The MSD Risk Assessment Among Forklift Operators as a Source of Data for Ergonomic Intervention—Comparison of Two Tools

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ABSTRACT

Two different methods: REBA (Rapid Entire Body Assessment) and the revised Quick Exposure Check (QEC) were applied for the assessment of three jobs involving forklift truck driving. The application of MSD risk assessment tools was followed by ergonomic checklists analysis. The results were used for ergonomic intervention program. Although both methods shown their usefulness in the MSD risk assessment, QEC results were more specific, gave more detailed information about possible ways of ergonomic intervention and better showed the decrease of MSD risk as an effect of changes applied.

INTRODUCTION

Forklift truck operators are subjects of many ergonomic analysis due to high physical and psychological requirements of their work [1], [2], [3], [4]. This job is related with reasonably high risk of musculoskeletal disorders (MSD), particularly those involving spine. The forklift truck operators need to perform many different head movements due to their job task requirement, including rotation over 45 degrees when reversing the truck and holding the head at lateral flexed position when loading the fork at high levels. For safety reasons, they repeat rotation during forklift or load reversing. Moreover, they lean to the side in consideration of better view during loading and unloading the vehicle. Therefore, even if they operate in a good quality vehicles with different adjustments possibilities, they are exposed to a risk of awkward postures. Thus, as a result, most of forklift operators experience neck pain. According to Flodin et al. [1], 49% of investigated forklift operators reported they experienced neck pain, in comparison to 30% of office workers. Moreover, the authors reported an association between neck extension and neck and shoulder symptoms among forklift operators. According to Van den Heuvel et al. [5], neck rotation over 45 degrees is a significant risk factor for neck pain as well. Such position is often observed among forklift operators. Moreover, Bovenzi claimed in a three-year follow-up study on the sample of 537 male professional drivers the association of neck and shoulder pain occurrence (NSP)
with cumulative whole-body vibration exposure. Additionally he found the relation between neck pain and driving with trunk bent or twisted [6]. Another problem of forklift drivers is lower back pain risk, which is over twice (2.1) higher in comparison to those not exposed to driving forklifts. The reasons are operator postures and additionally whole body vibration (WBV). Awkward operator’s postures as well as static workload are affected by cab design, seat, time spent seated, and the task performed [2]. The vibrations level is influenced by work factors like seat, speed, track, and tires. For that matter, the meta-analysis of the epidemiological studies conducted on forklift operators in relation to MSDs, such as lower back pain and neck problems, made by Waters at al. suggests that forklift operators are at increased risk of lower back pain [3]. The combination of vibrations and awkward postures is especially dangerous. For example, Male found the reason of back injuries of drivers of counterbalance trucks was running into potholes while reversing in awkward posture i.e. with back twisted [7].

In addition to trunk and neck bending and twisting as two sources of pain risk, Bovenzi noticed the other factor increasing neck and shoulder pain are psychological issues, like limited job decision, low social support and job dissatisfaction [6]. Similarly, Harley and Cheyne analysis shown the significant influence of stress caused by different pressures or work demands on risk of unsafe driving situations [8]. These pressures or demands at work can include working long hours, workload demands, and supervisory pressures. The authors pointed out rush feeling related with accidents rates among drivers. Moreover, high work demands effect in reducing safety level compliance [8]. Norris et al. noticed that job stress was one of the best predictors of future accident involvement in context of general driving behavior [9]. Similarly, Thun et al. in their analysis in the automotive industry in Germany found time pressure as the most negative factor impacting the ergonomic risk [10].

To prevent the poor results of forklift truck operator’s workload, the assessment of their current job requirements and risk is needed. The good evaluation gives a possibility for proper intervention and prioritizing the improvements. However, the evaluation of the same workstation with different methods gives often equivocal results due to the uncertainty of data and differentiation of risk assessment criteria [11], [12]. Therefore for the complete evaluation of the workstation the combination of at least two different methods can be required [12]. Takala et al. analyzed 30 different observational methods and found their choice should base on needs of decision-making process of evaluators [13]. Similarly David noticed the selection of methods depends on the application objectives. He found the main motivators for applying easy-to-use methods basing on observations are limited time and resources of assessors and the need of forming priorities for ergonomic intervention [14].

