Work 41 (2012) 1486-1492
DOI: 10.3233/WOR-2012-0342-1486
IOS Press

Adoption of ergonomic features in a new reach truck cabin design – a usability study

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Abstract. The task of handling reach trucks frequently involves poor working postures. The location of the steering wheel in most reach trucks is in front of the operator which requires the drivers to bend forward and stretch their hands for holding onto the steering wheel. To overcome visibility restrictions, this posture is aggravated by twisting and bending their torso sideways. This paper presents a usability study which was conducted to compare adoption of ergonomic features in a new reach truck cabin with the way they were intended to be employed for improving physical working conditions. Participants drove the reach truck on a test track performing tasks of varying complexity. Video recordings were utilized to facilitate the observations. The results indicate that improved ergonomics features of the reach truck are not used as intended. The test subjects instead adopted postures that they were accustomed to when driving common reach trucks. The possible contributing factors to this posture regression are discussed. The procedure used in this study is recommended for the companies to determine the effectiveness and adoption of ergonomics solutions.

1. Introduction

Forklifts are one of the very useful heavy equipments suitable for a wide range of industrial operations. Studies on the occupational health hazards and musculoskeletal disorders associated with forklift operations highlight the increased risk of lower back and neck pain among the forklift operators. Some of the health hazards contributing to lower back pain are exposure to whole body vibration, and awkward postures including static sitting, trunk twisting and bending, neck flexion and rotation. [1, 4]

Reach trucks, also known as narrow aisle trucks, are small forklifts used to lift and transport pallets of materials, and are typically used in warehouses or distribution centers. Reach trucks (Figure 1) move in a direction lateral to the natural seated posture of the operator. When handling pallets of materials, the work is performed on the right side of the operator cabin at different heights. This task includes steering the forks in a horizontal direction perpendicular to the reach truck, and lifting, lowering, and tilting them in addition to maneuvering. This requires the operator to sustain twisted torso postures with rotated neck and shoulder complex which is further exacerbated to overcome visibility restrictions.

There are a number of design factors and ergonomic recommendations for optimization of a forklift seat and therefore minimized strains ranging from discomfort and fatigue to pain and musculoskeletal disorders. For instance presence of an armrest and a tilting backrest support the arm and upper body, and carry a part of the arm and upper body weight which results into reduced lumbar disc pressure [1]. This is only possible if the operators make use of the back rest appropriately.

Poor placement of steering wheel and controls restrict shoulder rotation, which results in increased head rotation at awkward viewing angles [2]. The steering wheel in most reach trucks is located in front

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of the operator. The common placement of the steering wheel requires the drivers to bend forward and stretch their hands for holding onto the steering wheel. This posture is aggravated when the operators struggle with the visibility restrictions by twisting and bending their torso sideways.

When ergonomics theories are addressed in developing a new product to eliminate awkward working postures, it is expected that the operators accept and conform to the changes. However as operators have a tendency to follow their old habits instead of adopting new ones which are recently learned and less practiced [3], it is rather common for new products not to be used as intended.

2. Purpose and aim

A thorough study on a new cabin design of a reach truck with ergonomics in focus was performed with the aim of comparing the possible optimal working postures, with the postures operators adopt when performing working tasks of varying complexity. The purpose was to find out if and how the drivers utilize the new ergonomic features of the cabin.

Cognitive aspects, such as interpretation of symbols, controls and information have not been included, nor has a comparison been made concerning noise, vibration or life cycle aspects.

3. Method

3.1. Machine

The reach truck used in this study (Figure 2) was a recent model which benefited from various ergonomic features, the most important of which were a rearward inclining and tilting backrest, adjustable armrests on both sides, and the location of the steering wheel on the left armrest.

Figure 1 - A reach truck with the steering wheel located in front of the operator.

Figure 2 - The reach truck used in this study with a mini steering wheel located on the left armrest.

Table 1
Ergonomic features of the reach truck cabin used in the study.

