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Evaluation of Forklifts for Operator Comfort

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Abstract: **Although forklifts offer many benefits such as reducing manual material handling and enhancing productivity, there are factors that cause Musculoskeletal disorders (MSDs) to the forklift operators, such as severely twisted postures, prolonged sitting and exposure to vibration etc., ultimately leading to low productivity. The main objective of this study is to evaluate different make forklifts in a heavy equipment manufacturing industry (Voltas-diesel, Godrej-diesel, Doosan-diesel, Voltas- electrical and Macneill -electrical) and forklifts with different types of engine (diesel and electrically operated) based on subjective discomfort reported by the forklift operators using Corlett and Bishop's method of body mapping and Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). Forty four operators aged between 20-58 years driving five different make forklifts were the subjects. Operators working on Godrej-diesel reported more discomfort while operators working on Voltas- electrical reported less discomfort. Operators working on diesel operated forklifts reported higher discomfort compared to electrically operated forklifts but the difference is small. Body part wise analysis revealed that the operators reported the highest level of discomfort at the lower back irrespective of the engine type.**

Keywords: **Body Mapping, CMDQ, Discomfort, Forklift**

I. Introduction

The forklift is one of the most frequently used material handling equipment in industries and its ability to shift heavy loads efficiently has led to its universal application within manufacturing plants, warehouses, freight terminals and trade environments [1]. These forklifts offer many benefits such as reducing manual material handling and enhancing productivity [2]. Although forklifts offer these benefits, they also pose significant occupational hazards and cause for the development of musculoskeletal disorders (MSDs) and at the same time reduce the productivity. The productivity of operators and their performance mainly depends upon the workspace in which they work. Poorly designed work stations, force operator to attain an awkward posture which leads to MSDs, thereby reducing their efficiency and productivity [3]. The exposure to MSDs risk factors stems from the interface between the design of the equipment and cab interior (e.g., location of controls, windows, and mirrors) and characteristics of the task (e.g., duration of the task, location of the task that dictates the viewing angle).Thus, the design of the cab interior may influence awkward postures of the joints, whereas the longer duration of the task may influence the static exposure to awkward postures [4]. The operators workplace, which includes the environmental condition within the cabin, exposure to noises, the varying climatic conditions and the driving posture, needs to be considered as a stress factor contributing to the his health status and the driver's position in the cabin is closely related to the dimension of the workstation and to the adjustability of the seat; in particular, standard seats have been seen to be unsuitable for both small and heavy operators [5]. The posture is an important consideration in the design of work method and workplaces, because it affects the ability of workers to reach, hold, and use equipment, and influences how long they can perform their job without adverse health effects, such as discomfort, fatigue, and MSDs [6]. These working postures can be influenced by many factors, such as work station layout, location and orientation of work, individual work methods, and the workers anthropometric characteristics[7].The MSDs in professional drivers are associated with both ergonomic and psychosocial risk factors. The most commonly identified physical factors are prolonged sitting, whole-body vibration, ergonomic mismatch among drivers (disparity between anthropometric sizes of the drivers and their physical environment), the type of vehicle seat, and driving mechanisms (automatic or not automatic, etc.) and individual factors such as age, gender, weight, height, body mass index, and general health status are also associated with the work-related ailments of drivers [8]. Other than these factors the road profile and the condition of the tyres also influence the discomfort of the operators [9]. The objective of this study was to record subjective discomfort reported by the operators of forklifts of different makes (Voltas-diesel, Godrej-diesel, Doosan-diesel, Voltas-electrical and Macneill-electrical) so as to evaluate the role of design differences and type of engine on operator comfort.

II. Material and Methods

A. Forklifts details

The study was carried out in a heavy equipment manufacturing industry in India. Normal working hours for the forklift operation was eight hours with three breaks in between such as Morning tea break (10 min), Lunch break (30 min) and Afternoon tea break (10 min). Operating duration was about 5-6 hours in a shift. Forklifts are used to lift and transport small jobs like metal plates weighing 30 kgs to big/heavy jobs like valve bodies weighing 3 tons. These materials were transported within the shop floor or to other workshops and even over a distance of one km.

