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THE PREVENTION OF TRAUMA BY ERGONOMIC EQUIPMENT IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

Work posture is determined by interdependence between work design, the necessity to perform the particular activities, and the anthropometric dimensions of the workers, as well as being dependent also on individual preferences. Heavy physical work associated with awkward working postures and manual handling of materials in the construction industry can cause a various musculoskeletal pains and disorders. The aim of the study is to reduce the amount of low back pain as well as work injuries, caused by the improper lifting techniques, prolonged working in awkward postures and unnecessary tilting of the trunk, by using ergonomically designed equipment. A stress-strain analysis of the man-at-work system with respect to postural loads, manual materials handling and external forces depending on the particular tasks performed by the construction workers of 8 specialities as well as their influence on the lower back was carried out. The results obtained clearly indicate the benefits of ergonomic design used for manual handling of granite tiles (500×500×150 mm), concrete road kerbs (150×300×1000 mm) and porous sand-lime blocks (200×350×600 mm). Ergonomic devices do not reduce the weight of lifted elements (in case of a vacuum lift device the total lifted weight is even considerably increased), but the positive effect is achieved due to reducing the moment arms, because the workers perform the tasks with a straight back. Such ergonomic aids, as self-levelling work surface, an adjustable table, etc. can be used for masonry, transferring bricks from pallets, puttying and painting.

lifting, handling, construction, ergonomics, risk, posture

1. INTRODUCTION

It has been always considered, that heavy physical work involving awkward working postures and manual materials handling in the construction industry can cause various musculoskeletal pains and disorders. Third EU Working Condition Survey carried out in 2000 (Merllié and Paoli, 2001) shows that backache increased by about 3 % compared with EU survey carried out in 1995. This survey also reveals that 43 % of construction workers believe that their health and safety are at risk because of their work. That is the highest level compared with other sectors of economy. In the Lithuanian construction industry this level reaches 67 %.

In 2001 the European Foundation carried out (the authors Paoli, Parent-Thirion and Persson, 2002) a questionnaire – based survey on working conditions in 12 candidate countries to the European Union (Estonia, Lithuania, Latvia, Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Romania, Bulgaria, Cyprus and Malta) which is identical to the Working Conditions Surveys performed out in the EU in 1990, 1995 and 2000. The results of the survey obtained in candidate countries show, that the health and safety of workers are at risk because of their work (42 % vs. 27 % in the EU). This is reflected in the health problems reported by the workers: the problems are there much more serious than in the EU. The most frequently reported work-related health problems are: overall fatigue – 41 %, backache – 34 %, stress – 28 %, muscular pains in the neck and shoulders – 23 %.

According to Wakula, Wimmel, Linke-Kaiser, Hoffman and Kaiser (1997), concrete works, including reinforcement, casting work and filling in concrete at walls or for ceiling, are stress-factors that contribute to degenerative diseases of the intervertebral discs and lower back complaints.

In construction manual handling and lifting are the major causes of work-related back pain, and in particular low back pain, being also common in other work environments such as puttying, floor laying, in concrete works and working-postures analogous to those provided in the OWAS coding, as well as in work environment where there is no lifting or manual handling but sitting postures are required. In fact, back pain is extremely common. During a lifetime, there is a 70 % chance of developing low back pain and there is a 1:7 chance that any individual will presently be suffering from back pain. Since lifting and bending were related to only about one-third of back injuries, the prevention of back trauma due to lifting, will save only a small amount of injuries.

However, in order to devise a consistent strategy of preventing trauma in construction it is necessary to gain knowledge of specific tasks and well-defined situations in construction works.

2. METHODS

A stress-strain analysis of the man-at-work system with respect to postural loads, manual materials handling and external forces of different tasks of construction workers and its influence on the lower back were carried out. Various methods were used:

- A biomechanical approach based on a computer-aided man-model to analyze and calculate the compressive force resultant from postural loads and the action of external forces on the intervertebral discs. Each work task being studied was video-recorded both with and without the use of the ergonomic device in question. On the basis of the video-recording, the disc L5/S1 load was assessed.
- The subjects were asked to rate their perception of the work load during granite tile and concrete road kerb laying, manual lifting and handling of porous sand--lime blocks, manual transferring of bricks from pallets, concrete work, masonry, plastering and puttying on the following scale: 1 – no exertion at all; 2 – very rarely; 3 – rarely; 4 – frequently; 5 – all the time.