Part of machine	Ergonomic properties	Adjustable features
Seat	• Appropriate size and softness of the cushions	• Seat height • Horizontal placement • Weight adjustment
Back rest	• Appropriate size, angle and shape of the back rest • Tapered form of the back rest to provide enough space for shoulders when turning • Rearward inclining and tilting function • Cushion for lumbar support	• Back rest angle • Inflatable cushion for lumbar support • Removable headrest
Armrest	• Left-hand armrest	• Armrest height • Horizontal placement
	• Right-hand armrest	• Arm rest height • Horizontal placement
Steering wheel	• Placement of the steering wheel on the left-hand armrest	• Steering wheel horizontal distance • Steering wheel height
Fork controls	• Appropriate placement of fork controls	• Horizontal distance
Foot controls	• Appropriate placement of foot controls to provide enough space for knees and feet	• Vertical distance • Horizontal distance
Floor	• Floor space for good foot position while entry/exit	• Floor height

The presence of a left-hand armrest and the location of the steering wheel result in a symmetric sitting posture which prevents the hand and shoulder from stretching excessively and minimizes the strain on the shoulder and neck complex especially when turning the upper-body. Further the armrests together with the back rest support the weight of the arm and a part of the upper body, resulting in less pressure on the back.

The new cabin also included a wide range of adjustments offering the possibility of optimal working postures for a wide range of users. A list of ergonomic properties and adjustable features of the cabin is provided in table 1. These features result in minimizing awkward postures during extended periods of sitting [1].

3.2. Driving task

The reach truck was driven on a test track in a warehouse, with five special designated tasks, all on the same track. The test track was about 760 meters. The task varied from driving to and fro on a straight track to navigating a winding path. The designated tasks were to pick, place, lift and lower pallets within different heights ranging from 0 to 6 meters from the ground. There was no time limit defined for the test subjects for finishing the tasks.

3.3. Subjects

Six male professional drivers (37-57 years) participated in the study. The test subjects had never used the new cabin before. Their height and weight were 167-194 (mean ≈ 175) cm and 64-120 (mean ≈ 83) kg. Their anthropometric measures are provided in table 2.

In addition, one of the development engineers of the new cabin (male, 34 years, height 180 cm, weight 70 kg), who also had experience in driving forklifts, drove the reach truck on the test track. This was to provide a reference for optimal use of the new features which resulted in the best possible driving posture. This driver is referred to as the ‘reference driver’.

Table 2

Anthropometric measurements of the test subjects. TSx is the test subject’s number.

Dimensions	TS1	TS2	TS3	TS4	TS5	TS6
Height (cm)	167	169	194	173	174	175
Sitting height (cm)	51	54	63	54	53	52
Popliteal height (cm)	47	44	54	47	46	44
Arm length (cm)	75	77	9	79	78	81
Hand length (cm)	18	18	22	18	18	20
Weight (kg)	65	68	120	88	84	75

3.4. Test procedure

Anthropometric measurements and personal data of each participant were initially collected. Before the test, a detailed explanation of the possible adjustments of the new cabin was given and a practice trial was carried out to let the drivers get familiar with the reach truck and find a comfortable sitting posture. Thereafter, they commenced the test by driving through the defined test track and carrying out the five designated driving tasks. After the test drive, a questionnaire was filled in which was followed by an interview regarding their perceived comfort/discomfort.

It took approximately 10 minutes to complete the tasks, with 70% of the time spent on driving on the left-hand side, 20% on the right-hand side and 10% for handling the forks.

Data was collected in multiple ways during the test to study drivers' sitting behavior and handling of controls. Four black-and-white cameras with 3.6 mm lens were mounted on the reach truck facing different angles (Figure 3). One camera was mounted on the right side of the driver facing the test track to record the test procedure. The drivers' postures were recorded by 3 cameras mounted on the ceiling of the reach truck. These cameras recorded the driver's posture and his interactions with the instruments of the cabin from three angles; top-right to record the right hand posture, top-left to capture the handling of the steering wheel, and rear to record the posture of the back.