A total of 44 forklifts of five different (models) makes [three diesel operated (Voltas, Godrej and Doosan) and two electrically operated (Voltas and Macneill) forklifts designated as D1, D2, D3, E1 and E2, respectively] are operated by both the company employees and contractors. The details of the forklifts are given in Table 1.

Table. 1: Forklift details

Forklift	Number (%)	Operator cabin dimensions (in cm)					Seat height (in cm)
		Cabin height	Cabin width		Cabin breadth		
			Top	Bottom	Top	Bottom	
D1	19(43.18)	170	105	136.5	117.4	117.4	46.5
D2	7(15.91)	142.2	94.5	124	98.5	98.5	48.2
D3	7(15.91)	151.5	105.5	143	103.5	103.5	44.5
E1	5(11.36)	166	106	141.2	105	105	53.8
E2	6(13.64)	155.6	92.7	146	114.8	114.8	48.1

B. Operators' characteristics

All the 44 forklift operators (all male, age between 20-58 years) participated in this study. All the operators were provided with information about the study and prior consent was obtained from all of them. None of them reported any health issues that were likely to affect or be affected by participation in this study. The operators were divided into five groups based on the operating different make forklifts and same operators were divided into two groups based on operating the type of engine forklift. Table 2 shows the characteristics of the operators.

C. Discomfort assessment using Corlett and Bishop's method of body mapping

Corlett and Bishop's method of body mapping [10] was used to obtain the discomfort information from the forklift operators. It has been widely used in the assessment of discomfort among different working populations, such as sewing machine operations [11-12]. and Computerized Numeric Control Machine operators [13]. The questionnaire was explained to the operators, and then the details of their discomfort were obtained. The operators were asked to identify on the body map the body part with the discomfort, and state the level of discomfort as No discomfort, Minimal discomfort, Moderate discomfort, severe discomfort and Extreme discomfort (the discomfort scores being assigned values of 0, 1, 2, 3 or 4, respectively). Then they were asked to identify the next most uncomfortable body part and its level of discomfort. This continued till no more body parts were identified.

D. Frequency and Intensity of discomfort assessment using the Cornell Musculoskeletal Discomfort Questionnaire

Frequency and discomfort level was assessed using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). The CMDQ is a 54-item questionnaire containing a body map diagram and questions about the prevalence of musculoskeletal ache, pain or discomfort in 20 regions of the body during the previous week. It has been used in the assessment of musculoskeletal discomfort among different working populations, such as nursing personnel[14] and Computerized Numeric Control Machine operators [15]. To determine the frequency of discomfort and quantify the discomfort level, the musculoskeletal discomfort score was calculated following the scoring guidelines for the CMDQ. The Musculoskeletal Discomfort score was calculated as follows. First, the frequency of discomfort reported by the operators during the survey was scored as: Never (0), 1 or 2 times/week (1.5), 3 or 4 times/week (3.5), every day (5), or several times every day (10). The score obtained is multiplied by the Severity score (slightly uncomfortable = 1, moderately uncomfortable = 2, very uncomfortable = 3) and Interference score (Not at all = 1, slightly interfered = 2, substantially interfered = 3) to arrive at the weighted Musculoskeletal Discomfort score. This helped to identify the most severe cases.

Table. 2: Operators' characteristics

Forklift	Number	Parameter	Minimum	Maximum	Mean	Standard deviation
D1	19	Age (Years)	24	58	35.8	12.04
		Height (cm)	158	178	167.8	6.01
		Weight (kg)	50	86	65.0	9.55
		Experience (years)	0.5	19	5.1	5.38
D2	7	Age (Years)	20	56	31.1	12.28
		Height (cm)	160	182	166.4	8.00

