Ergonomics

A Checklist for Evaluating Cab Design of Construction Equipment

Scott Schneider, Column Editor

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Awkward postures during the operation of heavy construction equipment are a consequence of improper cab design and work procedures. Poor visibility of the task, limited room in the cab, excessive forces required to operate levers/pedals, and improper seat designs are some of the characteristics of a poorly designed cab. If not controlled, awkward posture of any body part can result in increased risk of fatigue, pain, or injury. Exposure to awkward postures, either repetitively or for prolonged periods, can lead to a variety of musculoskeletal disorders.

Laboratory studies have shown that non-neutral trunk postures (i.e., flexion, lateral bending, and/or twisting) caused increased levels of muscle fatigue and intervertebral disc pressure in the lower back.[1] Epidemiological studies have shown that flexion, lateral bending, and twisting of the trunk are factors in the development of low back pain.[2,3] Spinal disc compression can increase substantially when the trunk changes from a neutral to a flexed posture.[4] Furthermore, prolonged sitting can also result in an increased risk of low back pain.[5]

Laboratory studies of non-neutral shoulder postures have shown that prolonged elevation of the arms (abduction or flexion of the shoulder) causes extreme levels of muscle fatigue and discomfort.[1,6] Hagberg[7] demonstrated a positive relationship between shoulder elevation and increased risk of tendonitis in a cross-sectional field study. A relationship between non-neutral neck posture and the development of disorders has also been well documented.[8]

The objective of this article is to introduce a one-page checklist for evaluating cab design of construction equipment. The cab design evaluation checklist was developed, pilot-tested, and used to measure several characteristics of cab design (see Table I). The checklist was based on a literature review and was then discussed with the operators of construction equipment. The draft checklist was then pilot-tested with input solicited from and incorporated by trainers, operating

TABLE I

A checklist for evaluating cab design of construction equipment

	Yes	No	N/A	Comments
I. Characteristics				
1. Is the seat height adjustable?				1
2. Can the seat be adjusted horizontally?				2
3. Is the seat set at proper height?				3
4. Does the seat have a back support?				4
5. Does the seat have a lumbar support?				5
6. Are there armrests available?				6
7. Are the armrests adjustable?				7
8. Are the armrests set at proper height?				8
9. Do you feel any vibration from the equipment through the seat?				9
10. Do you feel any vibration from the equipment through the floor?				10
11. Do you feel any vibration from the equipment through the controls?				11
12. Is the seat firmly mounted to the floor of the cab?				12
13. Can the seat be tilted backward?				13
14. Can the seat swivel?				14
15. Is the location of the controls or levers adjustable?				15
16. Can you easily reach the levers or controls?				16
17. Can you easily operate the levers or controls?				17
18. Can you easily reach the pedals?				18
19. Can you easily operate the pedals?				19
20. Is the cab area large enough (e.g., uncramped area) for you?				20
21. Do you have sufficient upward visibility?				21
22. Is your view of the operation obstructed (e.g., cab guards, pipes/hoses, etc.)?				22
23. Do you feel the cab is noisy?				23
24. Can you control the temperature of the cab?				24
25. Does the equipment have steps?				25
26. Does the equipment have handrails?				26
27. Can you easily open/close the cab doors?				27
28. Does the equipment have proper means for entering the cab?				28
29. Does the equipment have proper means for exiting the cab?				29
II. Environmental				
30. Do you have a good general view of the ground?				30
31. Are the cab windows free from distracting reflections?				31

TABLE II
Background data of operators and equipment evaluated in this study

	Characteristics of the operator				Equipment information			
Operator[A]	Height (cm)	Weight (kg)	Age	Years of exp	Make	Model	Size	Type
1	165	52	33	11	Caterpillar	CAT 416B	Small	Loader/Backhoe
2	178	129	49	30	Caterpillar	CAT 446B	Small	Loader/Backhoe
3	183	86	38	17	John Deere	JD 710D	Small	Loader/Backhoe
4	165	70	58	36	Caterpillar	CAT M318	Medium	Excavator
5	178	100	56	40	Caterpillar	CAT M318	Medium	Excavator
6	168	86	35	15	Daewoo	DH 200W	Large	Excavator
7	170	66	35	12	Komatsu	PC 400LC	Large	Excavator
Mean	172.4	84.2	43.4	23.0				
SD	7.1	25.4	10.7	12.1				
Var	50.4	644.6	113.6	145.3				

[A]OE #1 is a female; all others are male operators.

engineers, and apprentices. A case study is presented in which overall cab design scores were calculated for each type of equipment.

