). After a thorough briefing, All respondents were asked to answer the occurrence of musculoskeletal symptom, experienced by them during last 12 months in various body parts (neck, shoulder, forearm/elbow, wrist, upper back, low back, knee and foot/ankle). The presence of MSDs was defined as ache, pains or discomfort in any of the eight body regions marked in body-chart (Figure 1). The symptoms of headaches, chest and abdominal pain were excluded, as they could be related to systemic illness.

The case definition of musculoskeletal symptoms is taken similar to National Institute of Occupational Safety and Health (NIOSH) (2) and is (i) the subject who felt musculoskeletal symptom in last 12 months in any of the body parts (ii) the symptoms that lasted for more than seven days at a stretch or it was felt for more than once in a month. MSDs due to non-occupational causes such as motor accident or sports activities were excluded from the study. To avoid the recall bias, the MSDs were restricted to past one year. The period of investigation was from 14 Mar 2016 to 3 Oct 2018. This study was approved for ethical consideration of Research Involving Human Research Subject, by NMIMS ethical committee.

The descriptive statistical analysis of data of 379 respondents was carried out to understand the distribution of demographic details including age, BMI, employment duration, working hours, smoking, job content, body parts affected and MSD prevalence. The variables under the

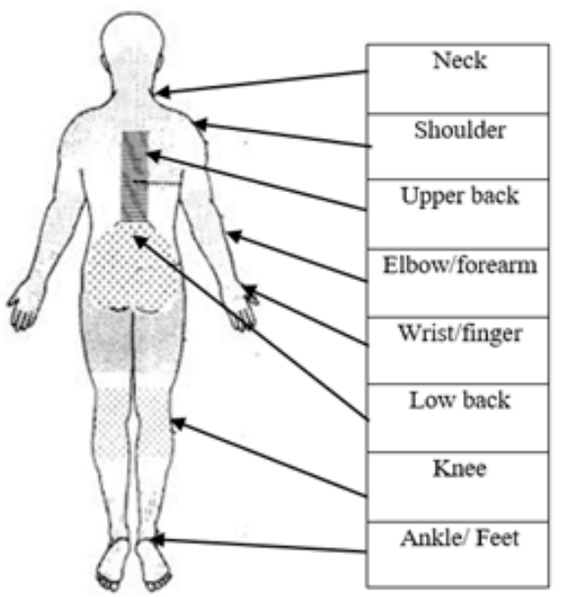
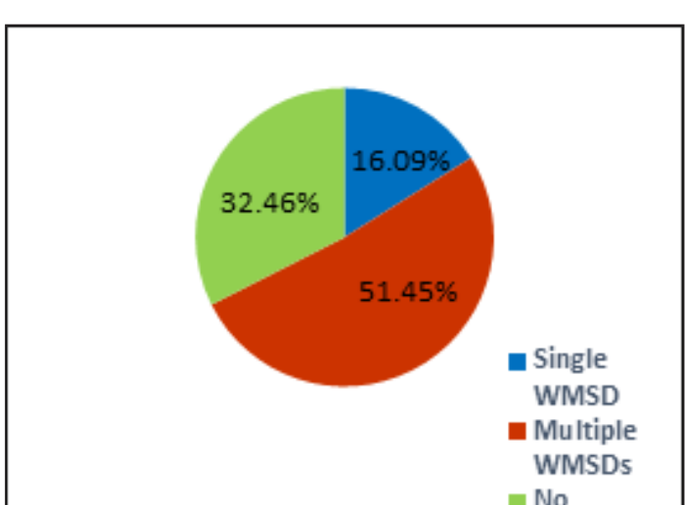


Figure 1. NMQ Body Chart.

Table 1. Demographic Data of Different Job Trades in Heavy Engineering Defence Personnel

Job Title	Age (Years) Mean (SD)	Duration of Employment (Years) Mean (SD)	BMI (kg/m^2) Mean (SD)	Working Hours (hours/day) Mean (SD)
Automobile Mechanic	30.60(6.57)	9.77(5.09)	26.31(2.417)	10.97(1.94)
Welder	33.14(5.73)	10.66(5.07)	27.49(1.90)	10.60(1.88)
Crane operator	35.68(5.85)	9.63(5.05)	28.32(1.94)	11.71(1.90)
Hydraulic System Mechanic	36.32(5.71)	14.09(4.81)	28.89(1.84)	10.82(1.92)
Total	30.62(6.08)	10.4(5.79)	27.04(2.41)	10.81(1.93)
	Range			
	Min Max	Min Max	Min Max	Min Max
	21 45	1 25	20.8 33.7	7 14