		Weight (kg)	50	83	63.4	10.13
		Experience (years)	1	5	2.9	1.46
D3	7	Age (Years)	20	29	25.9	2.91
		Height (cm)	162	184	172.7	8.30
		Weight (kg)	50	85	65.9	13.01
		Experience (years)	1	5	2.0	1.41
E1	5	Age (Years)	43	57	49.4	6.19
		Height (cm)	163	170	167.6	3.36
		Weight (kg)	53	72	65.8	8.84
		Experience (years)	3	15	5.8	5.22
E2	6	Age (Years)	23	54	33.7	12.86
		Height (cm)	159	175	169.0	5.44
		Weight (kg)	54	90	70.3	14.87
		Experience (years)	0.5	19	6.1	7.19
Diesel operated	33	Age (Years)	20	58	32.7	11.31
		Height (cm)	158	184	168.6	7.09
		Weight (kg)	50	86	64.9	10.15
		Experience (years)	0.5	19	4.0	4.35
Electrically operated	11	Age (Years)	23	57	40.8	12.87
		Height (cm)	159	175	168.4	4.46
		Weight (kg)	53	90	68.3	12.14
		Experience (years)	0.5	19	6.0	6.06

III. Results and Discussion

A. Discomfort assessment - different forklift models

Discomfort scores obtained from the forklift operators using Corlett and Bishop's Body Map in different forklift models (Mean ± standard deviation) are 2.28 ± 0.649, 2.46 ± 0.602, 2.34 ± 0.607, 2.18 ± 0.813 and 2.28 ± 0.672 while working on D1, D2, D3, E1 and E2, respectively. These are shown in Fig. 1. The operators working on D2 reported higher discomfort compared to other operators, while the operators working on E1 have felt lesser discomfort when compared to other forklift operators. In conclusion, E1 is the more comfortable forklift, when compared with other forklifts in operator's perspective.

B. Discomfort scores at various body parts - different forklift models

The mean discomfort scores reported in various body parts by the forklift operators operating the different make forklifts are shown in Fig.2. The results indicated that the operators have reported discomfort in most of the body parts (neck, shoulder, lower back, hip, knee and foot) and is higher at lower back irrespective of the forklift model.

C. Frequency of discomfort - different forklift models

Fig.3 shows the CMDQ discomfort score (discomfort score obtained from all the operators) for each frequency category, segregated based on forklift model. The operators working on D2 reported higher discomfort score in all frequency categories except 3 to 4 times a week category, while E1 operators reported lesser discomfort in all frequency categories except 3 to 4 times a week category.

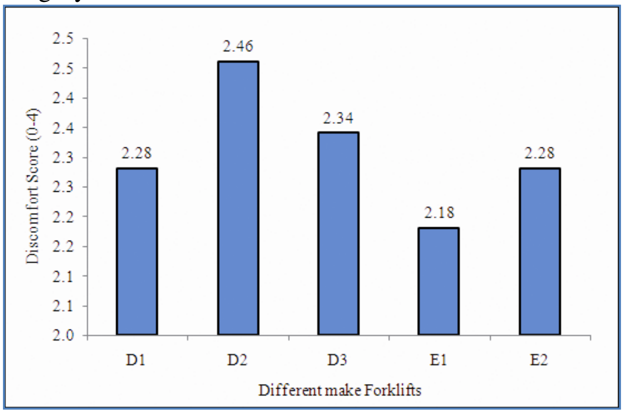

Fig.1: Mean discomfort score reported by the operators working on different make forklifts.

