A different approach for the evaluation of pushing and pulling in practice

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Abstract

Recent epidemiological studies show that pushing and pulling increase the risks of shoulder complaints and not necessarily of low back complaints. Moreover, the magnitude of the exerted hand forces during pushing and pulling is poorly related to the magnitude of the mechanical loading of the low back and the shoulder. In light of that, this paper combines results of several studies to present an approach for evaluating not only the exerted hand forces, but also the low back and shoulder load during pushing and pulling in practice, without the necessity to measure hand forces. During the interactive session we will introduce this approach and let you practise the approach using two cases from industry.

Keywords: pushing, pulling, low back, shoulder, risk assessment, biomechanical workload

1. Pushing and pulling increase the risk of shoulder complaints

Pushing and pulling (P&P) is a frequent activity for a great segment of the workforce. It has been estimated that nearly half of manual material handling consists of P&P [1]. P&P is defined as the exertion of a (hand) force by a person on an object or another person, the resultant force of which is directed horizontally [2]. Aside from that definition, a distinction can be made between P&P while walking in order to move an object, such as a trolley, and P&P while standing in order to operate an instrument, such as a lever. In the present study, we will focus on P&P in order to move objects over a certain distance while walking.

In terms of the ergonomic evaluation of P&P in practice, the guidelines presented by Mital et al. [3] and the working draft of ISO document “Ergonomics – Manual Handling – Part 2: Pushing and pulling” (N241- ISO/CD 11228-2) provide the most useful cut-off points for reducing the risk of fatigue and musculoskeletal complaints. These guidelines are based on perceived exertion, energetic workload, and partly on lumbar loading. However, recent epidemiological studies show that P&P appear to be a more significant risk factor for shoulder complaints than for low back complaints [4, 5, 6].

Although P&P have been found to be related to shoulder complaints, existing guidelines do not account for shoulder load. In addition, the guidelines focus on the maximum acceptable push or pull forces. This may suggest that the magnitude of force exertion is directly related to mechanical loading. However, Hoozemans et al. [7] could not confirm the assumption that higher magnitudes of initial and sustained exerted forces were
related to higher magnitudes of the mechanical loading of the low back and shoulder. One explanation is that the direction of the P&P force has a large effect on the mechanical load [8].

Another consideration that guidelines should take into account as regarding force exertion is that it is often difficult in practice to make valid assessments of these forces. Preferably, forces should be measured in the three dimensions simultaneously. However, the present paper introduces a different approach for the ergonomic evaluation of P&P that is complementary to the guidelines described above and do not require the assessment of P&P forces. This approach enables the practitioner to estimate the exerted hand forces, and the biomechanical load of the shoulder and low back based on the following P&P characteristics: 1) weight of the object, 2) the number of hands used, 3) the handle height and 4) the specific activity, i.e. pushing or pulling.

2. Different approach

As mentioned, the present approach is complementary to the guidelines presented by Mital et al. [3] and the working draft of ISO document, ‘Ergonomics – Manual Handling – Part 2: Pushing and pulling’. As said, the approach assesses the risk of P&P on low back and shoulder complaints and fatigue complaints. The first step in this approach consists of specifying how a task analysis should be performed in order to arrive at a relatively precise estimate of the mean frequency and duration of pushing and pulling in the workplace. The second step is to estimate the hand forces exerted and the mechanical load of the low back and shoulder. The third step involves comparing the force exertion and mechanical loading of the low back and shoulder with existing guidelines.