The tests were conducted between 4 and 9 PM and carried out in an industry building (warehouse) in Sweden over two days in February 2011.

3.5. Data analysis

To analyze the results, a theoretical expert analysis and a comparison between the optimal driving posture and the drivers' adopted postures based on video observations was carried out. A playback software capable of playing all four video channels simultaneously, was employed to facilitate the analysis. Different instances were saved as snapshots and simple stick figures were later drawn on the snapshots to highlight the chosen postures.

4. Results

Based on careful observations of all video recordings, two main working postures were identified as critical with regard to the driving tasks performed. Each of these postures were analysed at an extreme moment and compared with the optimal posture used by the test driver. The two selected working postures were:

- Cornering situations where rearward observation to the left is required. The torso and the head are rotated to the left. The test subject's left hand is resting on the armrest, using the steering wheel. Figure 4 shows the optimal posture demonstrated by the reference driver and the adopted working postures of three test subjects in cornering situations.

Figure 3 – Placement of the four cameras on the reach truck

Figure 4 - Cornering situations where rearward observation to the left is required.

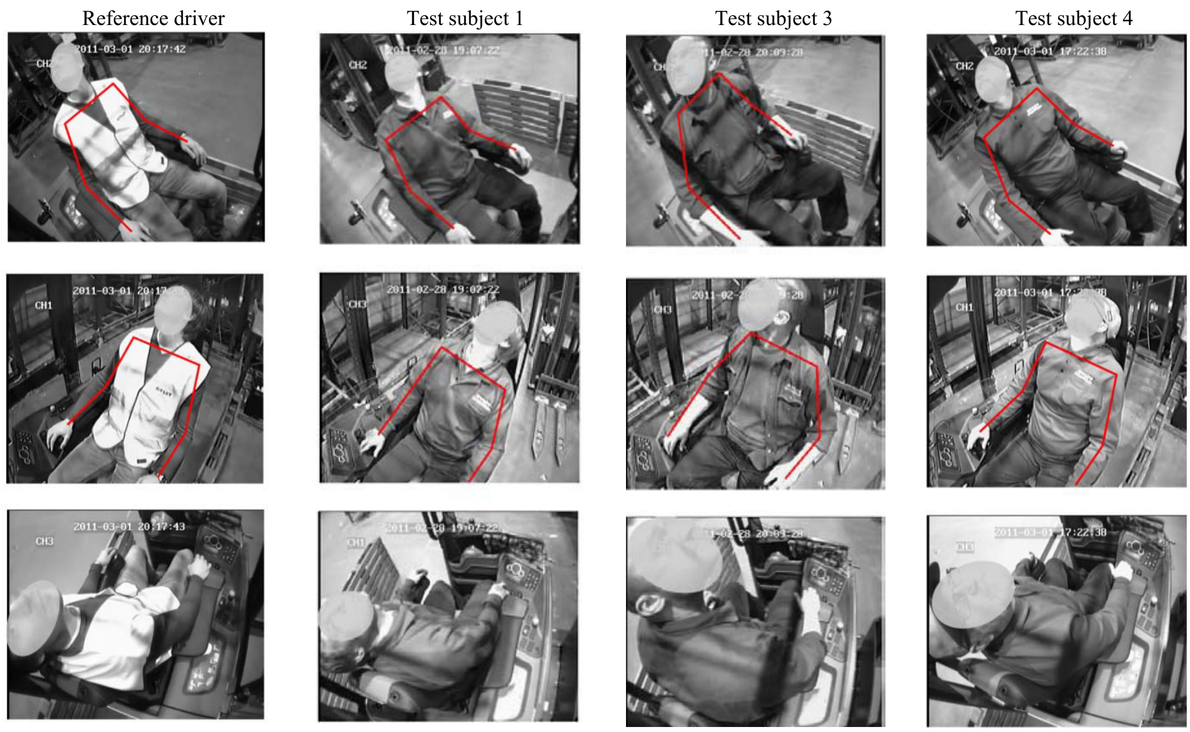

Figure 5 - Handling palettes on a shelf at a height of 6 meters.