THE CHARACTERISTICS OF ASSESSED JOBS

The ergonomic risk was assessed for workers operating in a food industry logistic area. Because of product requirements, the work area has a stable, low temperature 4-6°C. As in the work area operate cooling fans, the wind chill temperature is even lower. Due to cool microclimate, during 8 hours long shift two longer breaks and a warm recovery meal is provided for the employees. Three types of workstations were identified, i.e. (1) loading the goods on the TIR lorries, (2) loading the goods from the start point to the cooling cells and (3) attending on a cling film wrapper and delivery of
wrapped goods to the warehouse. Each kind of job is executed mainly as driving forklift vehicle.

1. Loading the goods on the TIR lorries – the forklift driving in cycles about 1 min. long. About 85% of goods require driving backwards due to their height. Six hours of effective driving per shift.

2. Loading the goods from the start point to the cooling cells. Approximately 150 pallets per employee per shift, transport to the cells require driving backwards in most cases. It is necessary to precisely enter the cell, the operator makes side bending in order to observe the load and adjusts the position of the forks (right / left) with joystick.

3. Cling film wrapper and goods delivery. Operator is responsible for feeding the semi-automatic wrapper with a palette of goods and delivering the wrapped goods to the warehouse in the meantime. One cycle takes about 3 minutes, the operator attend to about 150 pallets during one shift.

METHODS

For the evaluation of the workstations two methods were applied. Both tools are designed for quick evaluation of tasks from ergonomic point of view and they are commonly use. For the total assessment the REBA (Rapid Entire Body Assessment), which is a modification of the RULA (Rapid Upper Limb Assessment), was used. The method was introduced by Hognett and McAtamney and consider the workload of the entire musculoskeletal system related to both the use of force for the task and the need of maintaining the necessary posture of the body [15]. The REBA method takes into account all the body parts (trunk, legs, neck, shoulders, arms and wrists) and the grand score takes into consideration some additional factors like quality of hand-coupling and force [16]. The result determines the risk of musculoskeletal disorders and the range of ergonomic interventions necessary to reduce this risk [13]. The corrective actions should be carried out for all work postures evaluated at the medium level and above. The method allows for the evaluation of individual working positions independently of each other. When the workstation combines several working actions further interpretation is necessary. Takala et al. reported inter-observer repeatability was moderately good for leg and trunk postures but not for upper limbs [13].

For the assessment of specific parts of body the revised Quick Exposure Check (QEC) was applied. The method created by Li and Buckle in 1998 [17], and developed later gives a weighted score indicating relative risk of a body region, task, or risk factor [18]. The evaluation is made both by the observer and the worker themselves. The QEC method was checked for its inter- and intrareliability and validity. Moreover, new, shortened form design was investigated for its usability [19]. The QEC gives separate points results with interpretation for such body parts like back, shoulder, wrist/hand and neck and additionally assess some extra factors: driving, vibration, work pace and stress. Its intra- and inter-observer repeatability is moderate [13].

The relations between REBA and QEC results are not clear. Motamedzade et al. noticed a significant correlation between both methods results (r = 0.731 for final scores and r = 0.893 for action levels) [20], however Nadri et al. did not found significant correlation between their final scores [21].
Preliminary assessment

To identify the main ergonomic problems, NIOSH checklists were used. These lists cover all the main aspects of workplace ergonomics and are a widespread ergonomic assessment tool. Due to the specifics of the workstations and work processes examined, the following lists were applied: Ergonomic Hazard Identification Checklist, Workstation Checklist, Task Analysis Checklist [22]. The forms were completed on the basis of data from observation of work processes and analysis of registered video material. Table 1 presents the main ergonomic problems resulting from the NIOSH list analysis.

| Category                  | Main problems                                                                 |
|---------------------------|-------------------------------------------------------------------------------|
| Work postures             | Bending and twisting                                                          |
|                           | Awkward positions                                                             |
|                           | Seating with features of an awkward position                                  |
| Repetitive movements      | A large number of extreme (side bending) positions during work                |
|                           | Quick changes in body position                                                |
| Manual activities         | Repetitive movements in a cycle lasting less than one minute                  |
| Work environment          | Exceeding the optimal size (span) of the hand grip                            |
|                           | Performing manual activities at low temperature                               |
|                           | Adverse (cold) microclimate                                                   |
|                           | Noise                                                                         |
|                           | Time pressure (work pace)                                                     |

REBA and QEC assessment

Key job actions decisive for operator’s workload were identified by the observation. The following job operations were distinguished during the work process:

- Forklift driving, operating and maneuvering forwards (in brackets REBA classification: 3)
- Forklift driving and maneuvering backwards (4)
- Forklift precise maneuvering with side bending (5)
- Manual operations—preparing the palette for wrapping (4)

As mentioned above, REBA result when worker operates on different tasks needs further interpretation. The weighted average was applied, with taking into consideration different time schedules of tasks performed on specific workstations. This is the reason for the fractional values of point scores. The assessment was made on the basis of video material and knowledge of the production volume, allowing to estimate the number of activities performed during the work shift. The average times for maintaining working positions in the cycle have been adopted. As shown in the Table 2, for two kind of job (No 1 and 2) the intervention is needed.

| Job No.                                  | REBA result (interpretation) | Main risk factors                                          |
|------------------------------------------|------------------------------|------------------------------------------------------------|
| 1 (loading the goods on the TIR lorries) | 3,4 (Moderate)               | Sitting posture duration                                   |
|                                          |                              | Short work cycle                                           |
|                                          |                              | Trunk and neck twisting                                    |
| 2 (loading the goods to the cooling cells)| 3,5 (Moderate)               | Sitting posture duration                                   |
|                                          |                              | Back and neck side bending                                 |
| 3 (attending on a cling film wrapper and delivery to the warehouse) | 2,88 (Low) | Manual activities requiring force                           |

Table 2. REBA assessment results.
According to QEC results (Table 3) intervention is necessary for all the evaluated jobs, especially for back and neck. Also driving over 4 hours per day is noticed as a significant risk factor. Besides the static overload (sitting posture, twisting, bending) noticeable for both methods, QEC shows the influence of visual demand, which is an important feature of work tasks, decisive for their level of difficulty.

| Job No. | Back   | Shoulder/Arm | Wrist/Hand | Neck  | Work pace | Stress | Main risk factors                        |
|---------|--------|--------------|------------|-------|-----------|--------|------------------------------------------|
| 1       | 24 (H) | 22 (M)       | 22 (M)     | 14 (H)| 4 (M)     | 4 (M)  | Sitting posture duration                 |
|         |        |              |            |       |           |        | Visual demand                            |
|         |        |              |            |       |           |        | Neck and back twisted/ bended            |
| 2       | 24 (H) | 22 (M)       | 26 (M)     | 16 (VH)| 4 (M)     | 9 (H)  | Sitting posture duration                 |
|         |        |              |            |       |           |        | Visual demand                            |
|         |        |              |            |       |           |        | Neck and back twisted/ bended            |
| 3       | 28 (H) | 32 (H)       | 32 (H)     | 16 (VH)| 9 (H)     | 9 (H)  | Visual demand                            |
|         |        |              |            |       |           |        | Manual force and handling                |

Abbreviations: M—Moderate, L—Low, H—High, VH—Very high. Driving risk high due to long exposure for all the jobs.

The results from REBA and QEC assessment

At a glance, comparison of REBA and QEC results shows the higher risk categorization for QEC. Most reasons for the existence of risk are common for both methods:
- non-neutral working positions, i.e. twisting of the trunk and/or neck and side bending, mainly caused by the need to observe the load or the path of the forklift way
- long-term maintenance of the sitting posture
- repetitive activities (including awkward postures) during work
- quick changes in the working position, mainly due to the need of observing both sides of the forklift

It is worth to notice these reasons were identified by NIOSH checklists analysis (Table 1). The elimination of these factors would reduce the grand REBA risk score by at least one point in all tested positions. Also QEC results for body segments would be significantly (at least one category) lower. Therefore these finding were used for ergonomic changes conceptualization. Both methods showed the risk concerning with neck spine. In fact, interviews show that the ailments are not epidemiological, but some employees pointed to neck problems. Therefore the intervention was focus in this issue.

ERGONOMIC IMPROVEMENTS RECOMMENDATIONS ON THE BASIS REBA AND QEC RESULTS

The results from REBA and QEC assessment were used to propose improvements for forklift operators. Most of them focus on reducing the number and pace of changes of potentially dangerous postures and movements observed in the evaluation process, like twisting or bending. According to the guidelines of the British Health and Safety Service, the following methods should be used simultaneously to reduce the risk of forklift operators: (1) limiting the speed of the lift truck, (2) stretching exercises for
operators, (3) educating employees, (4) preparing the storage space and (5) suitable forklifts [23, 24, 25].