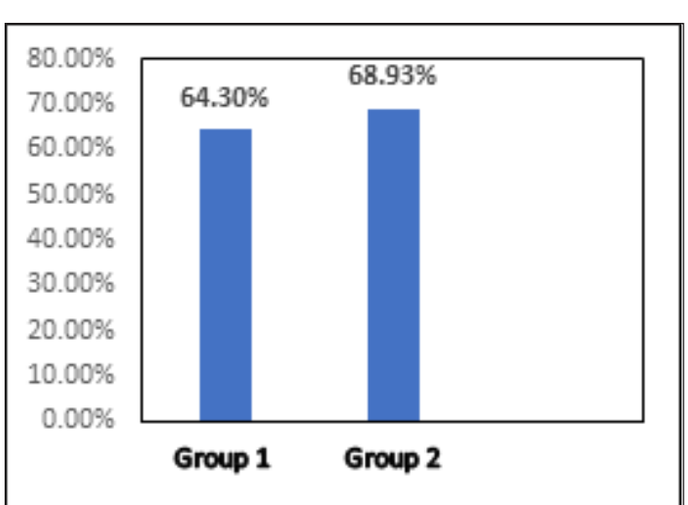


Figure 2. Distribution of Single and Multiple

Table 2. Single Vs Multiple WMSDs in Different Trades of Heavy Engineering Maintenance Workers

Job Title (Nj)	Workers with Single WMSDs (%)	Workers with Multiple WMSDs (%)	Total Workers with WMSDs (%)
G1 Automobile Mechanics (162)	17.28	47.53	64.81
G2 Automobile Mechanics (74)	8.10	58.10	66.21
Total Automobile Mechanics (G1 + G2)	14.40	50.84	65.25
G1 Hydraulic System Mech (28)	25	42.85	67.85
G2 Hydraulic System Mech (24)	12.5	33.33	45.83
Total Hydraulic System Mechanics (G1 + G2)	19.23	38.46	57.69
G1 Crane Operator (33)	12.12	54.54	66.66
G2 Crane Operator (8)	0	75	75
Total Crane Operator (G1 + G2)	9.75	58.53	68.29
G1 Welder (41)	31.70	56.09	87.08
G2 Welder (9)	0	88.88	88.88
Total Welder (G1 + G2)	26	62	88
Total (379)	16.09	51.45	67.54

study were further classified as predictors and response. The demographic variables, smoking and job contents were classified as predictors, whereas MSDs prevalence was taken as response variables. Logistic regression was used to examine the relationship between predictor variable and response variable with 95% of level of significance.

4. Results

Table 1 presents distribution of research respondents by age, duration of employment, BMI, Daily working hours with respect to Job title.

A total of 704 WMSDs were reported by 256 workers. 16.09% respondents reported single WMSDs, whereas 51.45% had multiple WMSDs, making an aggregate of 67.54% (Figure 2, Table 2). Multiple WMSDs are higher than single WMSDs. Among all job title, personnel suffering from multiple WMSDs are much higher than personnel suffering with single WMSDs. Welder reported highest prevalence of single as well as multiple WMSDs.

Table 3 presents WMSDs symptom prevalence by body parts according to age, duration of employment, working hours BMI and smoking habit. Low back (47.11% Vs 38.18%) and foot/ankle WMSDs (23.07% Vs 18.18 %) were more in higher age group (above 35 years) as compare to lower age group (≤35 years). Both age groups had near similar prevalence of knee (31.73% & 32.72%) and shoulder (16.34% and 15.63%) WMSDs. Neck (14.18% Vs 8.65%), upper back (16.36% Vs 10.57%), elbow/forearm (20% Vs 17.3%) and wrist (13.81% Vs 8.65%) WMSDs were more prevalent in younger age group (≤35 years). Work experience is reflected by the duration of employment. Personnel having >15 years of work experience