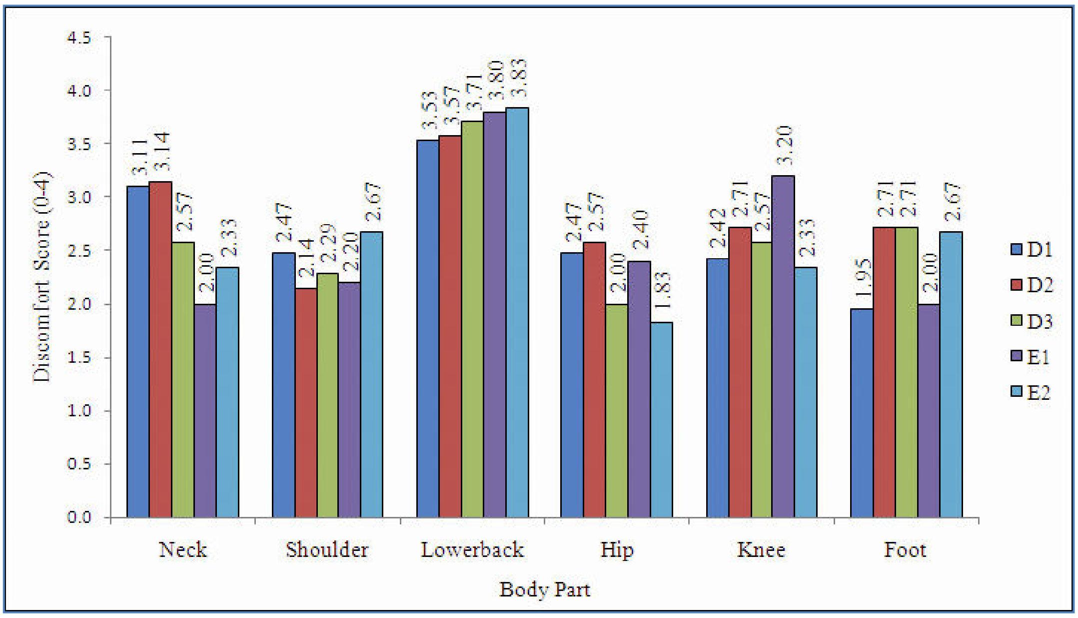

Fig.2: Discomfort scores reported in various body parts in operating different make forklifts

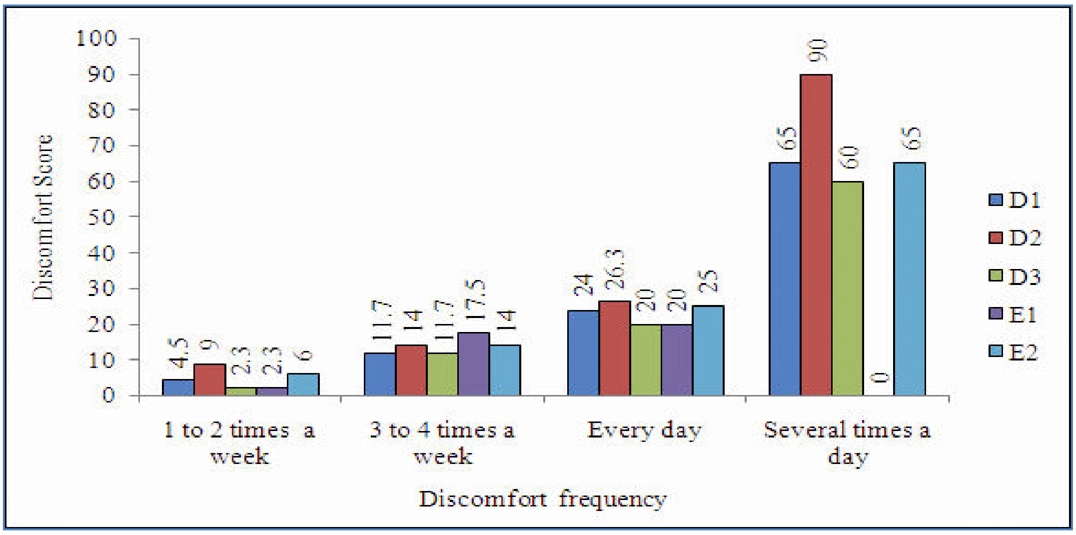

Fig. 3: Discomfort score reported by operators at different frequency categories

D. Discomfort assessment - different engine types

Discomfort scores obtained using Corlett and Bishop's Body map for diesel and electrically operated forklifts are shown in Fig.4. Though operators working on diesel operated forklifts have reported higher discomfort scores (2.33 ± 0.60) (Mean ± standard deviation) compared to electrically operated forklift operators (2.24 ± 0.70), the difference is small.

