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A CROSS-SECTIONAL SURVEY OF CONSTRUCTION WORKERS: AN ERGONOMIC APPROACH

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Abstract. Musculoskeletal disorders cause ill health and decreased work ability, thereby increasing the costs of absenteeism for companies and interfering in social security systems on a national scale. Our research aimed to identify ergonomic risks encountered by trades on sites of small and medium construction companies, to develop interventions to reduce those risks.

Construction employees, from a twelve Lithuanian small and medium companies of construction industry, were randomly selected and invited to complete a survey on different discomfort of the body parts. The questionnaire included questions about stratification of the sample, appearance of troubles, i.e. symptoms of musculoskeletal disorders, in neck, shoulders, elbows, wrists, hands, the upper back, hips, thighs, knees and ankles/feet. The questionnaire was distributed to 35 % of the twelve companies' population, for a total of 440 questionnaires. Of 276 questionnaires were completed for a 62.7 % response rate. Investigations shows that for all construction workers the most common location of pain and/or discomfort was the lower back which was different in all eight groups of seniority (range: 10.51 % – 27.0 %). The complaint is considered the main reason for an awkward work posture, and high use of physical force. Very often, workers work leaned in static posture, running from 5 to 10 min. Workers also suffer pain and/or discomfort in ankles/feet (range: 12 % – 22.99 %), in neck – (range: 6.25 % – 19.63 %), in shoulders – (range: 12–% – 16.61 %), and in knees – (range: 4.55 % – 14.63 %). The strategy in construction suggests that ergonomics be integrated into apprenticeship and vocational schools training programs. Training of workers is necessary but not sufficient to insure ergonomic change. Also require to be supported with other resources at the owner and contractor level.

Keywords: ergonomics, ergonomic risk factors, musculoskeletal disorders, self-reports, construction, work system, physical work.

Introduction

High physical work demands are considered the primary risk factor for work-related musculoskeletal disorders (Fallentin 2003, Kaminskas 2003, 2007). In particular, the manual handling of materials in different awkward postures increases the risk of musculoskeletal disorders (Marras *et al.* 2000). Musculoskeletal disorders cause ill health and decreased work ability, thereby increasing the costs of absenteeism for companies and interfering in social security systems on a national scale.

Worldwide, the prevalence of musculoskeletal symptoms involving one or more body regions (Goldsheyder *et al.* 2002, Rwamamara 2006) and occupational injuries (Chau *et al.* 2004) among bricklayers and bricklayers' assistants is higher than it is among construction workers in general. Interventions into the physical work demands placed on these workers are necessary in order to reduce the risk of musculoskeletal disorders.

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.

In contrast to many occupational diseases that have their origin in exposure to particular hazardous agents, most musculoskeletal disorders are characterized as multifactor. Findings of scientific research have identified physical, psychosocial/organizational, and individual occupational risk factors for the development of work-related musculoskeletal disorders (David 2005).

In work settings ergonomic risk factors particularly musculoskeletal disorders are the most common work-related health problem in Europe, affecting millions of

workers. The fourth European working conditions survey (EWCS 2005) revealed that WMSD are the most common health problems in the EU-27: 25 % of European workers complained of backache and 23 % of muscular pains (EUROFOUND 2007; Colombini, Occhipinti 2006).

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 (Paoli *et al.* 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 % (Kaminskas, Kazlauskaitė 2002).

The annual prevalence of neck pain varied from 27.1% in Norway to 47.8 % in Québec, Canada. Each year, between 11% and 14.1 % of workers were limited in their activities because of neck pain. Risk factors associated with neck pain in workers include age, previous musculoskeletal pain, high quantitative job demands, low social support at work, job insecurity, low physical capacity, poor computer workstation design and work posture, sedentary work position, repetitive work and precision work. Côté *et al*. (2008) found preliminary evidence that gender, occupation, headaches, emotional problems, smoking, poor job satisfaction, awkward work postures, poor physical work environment, and workers' ethnicity may be associated with neck pain. There is evidence that interventions aimed at modifying workstations and worker posture are not effective in reducing the incidence of neck pain in workers.

Musculoskeletal pain (MSP) is one of the most common occupational health problems, and workers in the construction industry are at high risk of MSP. In 1996, the Japanese Ministry of Labor reported that low back pain (LBP) is the primary (about 60 %) cause of occupational risk leave for 4 days or more and that the construction industry has the second largest business area in terms of number of patients. In the US a nationwide health interview survey showed that construction workers are the highest risk group for work-related LBP. A Dutch study showed that non-sedentary workers, such as construction workers and plumbers, have a relatively higher prevalence of LBP, whereas sedentary workers have a lower prevalence. Whereas construction workers belong to high-risk groups for MSP, there have been few reports on MSP in construction workers (Ueno *et al.* 2005).