Table 3. Personal Characteristics Associated with Body Region wise WMSDs

Body Region Personal Characteristic	Low Back (%)	Neck (%)	Knee (%)	Shoulder (%)	Foot /Ankle (%)	Elbow/Fore arm (%)	Upper Back (%)	Wrist/ Fingers (%)
Age								
≤35Years (275)	38.18	14.18	32.72	5.63	18.18	20	16.36	13.81
> 35 Years (104)	47.11	8.65	31.73	16.34	23.07	17.3	10.57	8.65
Duration of Employment								
≤15 Years (267)	39.70	14.60	32.95	13.48	19.47	19.47	12.73	10.11
>15 Years (112)	42.85	8.03	31.25	21.43	19.64	19.64	19.64	17.86
Working Hours								
Up to 8 (49)	16.32	10.20	12.24	22.92	2.04	16.32	20.41	6.12
>8 – 10(119)	26.89	16.97	35.96	1.68	18.48	11.76	10.08	7.56
>10 (211)	54.03	11.37	35.54	22.27	24.17	24.17	16.11	16.58
BMI								
< 25 (113)	34.51	19.47	41.59	11.50	20.35	19.47	19.47	10.62
25-29.99(197)	45.18	9.64	29.95	31.86	20.51	21.32	14.72	14.72
≥30 (69)	37.68	10.15	24.64	15.92	15.92	13.43	7.24	8.69
Smoking								
Yes (203)	49.26	15.27	43.84	22.17	23.64	28.57	23.64	12.31
No (176)	30.68	9.66	19.32	8.52	14.77	8.52	4.54	5.68

Table 4. Job Title Associated with Body Region wise WMSDs

Body Region Job Title	Low Back n(%)	Neck n(%)	Knee n(%)	Shoulder n(%)	Ankle/ Foot n(%)	Elbow/ forearm n(%)	Upper back n(%)	Wrist/ Fingers n(%)	MSD Incidents
G1Automobile Mech	59.46	12.16	39.19	25.67	28.38	17.56	6.76	9.46	147
G2 Automobile Mech	40.1	21.60	21.60	11.11	12.96)	20.37	22.84	10.49	261
G1 Welder	77.77	44.44	66.66	55.55)	33.33	55.55	27	27	36
G2 Welder	51.22	7.32	43.90	12.19	21.95	19.51	19.51	39.02	88
G1 Crane Operator	37.5	0	25	62.5	50	50	12.5	0	19
G2 Crane Operator	33.33	9	515.15	33.33	45.45	42.42	15.15	9	67
G1 Hydraulic System Mech	29.16	8.33	20.83	12.5	25	29.16	12.5	0	33
G2 Hydraulic System Mech	42.86	14.28	25	14.28	28.57	25	28.57	10.71	53
Total Frequency of Occurrence N=379 (%)	44.85	15.83	28.23	18.46	22.95	24.01	18.46	12.92	704

suffered more from low back (42.85% Vs 39.70%), Upper back (19.64% Vs 12.73%), shoulder (21.43% Vs 13.48%) and wrist (17.86% Vs 10.11%). Whereas personnel having work experience ≤ 15 years had reported higher neck WMSDs (14.60% Vs 8.03%). The distribution of knee, foot/ankle and elbow/forearm WMSDs was nearly same, irrespective of work experience. It was observed that, 55.67% of defence maintenance workers worked more than 10 hour a day and 31.4% worked between 8-10 hours per day, which is higher as compared to normal industrial workers (8 Hours/days). High

Table 5. Logistic Model Derived Odd Ratio for Prevalence of WMSDs (N= 379)

Model	Parameters	Coefficient	P value	Odds Ratio	95% CI	
					Lower	Upper
M1	Age (Years)	0.0027	0.870	1.00	0.96	1.03
	Employment Duration	-0.0005	0.973	1.00	0.97	1.03
	BMI	0.0547	0.210	1.06	0.97	1.15
M2	Working Hours	0.60541	**0.000***	1.83	1.58	2.12
M3	Smoking	1.7075	**0.000***	5.52	3.43	8.48

rate of WMSDs (except upper back WMSDs) were seen in defence maintenance personnel working more than 8 hours/day. However, personnel with up to 8 hours/day of working reported higher incidence of shoulder upper back WMSDs. Based on WHO standards, we found that 51.98% of our respondents were overweight (BMI 25-29.99 kg/m^2) and 18.25 were obese (BMI ≥ 30 kg/m^2). Significant impact of BMI on WMSDs was however not seen in the respondents.53.56 % of respondents were smokers in our study and higher incidence of WMSDs were seen in all body regions of defence maintenance personnel who were smokers (Table 3).

