

Maximum acceptable work loads for repetitive lifting tasks

An experimental evaluation of psychophysical criteria

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Three main approaches can be used to determine the load a worker can lift safely. These approaches are based on estimations of biomechanical, physiological, and perceptual stresses.

The biomechanical models (5, 7, 9) emphasize the loads on the musculoskeletal system during the lifting task and provide estimations of the forces and torques generated during the task. The limitations of the biomechanical models are primarily that they do not directly predict lifting capacity, that they are static in nature, and that they have only considered sagittal lifting.

The physiological models (1, 11) are based on predictions of the metabolic energy expenditure in lifting and in other manual materials handling tasks. As in the case of the biomechanical models, the physiological models are restricted to lifting in the sagittal plane only. Moreover, these models make unvalidated assumptions with regard to the additivity or comparability of energy costs for different tasks.

As an alternative or a complement to the biomechanical and physiological models, lifting capacity prediction models have been developed on the basis of a psychophysical approach. These models are among the few available for determining the maximum acceptable level of work load in manual handling tasks. The method used in some respects resembles one of the basic psychophysical methods, ie, the method of adjustment, used to determine perceptual threshold (8). The procedure is to ask the subject to adjust his or her work load, ie, the weight or the frequency of lifting, to the maximum he or she can perform without overexertion or excessive fatigue. According to this procedure, the subject will start on one occasion with a heavy weight or a high frequency and on another occasion with a light weight or a low frequency. The two results are then averaged. Generally the subject is given 20–40 min to adjust the work load.

Using this technique, some researchers (3, 6, 12, 13, 16) have systematically collected estimates of work load during different manual materials handling activities standardized and simulated in the laboratory. The results of a series of studies using the psychophysical approach have been summarized and integrated by Snook (15). In his report Snook presents a series of

tables indicating the maximum weights predicted to be acceptable to 10, 25, 50, and 90 % of the male and female working populations. Similar tables have also been published by Ayoub et al (2), who combined their own data with the data published by Snook (15). According to Snook (15), the proper use of these tables can reduce the occurrence of injuries more effectively than the selection of workers for the job or the training of workers to lift properly.

Undoubtedly the psychophysical approach is very attractive in its simplicity and deserves serious attention. The applicability of the method relies on the assumption that the subject is able to estimate with some accuracy his or her highest tolerable work load. Furthermore, it is assumed that the work loads accepted by subjects under conditions which simulate real work are below the loads leading to manual handling injuries among workers. However, as yet, it is not known to what extent these assumptions are valid.

The results of three experiments (10, 13) performed to test the reliability and validity of the psychophysical approach in determining maximum acceptable work loads for setting lifting standards are presented and discussed in this report.

Experiment 1

In the first experiment (14) five brewer's draymen with 4–10 years of occupational experience were studied during horizontal lifting work, which simulated an order-filling task at a brewery. The lifting task consisted of lifting a case (36 × 36 × 24 cm) 1.1 m horizontally at a height of 60 cm. A treadmill was used to transport the case back after each lift. The work was performed in cycles of three consecutive lifts followed by a rest period. Each cycle lasted 36 and 18 s, respectively.

The subjects had no difficulty in following the instructions. Thus, it only took about 10 min for them to make their choice of maximum acceptable weight. The choices were consistent irrespective of whether a subject had started with 5 or 25 kg in the case. The intersubject rankings with regard to the maximum acceptable weight were identical for all the trials and indicated that the reproducibility of the results was very satisfactory. However, the interindividual variation was large, and it did not appear to be related to the

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subjects' physical characteristics, eg, body size, muscle strength, and aerobic power. Thus the lightest weight (5.3 kg) was selected by a relatively powerfully built person with considerable muscle strength and high aerobic power, whereas the heaviest weight (17.0 kg) was chosen by a much shorter and lighter subject with less muscle strength and lower aerobic power.

Other results of this experiment should also be taken into consideration when the validity of the psychophysical approach is assessed. First, when the lifting rate was doubled, the average weight selected was only lower by 11 %, although the subjects performed 74 % more work. This result indicates that physiological factors might not be the primary determinants of the work loads selected. Second, in a study of vertical lifting with the same instructions and comparable lifting rate (17) subjects preferred to work with about twice as heavy a case as in the present study. This result clearly indicates that horizontal lifting, which is very common in real materials handling situations, imposes a greater strain than vertical lifting. This fact would suggest that the values of maximum acceptable work loads collected in standardized lifting situations only have a very limited representativeness.

Experiment 2

Two groups of subjects participated in experiment 2 (10). One group consisted of eight warehouse workers with occupational experience with lifting work, and the other group consisted of eight office employees without such experience. A diagonal lifting task was used in this experiment. It consisted of four consecutive lifts. The first lift was from a table on the left side/knuckle height to a shelf on the right side/knee height. The second lift was moving the case back to the table. The third lift was from the table left side/knuckle height to a shelf on the right side/shoulder

height. The fourth lift, concluding the lifting cycle, was moving the weight back to the table.