164 construction workers were interviewed by filling in the questionnaires.

3. MATERIALS

When analyzing the workload of granite tile pavement workers of the Lithun Construction Company (n = 12), the modes of handling granite tiles with and without ergonomic devices were evaluated. The work dealing with handling of granite tiles included he following operations:

- First, two workers take by hand granite tiles (500x500x100 mm up to 78 kg each) from a stack's four upper rows (totally 16 tiles) and put them alongside the stack on the pavement;
- Later they lift the granite tile by a mechanical lifting device as seen in Figure 1, carry the tile and put it accurately at the particular place on the paving basement. For taking the granite tile out of the pavement (in order to adjust the basement level) a pneumatic lifting device was used (Figure 2)

Figure 1. The handling of a granite tile with a mechanical lifting device.

Figure 2. The handling of a granite tile with pneumatic lifting device.

For the analysis of the physical workload of road kerb layers there were selected workers both of the Construction Company „Vigasta“ (n = 6) applying old-type hooks (as shown in Figure 3) for road kerb lifting and the workers of the Lithun Construction Company (n = 6) who used the ergonomical road kerb lifting device (Figure 4).

Figure 3. Handling the road kerb with old-type hooks.

Figure 4. Handling the road kerb with a mechanical ergonomic device.

Porous sand-lime block layers of the Construction Company “Ranga IV” (n = 19) used blocks with milled grooves (for better gripping) and without them (Figure 5) for masonry work.

During the transfer of sand-lime bricks from pallets to a conveyer (as seen in Figure 6) the reloaders of the Company “Silikatas” (n = 6) performed tilting and twisting of the trunk on the average 4 000 times per shift.

Figure 5. Method of handling porous silicate blocks.

Figure 6. Working posture of brick reloader.

The workers of small Construction Companies (n = 16) performing interior puttying and painting operations made use of conventional benches and the ergonomic benches suggested by the author (Figures 7a, 7b), the planes of both the workers stand and material storing were adjustable.

Figure 7a. An ergonomic bench used in puttying process.

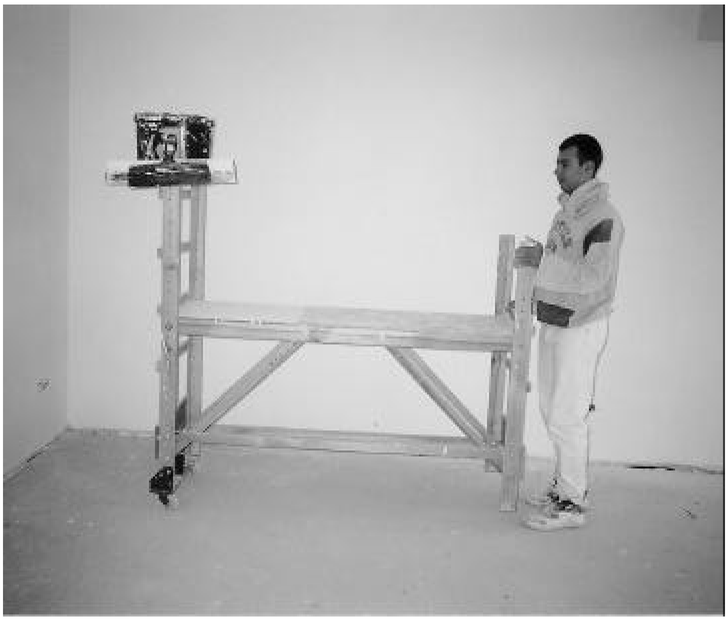

Figure 7b. Moving an ergonomic bench from one place to another.

In addition, in the questionnaire – based survey involving 49 masons, 28 concrete workers and 22 plasterers of the Construction Company “Panevëþ io statyba” (n = 41) and Construction Company “Ranga IV” (n = 58) was made.