Highest WMSDs were reported in low back (170, 44.85%), followed by knee (107, 28.23%), elbow/forearm (91, 28.01%), ankle/foot (87, 22.95%), shoulder (70, 18.46%), upper back (70, 18.46%), neck (60, 15.83%) and wrist/fingers (49, 12.92%). Low back WMSDs were high across all job titles. With respect to job titles, G1 welders reported maximum percentage of WMSDs in all body region. Automobile mechanics G1 and G2 both, also had high number of all type of WMSDs. Both groups of crane operators (G1 & G2) reported high percentage of ankle/foot (50% & 45.45%), elbow/forearm (50% & 42.42%), and shoulder (62.5% & 33.3%)WMSDs. Hydraulic system mechanics (G1 & G2) reported more percentage of WMSDs in low back (29.16% & 42.86%), elbow/forearm (29.16% & 25%) and ankle/foot (25% & 28.5%). WMSDs of Wrist/finger were maximum in welders (Table 4).

Four models (M1 to M4) were derived to find out the significant risk factors of WMSDs through logistic regression. We found that the prevalence of WMSDs were significantly affected by daily working hours (OR = 1.83, 95% CI = 1.58- 2.12) and smoking (OR = 5.52, 95% CI = 3.43 – 8.48). Smokers had five and half times more chance of being affected by WMSDs as compared to non-smokers (Table 5). G1 automobile mechanics (OR =2.64, 95% CI= 1.04 - 6.72) and G2 welders (OR = 2.32, 95% CI = 1.21 – 4.36) were at higher risk of developing WMSDs, due to their trade demand and type of work (Table 6).

Table 6. Effect of Occupation on Prevalence of WMSDs

Model	Job title	Coefficient	P value	Odds Ratio	95% CI	
					Lower	Upper
M4	G1 Automobile Mechanics	0.9760	**0.045***	2.64	1.04	6.72
	G2 Automobile Mechanics	0.8640	**0.034***	1.03	0.98	1.08
	G1 Welder	0.5413	**0.026***	1.07	1.01	1.12
	G2 Welder	0.8721	**0.012***	2.32	1.21	4.36
	G1 Crane Operator	-0.0195	0.383	0.98	0.94	1.02
	G2 Crane Operator	0.0321	0.0271	1.04	0.97	1.11
	G1 Hydraulic System Mech	1.0470	0.063	2.87	0.94	8.75
	G2 Hydraulic System Mech	-0.0211	0.083	0.97	0.92	1.02

5. Discussion

In this study, we investigated the prevalence of Work-Related Musculoskeletal Disorders (WMSDs) and their association with type of job in heavy engineering maintenance work force of Indian defence. We found that large numbers of personnel suffer with WMSDs, but this is not reflected in their medical records or defence hospital data. Aches and pain during working are taken as acceptable norms or usual part of life by these personnel. There is lack of awareness about prevention, treatment and ergonomic care. They also hesitate in repetitively reporting the discomforts and pains frequently, as it may be taken as sign of excuse from the work.

67.54% of respondents reported WMSDs with total of 704 WMSDs in 379 respondents. This is because 51.45% of respondents reported multiple WMSDs and 16.09% had single WMSDs. Low back WMSDs was high among all job titles (44.85%) of heavy engineering. High Prevalence of low back WMSDs is also reported by Torp *et al.*, (1996) in car mechanics and Morken *et al.*, (2007)[28] in Norwegian Royal navy[18,19]. They have very high physical and cognitive demands, both as soldier and technicians respectively. The strategic machine/equipment may not be designed ergonomically for its maintainability, which force personnel to work in awkward posture for long time. Also, it is not always possible to take out defected machinery part out of the heavy machinery or

vehicle and it must be repaired in situ, allowing very limited space to access them. We have observed them working in squat, semi squat, back flexed to complete range in standing position, kneeling positions and even lying under the vehicle with their hand raised above shoulders. These factors such as dual role, high physical and cognitive demand, awkward posture, long working-hours predispose them to high risk of WMSDs[20–23]. Welders reported Wrist/finger WMSDs they are exposed to hand transmitted vibration, while using heavy drilling equipment or pneumatically operated cutting tools. Similar results were reported for steel maintenance workers[20], and for machine operators using vibratory drilling tools 7 mm displacement amplitude[24, 25].

Automobile mechanics too had high number of all type of WMSDs with maximum affection in low back. They were found to have never ending repair work lined up. Repair work in night-time, in-situ work and work underneath the vehicle/equipment poses issues of inadequate illumination, which is reported risk factor for WMSDs[11,26]. While repairs, Hydraulic system mechanics perform repair and maintenance of weapon systems which includes heavy barrels, hydraulic cylinders and cradle system. It requires lifting, holding and carrying heavy components, application of excessive force for twisting and turning of levers. Resultantly, they suffer more from low back, elbow/forearm and ankle/foot WMSDs.