In a British study, the 1-year cumulative incidence of low-back pain was 40 % for construction workers as compared with 28 % for managers (Macfarlane *et al*. 1997**)**. Cross-sectional studies have suggested that bricklayers bear a particularly high risk for developing low-back pain and low-back disorders. Longitudinal studies are needed to identify further the hazardous aspects of construction work with respect to low-back disorders in order to verify the occupational origin and to recommend and introduce effective preventive measures (Latza *et al*. 2002).

According to the longitudinal analysis, laying large lime sandstones was a potential risk factor for the 1-year prevalence of low-back pain in construction workers without low-back pain in the baseline survey. In the ergonomic evaluation that was part of the Hamburg Construction Worker Study, was characterized the work of bricklayers as repetitive, involving the manipulation of heavy loads (Grunwald *et al.* 1998). Most of the observed activities of the bricklayers were carried out in a standing position (94.2 %). Thus more than 50% of their work hours were spent in a bent position. On the average, a bricklayer moved about 881 kilograms per hour. Handling lime sandstones was regarded as a comparatively strenuous task. A bricklayer doing piecework on a large construction site moved more than 1 tone per hour when laying large lime sandstones.

Grunwald *et al.* (1998) indicated that condition of the individual recognition of an occupational disease or the introduction of a new occupational disease in Germany or other countries is a probable occupational etiology. This condition has been translated into a probability of an occupational cause of more than 50 %. The approach poses problems if the underlying disease prevalence is high in the general population. As a consequence, alternative measures to quantify the leftward shifting of disease onset have been suggested, similar to the model of years of life lost. The concept of the risk or rate advancement period has been used in recent studies to quantify the temporal advancement of the risk or rate of a chronic disease that increases with age.

Our research aimed to identify ergonomic risks encountered by trades on sites of small and medium construction companies, develop interventions to reduce those risks.

Methods

Construction employees, from a twelve Lithuanian small and medium companies of construction industry, were randomly selected and invited to complete a survey on different discomfort of the body parts. The questionnaire included questions about stratification of the sample, appearance of troubles, i.e. symptoms of musculoskeletal disorders, in neck, shoulders, elbows, wrists, hands, the upper back, hips, thighs, knees and ankles/feet. The questions about musculoskeletal symptoms were adopted from the so-called Nordic Questionnaire. The specific symptoms asked about were

pain, ache, and discomfort in different body parts during the last year and during the last few days.

The questionnaire was distributed to 35 % of the twelve companies' population, for a total of 440 questionnaires. Employees had two weeks to respond. Of the 440 questionnaires distributed, 276 questionnaires were completed for a 62.7 % response rate.

Results

The findings from this survey reported in this paper are from the 276 respondents who identifies as construction workers as shown in Table 1. Of these 76 were identified as other than construction workers (office workers, engineers, managers and administrators, etc.). From the 276 respondents who completed questionnaires 146 reported musculoskeletal discomfort or/ and pain. The mean age of the respondents who reported musculoskeletal discomfort or/ and pain is 38.78 years (SD: 12.6) and the mean number of years' working experience in the trade is 15.48 years (range: 1 – 40). For the group of who did not report musculoskeletal discomfort or/ and pain these figures average is 35.16 years of age (SD: 11.3). In Fig 1 percentage of respondents vs. previous experience according trade in years is provided. From 276 which were involved in survey, 5.43 % working for up to 1 year, 14.13 % from 2 to 5 years, 18.12 % of 6 to 10 years, 21.38 % from 11 to 15 years, 9.78 % of 16 to 20 years, 6.88 % from 21 to 25 years, 13.77 % from 26 to 30 years and remained employed for more than 31 years in construction sector.

Table 1. Construction worker survey respondents

Musculoskeletal pain/discomfort	Yes	No
Total respondents	146 (100)	130 (100)
Trade/Occupation	percent	percent
Bricklayer	16.44	19.23
House painter	8.22	18.47
Plumber/pipefitter	10.27	16.15
Woodworker	7.53	5.38
Roadman	5.49	1.54
Pane man	10.27	0
Equipment operators	10.96	15.38
Other	30.82	23.85
Gender		
Male	87.76	86.53
Female	12.24	13.47
	Mean/SD	Mean/SD
Years in trade	15.48/10.8	14.41/11.2
Age	38.78/12.6	35.16/11.3

The construction workers population reported on musculoskeletal pain and discomfort which they felt was related to their work (Fig 2). More than 53 percent reported such pain or discomfort within the past 12 months, while 19 percent had seen a physician for this problem during that period and 17 percent had missed work.