During the first part of the experiment the subjects selected acceptable weights at three different work paces and acceptable work paces for three different weights. During the second part of the experiment the subjects performed the lifting task repeatedly using five different weights and five work paces. On this occasion the aim was to study the relation between the objective and the subjective work loads. An analysis of the results obtained during the first part of the experiment revealed that there were large and systematic differences in the selection of work loads between the two groups of subjects, who had been instructed by two different persons. A thorough investigation afterwards revealed that this bias was due to the fact that during the lifting task one of the instructors had reminded the subjects to adjust the work load if they felt like it. No such action was taken by the other. Thus, reminding some of the subjects that they could adjust the work load any time they wanted produced a systematic increase in the maximum acceptable work load finally selected by these subjects. This result clearly indicates that the data collected by the use of the psychophysical approach are highly dependent on the procedure adopted when the subjects are instructed. It seems evident that this characteristic of the method must constitute a definite limitation to its applicability. As expected from the results of the previous experiment, perceived work load for this type of lifting task was found to be a positively accelerated function of the objective work load, as it is defined by the weight lifted and by the work pace.

Experiment 3

In the third experiment (10) two new groups of subjects were chosen according to the same criteria as in

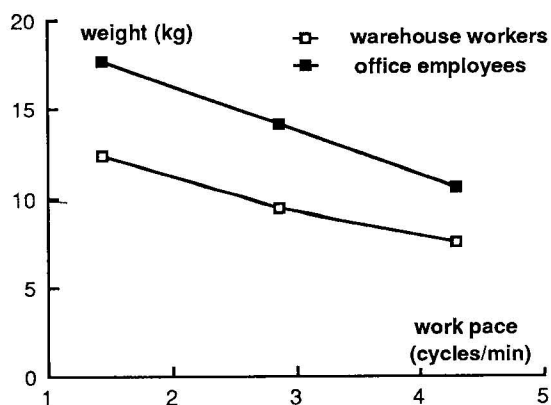


Figure 1. Mean values of acceptable weight for lifting work at three lifting frequencies for eight warehouse workers and eight office employees.

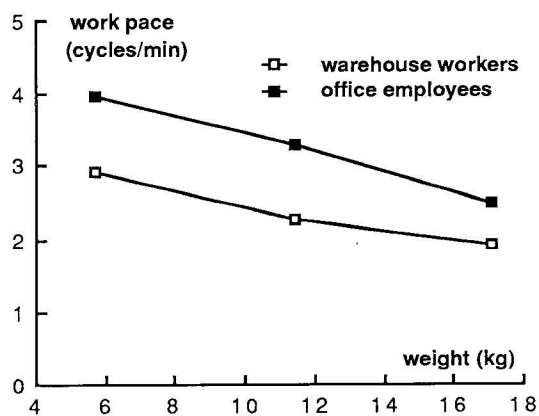


Figure 2. Mean values of acceptable lifting frequency for three different weights for eight warehouse workers and eight office employees.

experiment 2. The lifting task and the general procedure of this experiment was the same as in the first part of experiment 2. However the instructions given to the subjects were further standardized, and all the subjects were instructed by the same person. The subjects selected acceptable weights at three different work paces and acceptable work paces for three different weights. They also selected an acceptable work load by changing both the weight and the work pace. For each work load selected, the subjects rated perceived exertion according to Borg's scale (4). The entire procedure was then repeated, a replication of each selection of work load thereby being obtained.

On the whole, the reproducibility of the selected work loads was satisfactory also in this experiment. However, it was apparent that selecting the work pace was an easier and more reliable task than selecting a weight.

Two features of the results of this experiment are relevant for the assessment of the validity of published data concerning maximum acceptable work loads collected with the psychophysical approach. One feature is that occupational experience of lifting work had a negative effect on the selection of work loads. Thus, as shown in figures 1 and 2, the maximum acceptable work loads selected by the warehouse workers were systematically lower than those selected by the office employees. This phenomenon was also clearly evident when subjects were free to select both the weight and the work pace in the same trial. Then the warehouse workers, on the average, selected a 78 % lower weight and an 87 % lower work pace. Although they selected lower work loads, the warehouse workers consistently rated overall perceived exertion, as well as the perceived exertion on the arms and shoulders, the back, and the legs higher than the office employees. The other feature of significance with regard to the validity of the method, is that the subjects' physical characteristics, eg, body size, muscle strength, and aerobic power, showed no relation to the work loads they selected.

Concluding remarks

On the whole, the results of the three experiments suggest that the psychophysical data concerning the maximum acceptable work load for repetitive lifting tasks which have been published in recent years (2, 6, 11, 13, 15) should be used with great caution. The main reason is the limited representativeness of the simulated and standardized manual materials handling activities on which the data are based. Furthermore, as our experiments have shown, it is difficult to reach a satisfactory understanding of the significance and im-

plication of the concept of maximum acceptable work loads for lifting tasks. Our results indicate that the process of selecting a work load might be governed by cognitive and motivational factors, as well as by perceptual stimuli.

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