4. RESULTS

The compressive forces acting on the intervertebral disc L5/S1 were calculated using the biomechanical approach for the following tasks: granite tile paving, concrete road kerb laying, manual handling of porous sand-lime blocks, bricks reloading and concrete works as shown in Figure 8, point a to k. Figure 8 also gives a rough idea of the magnitude of the compressive forces which are involved in three different lifting postures (lines A,B,C) of a “standard person” calculated by Pheasant (1991). In the first position (A), the trunk is inclined by 30° and the load is 250 mm in front of the L5/S1 disc. In the second position (B), the trunk is in a horizontal position and the load is 400 mm away from the spine. In (C), the trunk is inclined at an angle of 45° and the load is 600 mm away from the spine.

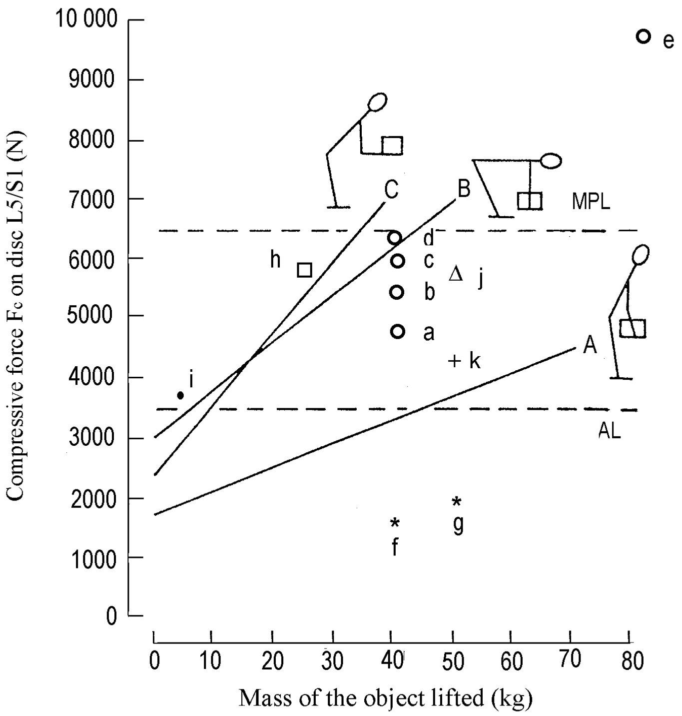

Figure 8. The comparative analysis of data on the compressive loading on the spine with NIOSH recommendations. MPL – maximum permissible limit; AL – action limit; a, b, c, d points – manual lifting of granite tiles by 2 workers, with body inclination angle of 30°, 45°, 60° and 90°, respectively; e – the same load lifted by a single worker; f – lifting granite tile with a mechanical lifting device; g – lifting granite tile with a vacuum lifting device; h – manual lifting of porous sand-lime blocks; i – reloading of silicate bricks in stooped posture; j – road kerb lifting with old-type hooks; k – road kerb laying with a mechanical lifting device.

Because of the posture of the trunk alone, these compressive forces may reach F_c = 3070 N for “reloading of silicate bricks” (as shown in Figure 6) and for “concrete works”.

Adding the external loads (the weight of lifted materials,and the acting forces) results in the increase of the compressive forces to $F_{c,j}$ = 5 447 N for lifting of road kerb by the old-type hooks and $F_{c,a}$ = 4 658 N, $F_{c,b}$ = 5 230 N, $F_{c,c}$ = 5 905 N, $F_{c,d}$ = 6 420 N for manual lifting of granite tiles by two workers with the angle of the body inclination being 30°, 45°, 60° and 90°, respectively (Figure 8, points j,a,b,c,d). The calculations are based on the data obtained by Kaminskas (2001).

Due to the aplication of ergonomic devices for granite tile lifting (see Figure 1) and concrete road kerb laying(Figure 4), the compressive forces on the intervertebral disc L5/S1 decreased at least by three times and 32 %, respectively. The above decrease of the compressive forces was achieved only for the workers specially trained in the correct lifting techniques of “straight back-bent knees”. In the cases when ergonomic devices are used for the handling of heavy granite tiles (up to 78 kg)and concrete road kerbs (up to 100kg) the moment arm of forces due to the lifted weight can be reduced to zero.

Comparing the data of the survey (Figure 8, points a to k) with the recommendations of the National Institute for Occupational Safety and Health (NIOSH) we can see that, for all types of manual lifting and moving of heavy loads not taking into account major principles of ergonomics, the compressive forces in the L5/S1 disc exceed the action limit (AL) recommended NIOSH (1981).