2.1. Step 1: Assessment of frequency and duration of pushing and pulling

Quantification of exposure at the workplace to – say – pushing and pulling is time consuming. Ergonomic practice is helped by a data collection strategy that is effective in obtaining estimates for group mean exposure with sufficient accuracy (small bias) and precision (small random error). This strategy can be employed with a minimal investment of resources [9]. Several methods are available for the assessment of activities at the workplace [10]. The use of a hand-held computer to record activities of interest during direct observation of workers at the workplace has proven to be a feasible and valid activity assessment method [11, 12] (see Fig. 1). However, the question is how many workers need to be observed and how many repeated measurements are required per worker to arrive at a relatively precise estimate of the mean exposure to activities for a group of workers (in terms of frequency and duration). Hoozemans et al. [13] used a bootstrap procedure to examine measurement efforts to assess the frequency and duration of pushing. The results showed that the group mean exposure to pushing in terms of frequency and duration was largely determined by interworker variation, as increasing the number of workers increased precision of the group mean more effectively than did increasing the number of repeated measurements per worker. Within the maximum of 15 workers used in the bootstrap simulations, it appeared that, beyond 10 workers, the P95-P5 intervals decreased by <5% for every worker that was added, when each worker was observed at least 8 periods of 30 minutes. If workers were observed exactly 4 periods of 30 minutes per worker, an additional 4 workers were required to compensate for the loss of precision. Moreover, adding 8 more periods of 30 minute for each of these 10 workers i.e. observing a full working day instead of half a working day, little precision was to be gained. Within the same study comparable results were found for other occupational groups and other activities such as pulling, lifting, and carrying.

For example, the board of a waste management company wanted to know whether it was possible for one employee, rather than two, to collect four-wheeled waste containers. An empty metal container weighs 185 kg and the mean weight of full containers is 110 kg (total 295 kg). A task analysis among 10 workers during half a working day revealed that about 0.8 four-wheeled containers per minute were pushed at hip height with two hands over a distance of about 10 m (see also last section of § 2.2 and § 2.3).
2.2. Step 2: Estimating hand force exertion and mechanical load of low back and shoulder

Characteristics of P&P activities can be used to estimate hand force exertion and mechanical load at the shoulder and low back, without biomechanical measurements. For this purpose, the biomechanical study of Hoozemans et al. [7] was used, in which the forces exerted and the mechanical load on the low back and shoulders during pushing and pulling four wheeled containers were calculated based on three task constraints: the use of one or two hands, three cart weights, and two handle heights. During the interactive session we will introduce the equations for calculating the effect of the weight (kg) of a four-wheeled container (including its own weight) on the initial value and sustained value of the forces exerted and the mechanical load on the low back and shoulders, depending on the activity (pushing or pulling), handle height (hip or shoulder height) and number of hands used (1 or 2).

Regarding the waste collection example (see also last section of § 2.1 and § 2.2), the hand force exerted to set the four-wheeled waste container into motion (initial value) while pushing with two hands at hip height was 350 N. The corresponding maximum compression force on the low back was 2079 N and the moment at the shoulder was 80 Nm.

2.3. Step 3: Comparison with guidelines

The hand forces exerted are compared with guidelines of Mital et al [3], the compressive forces at the low back with the NIOSH 3400 N criterion [14], and the moment at the shoulder with the shoulder-moment strength mean prediction equations for exertions in the sagittal plane [15].

Regarding the waste collection example (see also last section of § 2.1 and § 2.2), according to Mital et al. [3], 230 N is the maximum acceptable initial force for pushing a four-wheeled waste container at hip height (95 cm) with two hands over a distance of 7.6 m and a frequency of 1 cart per minute for male workers in the 90th percentile. According to the equations of Chaffin et al. [15], 61 Nm is the maximum acceptable shoulder load for pushing at hip height for 90% of the male population. The initial values for the push forces exerted and corresponding shoulder load exceeded the maximum acceptable values. In light of this, the board of the waste management company was advised that collecting four-wheeled waste containers by one employee is unacceptable in terms of the physical workload.

3. Interactive session

During the interactive session the approach will be presented using the following five questions:
1. Why is a different approach useful to assess the risk of pushing and pulling?
2. What is the difference with existing guidelines such as Mital and ISO document “Ergonomics – Manual Handling – Part 2: Pushing and pulling”?
3. How does the approach work in practice?
4. Does the approach contribute to the selection of ergonomic interventions?
5. How time-consuming is the approach?

The session is organized in the following manner:
Sit back and learn (45 minutes):
- about the latest evidence whether pushing and pulling is a risk factor for musculoskeletal complaints;
- why and how the approach is developed;
- how the approach contributes to the selection of ergonomic interventions.

Get active and experience (60 minutes):
- how the approach works using two cases from industry;
- how the approach is complementary to existing guidelines such as such as Mital and ISO document Ergonomics – Manual Handling – Part 2: Pushing and pulling.

Sit up and share (15 minutes):
- what you as an expert think the pros and cons are of the presented approach.
References