Case Study

The checklist was designed to be a systematic evaluation tool that could be used to assess the characteristics of a cab. A majority of the questions in the checklist were structured so that satisfactory ergonomic conditions resulted in affirmative answers to the questions. There were three questions that had to be worded in an inverse relationship to avoid ambiguity. If supplying a categorical answer was difficult, the answer was qualified by an overall assessment of the characteristics of concern.

After the evaluation of the cab design, an overall assessment score for the cab was calculated. This was done by assigning equal weights to each of the answers, and a percentage of affirmative answers were determined. The closer the calculation was to 100 percent, the better the design or the acceptability of the cab. Some features of the cab may be more important than others, but the simple approach of equal weights was considered here as used by Lifshitz and Armstrong.[9]

Equipment and Operators Studied

The study was performed at several different construction sites in the Greater Boston, Massachusetts area. Seven journey-level (experienced) operators (6 males and 1 female) employed by two major contractors were studied (see Table II). The operators' ages ranged from 33 to 58 years (43.4 ± 10.7); experience ranged from 11 to 40 years (23 ± 12.1); height ranged from 165 cm to 183 cm (172.4 ± 7.1); and weight ranged from 52 kg to 129 kg (84.2 ± 25.4). Each operator used a different piece of construction equipment. Operators were briefed about the study, and they each signed a consent form to participate in this research.

Results

All seven equipment types listed in Table II were evaluated. The overall total cab score was calculated using all 31 questions in the cab design evaluation checklist. The results of the overall cab design score are summarized in Table III. The overall total cab design scores for the seven equipment types ranged from 71 to 87 percent, with a 6.5-percent standard deviation. The following concerns were found:

1. Seats did not have lumbar support in all of the equipment (100%).
2. In a majority of the equipment (86%), the vibration could be felt from the equipment through the floor.
3. In a majority of the equipment (86%), the temperature of the cab could not be controlled.

TABLE III
Evaluation of cab characteristics using the cab design checklist

	Equipment information			
Operator	Make	Model	Type	Overall total cab score[A]
1	Caterpillar	CAT 416B	Loader/Backhoe	74
2	Caterpillar	CAT 446B	Loader/Backhoe	74
3	John Deere	JD 710D	Loader/Backhoe	71
4	Caterpillar	CAT M318	Excavator	87
5	Caterpillar	CAT M318	Excavator	81
6	Daewoo	DH 200W	Excavator	81
7	Komatsu	PC 400LC	Excavator	71

[A]Overall total cab score computed using all questions in the checklist.

4. In a majority of the equipment (71%), the locations of the controls and levers were not adjustable.
5. More than half of the equipment (57%) did not have adjustable armrests.
6. In more than half of the equipment (57%), vibrations were felt at the seats and at the controls.
7. The seat did not swivel in more than half of the equipment (57%).

Discussion and Conclusion

Postural requirements of work should be considered in the design of work procedures and equipment in construction. The relationship between awkward posture and the development of fatigue and musculoskeletal disorders has been reported in laboratory and epidemiological studies. Despite the fact that operating heavy equipment has been found to result in a high prevalence of musculoskeletal symptoms and injuries,[10] there is a lack of quantitative data describing postural stresses among operators of construction equipment. This could be due to the time and complexity in collecting and analyzing postural data. The current study introduced a checklist for evaluating cab design and presented a case study using the checklist.

The checklist is a general assessment tool. The checklist was useful in identifying characteristics that needed improvement. One limitation of a checklist is that it is, at best, an analytical tool.[11] It can assist in the process of identifying potential problems within a system, but for quantifying the problems, a comprehensive and systematic methodology is required for evaluating the work system. The checklist provides a static, instantaneous snapshot of characteristics during a specific time. Nevertheless, this and other checklists provide the critical point of departure in initiating the ergonomic analysis.[9,12–14]

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