1. Speed limit. Speed increases the impact shocks and vibrations on the operator’s body as well as the risk of accidents [7]. This method has already been applied and the maximum speed of the lift trucks has been reduced from 12 km/h to 9 km/h.

2. Stretching exercises. Half-minute (30s) stretching exercises involving hands, arms and neck are a simple method of reducing discomfort. For lift trucks operators often working in an awkward position, it is recommended to use the breaks that appear in the work process for simple, short exercises. Besides the breaking of static load, the exercises are a way for warming up in the cool environment.

3. Education of employees. The aim of the training is to increase employees' awareness of available preventive activities and work techniques, including presentation of neutral and awkward positions of individual body segments (neck, head, back), encouraging physical activity at work and outside work. Particular attention should be paid for adjusting the operator's seat and the correct seating posture. This includes seat adjustment before the driving - setting (front - back) in order to get easy access to pedals and steering wheel, emptying back pocket (wallet/phone removal) before the drive and deep seating with good back support, especially in the lumbar region [25]. Besides the influence on ergonomic hazard decrease, the operators’ training together with organizational changes (shock-absorbing posts) was found to be an effective way of reducing costs of material damages caused by collisions with forklift trucks [26].

4. Warehouse space. Regular inspection of storage space to remove unevenness such as cracks in the floor, potholes, bad fitted ramps etc. Any roughness increases the physical stress of the operator. Another problem can come from the organization of work in a warehouse space. An important element increasing the difficulty of work, especially at the TIR loading lorries area, is the presence of other forklift vehicles. According to International Labour Organization psychological stress associated with increased risk of accidents involving other vehicles is one of the reason the workload of forklift truck operators [27]. Improvement may consist in such organization of work that a limited number of vehicles operate in the area. The other important issue is the warehouse environment with cool microclimate. In such cases some manufacturers propose employees the activities requiring physical work instead of continuous using manual handling support for higher thermal comfort. The other solutions build on the improvement of the microclimate of forklift truck cabin by heating seat, floor and/or handles, but these enhancements are limited by protective cloth of operators [28]. The basic way of preventing the effects of chilling is providing more breaks in comparison to law regulations, which is already done by the employer.

5. Forklifts. The model used by employees in the investigated warehouse is equipped with a set of regulations in a sufficient range [29]. Employees, however, complain about poor visibility in the spherical mirror, hence the backward ride takes place rather without the use of a mirror. According to Chin-Bong et al., over 80% of dangerous vehicle accidents and events involving a forklift truck, such as pedestrian or other vehicle deductions or falls from a ramp are caused by visibility problems [30]. At the same time, most of the observed risky working positions result from the need for observation with overcrossing safe visibility zones (over 55 degrees in lateral plain, over 60 degrees in medial plain [31]. Tracking control system mounted on the vehicle or in places with high visual demand, like cooling cells, could help to avoid this overcrossing. A popular solution are also reversing sensors, automatically switching on when driving backwards and informing about an obstacle via an alarm signal. These
sensors can also be integrated into the truck's drive, resulting in an automatic speed reduction [32].

**SUMMARY**

As the result of the analysis the changes concerning speed limitation, educating employees (additional trainings, adjusting the forklift truck, physical activity), checking the storage space floor, better work organization for reducing risk of collisions and additional laser pointers mounted on forklift trucks in order to show the position of load were applied. These improvements let reduce risk assessed by REBA and Quick Exposure Check methods, although QEC reduction is more significant.

Both methods were useful for MSD assessment, however their application give the assessor different information. REBA grand score allow to more general evaluation, while Quick Exposure Check takes into account more factors and assess them separately. Therefore the influence of psycho- and physiological factors (visual demand, work pace and stress) on the workload can be visible. As it was shown above, psychological issues influence not only on accident ratio and employee stress level, but can cause MSD as well [6, 8, 10]. Moreover, according to revised QEC investigation, driving is considered to be a significant risk factor [18]. Consequently its occurrence over 4 hours per day is assessed as the high level of risk. On the other side, the differentiation of interpretation for a single job assessment, like for loading the goods from the start point to the cooling cells (Job 2 in Table 3) may result in confusion. Nevertheless, in this specific situation a risk associated with MSD as well as its reduction by ergonomic intervention was more perceptible for QEC method. The utility of REBA method for the specific application seems to be lower in comparison to QEC due to necessity of considering different body postures for one job. Quick Exposure Check allow for this differentiation, which make the assessment procedure easier.

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