Crane operators reported high percentage of ankle/foot, elbow/forearm, and shoulder WMSDs[27,28]. They frequently get engaged in recovering heavy vehicle from accidental site, many a time in hilly terrain. Their task involves frequent mounting and dismounting from crane, lifting fixing heavy chain, D shape blocks & shackles to objects. Manually heavy material handling has been very well identified as cause of WMSDs in manual material handlers[30].

Across all Job titles, multiple WMSDs were higher. Smokers and overweight personnel reported more multiple WMSDs. Similar findings were reported by Vieira, Kumar, and Narayan (2008) genetic disposition, personal traits and habits. Not all risk factors can be controlled. Preventative programs frequently focus on workload, organizational and psychophysical issues. Smoking, no-exercise, and overweight generally receive less attention. This study assessed the association between smoking, no-exercise, and overweight and low back disorder in welders and nurses. A retrospective epidemiological study and a questionnaire survey were conducted. The records of injuries were examined and 111 workers (64 welders and 47 nurses in welders. They observed smoking, and overweight as increased risk of low back disorder[29]. Morken T *et al.,* (2000) and Knapik *et al*., (2004) also reported positive correlation between smoking and MSDs in Aluminium industry workers and combat recruits[13,31]. Though smoking has effects on the immune system that has long-term consequences for tissue healing even after smoking cessation[32], it is a modifiable risk factors that if addressed can reduce the prevalence of MSDs[33].

Defence maintenance personnel, who worked more than 8 hour/day had more WMSDs. This is probably because their average daily working hours are much higher than normal industrial norms (ILO 1930, Convention 1 and 30) which is 8 hours/day[34]. Defence personnel officially are otherwise on duty for any emergent requirement, except during leaves. In addition to their professional jobs, they perform physical training, other administrative and security related tasks in rotation as per schedule. They work in shift and provide round the clock support to combat troops for any maintenance related tasks. M. Bovenzi & N. Stacchini (2002)fork-lift truck drivers, and 46 crane operators. The vector sum of the frequency-weighted r.m.s. acceleration of vibration measured on the seatpan of port vehicles and machines averaged 0·90 m/s^2 for fork-lift trucks, 0·48 m/s^2 for straddle carriers, 0·53 m/s^2 for mobile cranes, and 0·22 m/s^2 for overhead cranes. The 12-month prevalence of low back symptoms (LBP, sciatic pain, treated LBP, sick leave due to LBP) too had reported 'increase exposure to work' as low back pain risk in 245 machine operators involved in maintenance operation[35]. Long working hours is the proven risk factor of occupational injuries among automobile and maintenance worker[36].

6. Conclusion

This study revealed high prevalence of WMSDs among heavy engineering maintenance personnel of Indian defence forces. Specifically, Low back, knees, ankle/foot and elbow/forearm were most affected areas. Moreover, this study revealed more presence of multiple WMSDs, with high BMI, long working hours, smoking and four different job trades (automobile mechanics, welders, crane operators and hydraulic system mechanics) as risk factors. The ergonomic risk factors in terms of workload, work pressure, awkward posture, in appropriate workspace, long working hours, shift duties, tough terrain and poor illumination might lead to many WMSDs in these personnel.

6.1 Relevance of Study

This is the first study to link WMSDs in defence forces and maintenance workers, especially in Indian scenario. Up till now, the focus was on combat forces and recruits, mainly highlighting training methods, uniforms, shoes, or reducing organisational stress[37–39]. The results of this study will be applicable for community of heavy engineering maintenance workforce for their WMSDs.

6.2. Recommendations

Authorities should install the measures for screening of WMSDs and their work-related ergonomic risk factors to prevent WMSDs. Initiatives and intervention to control these risks is advocated by early recognition and appropriate treatment. Reporting of WMSDs to be institutionalized for further analysis and plan for prevention measures.

6.3 Limitation of Study

The findings of this study are limited to assessment of risk factors without direct measurement of postural assessment (through video recording) with constraints of non-applicability of industrial law to defence maintenance personnel. Even 12-month recall period used by us would have likely caused recall bias to some extent as[40] reported that longer recall period can cause recall bias, if injuries are less severe.

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