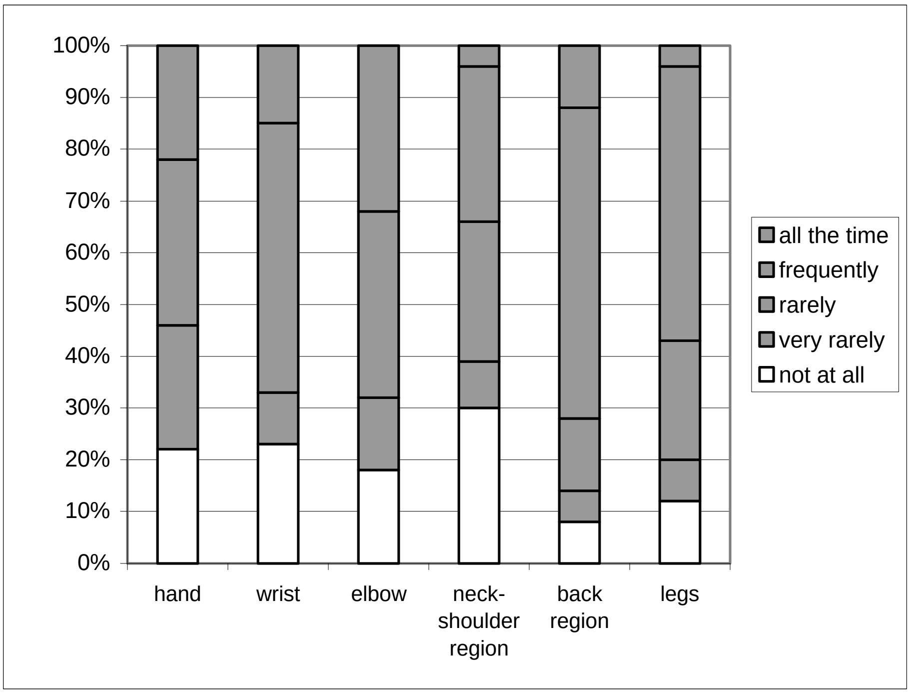

Figure 9. Complaints of the pains in the particular parts of the body due to working posture.

According to the questionnaire-based survey on working conditions in Lithuanian construction industry with respect to eight major construction works (masonry, concreting, plastering, puttying and painting, road kerb laying, porous sand-lime blocks handling and stone tile laying) more than 59 % of the interviewees indicated that they often were suffering pain in the lower back region, 12 % of them complained of constant pains (Figure 9). Complaints about the frequent pains in the legs were reported by 54 % of the interviewees and 6 % of the workers suffered all the time. Many of the construction workers were also suffering from pains in the neck-shoulder region, as well as in the elbows and hands.

The survey also indicated that when ergonomic equipment was introduced the performance efficiency increased by more than 15 %. Job satisfaction is also higher (92 % vs. 67 % before the ergonomic equipment was implemented).

5. DISCUSSION

It is widely recognized that there is a correlation between the compressive forces acting on the intervertebral disc L5/S1 and lower back pains complaints. The calculations showed that the spinal loading resulting from tilting the trunk through 90° without the application of the external loads (e. g. without lifting a weight at all) is equivalent to lifting about 30 kg of weight in the most convenient position. Thus, due to using the ergonomic aids, the extremes tilting of the trunk was reduced for brick reloaders and puttying workers.

The results of the study presented in the paper show the benefits of the ergonomic aids used for manual lifting of heavy granite tiles (up to 78 kg) and concrete road kerbs (up to 100 kg). The risk of lower back injuries becomes quite insignificant when ergonomic devices are used. In this case, the compressive forces acting on the intervertebral disc L5/S1 were reduced from 5 905 N to 2 105 N for stone tile pavers and from 5 447 N to 4 128 N for road kerb layers.

These devices do not reduce the weight of the element to be lifted but by applying a vacuum lifting device the total lifting weight is considerably increased, but the positive effect is achieved due to the fact that the workers can perform the task with a straight back.

The prevention of trauma in the construction industry requires the worker’s participation in the work of improving the quality of the innovative ergonomic devices and the stimulation of the innovation process.

Moreover, their adaptation during the implementation process (internal diffusion) may be improved. The promotion of the devices in the construction industry should involve both the workers and the target group.

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