E. Discomfort scores at various body parts – different engine types

The mean discomfort scores (using Corlett and Bishop's Body Map) reported in various body parts by diesel and electrically operated forklift operators are shown in Fig.5. The operators reported that, the discomfort was highest at lower back, irrespective of the type of engine forklift . Followed by low back, diesel operated forklifts operators have reported higher discomfort in the neck, while electrical forklift operators reported higher discomfort in the knees.

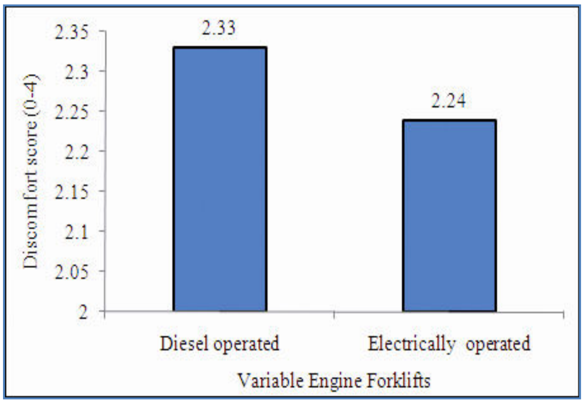

Fig.4: Mean discomfort score reported by the operators working on two different engine forklifts

F. Frequency of discomfort – different engine types

The CMDQ discomfort scores (discomfort score obtained from all the operators) for each frequency category engine-type wise are shown in Fig. 6. Forklift operators working on diesel operated forklifts reported higher discomfort score in all frequency categories except 3 to 4 times a week category.

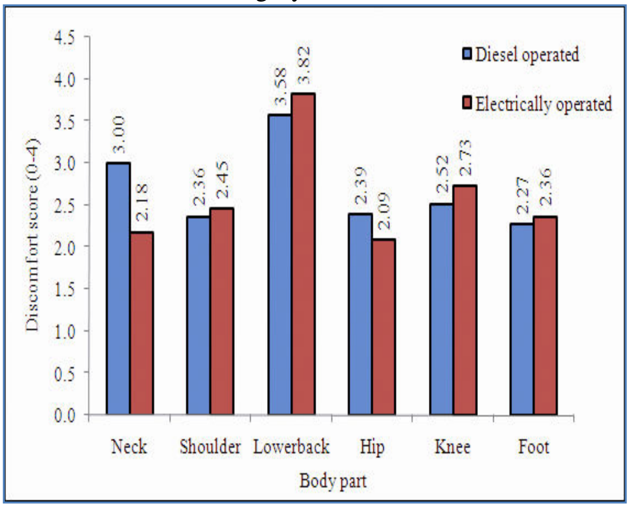

Fig.5. Mean discomfort scores reported in various body parts in operating various engine forklifts

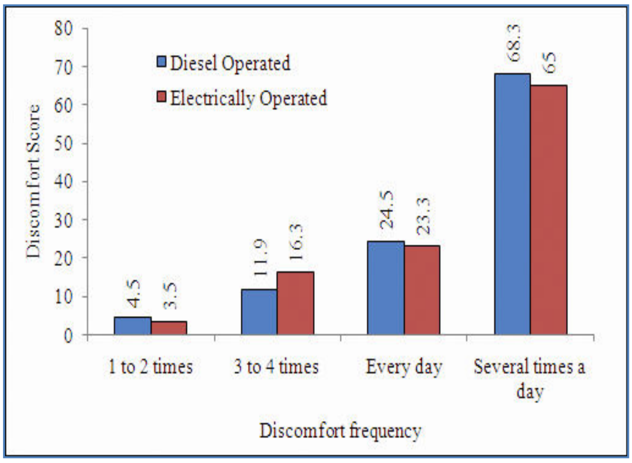

Fig.6. Frequency of discomfort at various engine forklifts

IV. Conclusion

Operators working on Godrej-diesel reported higher discomfort scores, while operators on Voltas-electrical have reported least discomfort. Overall, operators working on diesel operated forklifts reported higher discomfort when compared to electrically operated forklifts, but the difference is small. Forklift operators reported discomfort at all body parts (neck, shoulder, lower back, hip, knee and foot), the highest being at the lower back.

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