- Handling the palettes on the shelves of 6 meters height. Leaning forward, the torso is rotated to the right-hand side. The head is twisted to the right and tilted in the opposite direction (left). The left hand rests on the steering wheel while the right hand operates the fork controls. Figure 5 shows three test subjects' adopted working postures and the optimal posture of the reference driver at this working moment.

The main difference between the reference optimal postures and the adopted postures of the test subjects is the degree to which the tilting and inclining function of the backrest is used. Analysis of the optimal postures shows that the reference driver utilizes the inclining backrest to a great extent, in both working moments.

The adopted postures of the test subjects were however considerably different; they did not use the inclining feature of the backrest and did not lean back to the same extent as demonstrated by the reference driver.

This comparison further shows that the handling of the steering wheel by the test subjects was identical to that of the reference driver. It was only possible to handle the steering wheel in one way.

5. Discussion

The test subjects showed a tendency to keep the working postures they were accustomed to when using other reach trucks instead of adopting the optimal posture that the new cabin made possible. Probing into why the users did not adopt the optimal working postures can lead to many answers. Recently learned principles are more prone to regression than the older and over learned responses [3]. The test subjects' behavior conformed to this pattern. Other contributing factors are anthropometry, age and fitness.

Another reason for posture regression was the wide range of customizations and difficulty in effectively and intuitively communicating the new features of the product. However, if there is only one possible way for using a new feature, the operators are left with no choice but to accept a new routine. This was the case with the steering wheel. The core idea of the new cabin design was to improve the physical ergonomics by changing the location of the steering wheel in order to eliminate adoption of awkward working postures. To achieve this, the design of the user interface of the cabin is central, since the drivers need to understand the interface to be able to use the new features of the cabin in order to adopt appropriate working postures. If the design does not communicate the appropriate use of the machine when performing the task, the operators adopt the hazardous body postures that they are used to. This highlights a distinct link between physical and cognitive ergonomics in the operator-truck systems. Therefore to achieve improvements in physical ergonomics, knowledge in the cognitive field of user interface design is required.

Insufficient instructions, training and time for adaptation also contributed to the way test subjects adopted postures that they were accustomed to when carrying out the tasks. Therefore, more instructions are required for users of a new cabin design to get familiar with the new features and internalize adopting optimal working postures.

Another notable point about the posture regression was that all of the test subjects had a great focus on completing the designated tasks; therefore, they made less effort to adopt appropriate working postures.

Employing several video cameras in the test procedure made viewing from different angles possible and provided a more complete perspective for studying the drivers' sitting behavior. This considerably facilitated the observation.

This study also highlights the importance of product evaluation with user involvement. Clearly, there is a great benefit for companies and product developers to conduct usability and ergonomics evaluations, i.e. theoretical expert analyses and evaluations with real users.

6. Conclusion

The result from studies of (1) theoretical expert analysis of the new cabin design, (2) video observations of sitting postures during work, and (3) comparison between the optimal and adopted sitting postures showed that:

In most reach trucks, the steering wheel is located in front of the driver and requires the driver to keep his left arm stretched in all situations. As a result the driver has to struggle to hold onto the steering wheel especially in restricted visibility situations where trunk twisting and bending occurs. In instances when ergonomics solutions are employed in the design of the reach truck cabins, features like the inclining and tilting function of the backrest are expected to be utilized. But operators bend forward in order to hold the steering wheel.

Although the steering wheel in the new cabin was located on an armrest to facilitate adoption of a good working posture, the tilting and inclining function of the backrest was not used by the test subjects to the expected extent. The operators kept the posture that they were familiar with in common reach trucks and held onto their routines, rather than adopting the optimal posture that the new cabin made possible.

Another conclusion drawn from this study is the significant role of cognitive design aspects in improving the working situation and the degree to which it can contribute to good physical ergonomics postures.

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