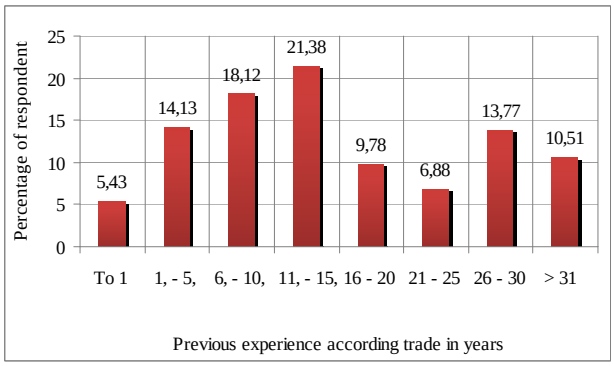

Fig 1. Number of respondents vs. previous experience

Fig 2 shows that construction workers reported pain or discomfort increases with seniority of their trade, with the exception of workers of seniority to one year. First, in this group was only small part of workers (5.43%), and some of them had health problems in previous trade (non construction). Second, often young workers in construction face ergonomic risk factors such as forceful exertions and awkward postures.

Data were tabulated from the body-mapping exercise. The most common location of pain was the lower back, where 81 dots were placed, followed by the neck with 62, shoulder with 61 and ankles and foot whit 61.

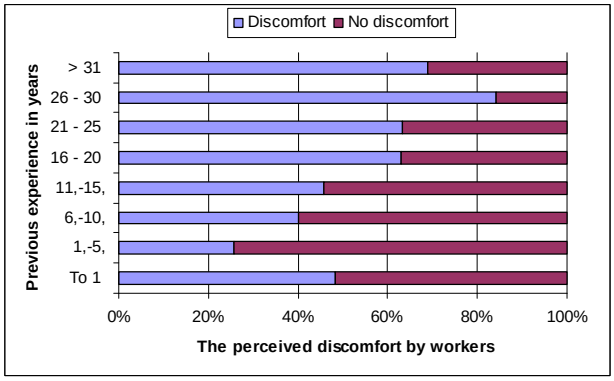

Fig 2. Relation between previous experience and perceived discomfort or pain

Other frequently noted locations were left or right knee with 46. For upper extremities – wrist, elbow, hips/thighs and shin – pain and discomfort was much more common on the right than the left side (see Table 2).

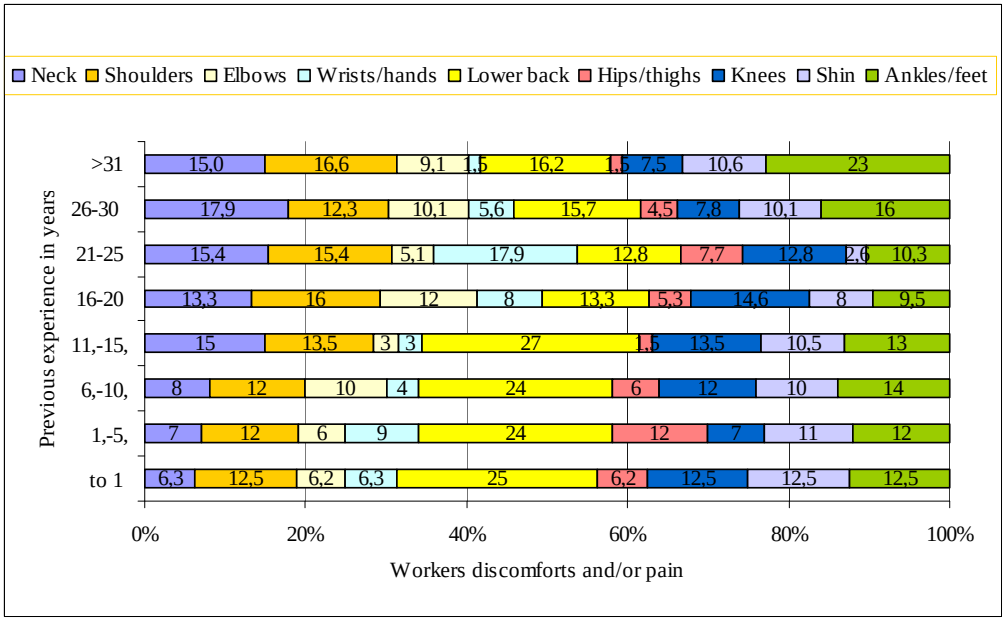

Fig 3. The prevalence of discomfort and/or pain in individual experience of trade groups

Investigations shown that the number of effected workers to pain and discomfort were strongly depending on years in trade of each 8 groups. In first group, when up to 1 year in trade (construction) of 15 workers the 8 workers felt pain and discomfort, in second group (from 2 to 5 years) of 39 workers the 10 felt pain and discomfort, in third group (from 6 to 10 years) of 50 workers the 20 felt pain and discomfort, in fourth group (from 11 to 15 years) of 59 workers the 27 felt pain and discomfort, in fifth group (from 16 to 20 years) of 27 workers the 17 felt pain and discomfort, in sixth (from 21 to 25 years) of 19 workers the12 felt pain and discomfort, in seventh group (from 26 to 30 years) of 38 workers the 32 pain and discomfort, and in eight group, when work in trade more than 31 years in the construction sector of 29 workers the 20 felt pain and discomfort.

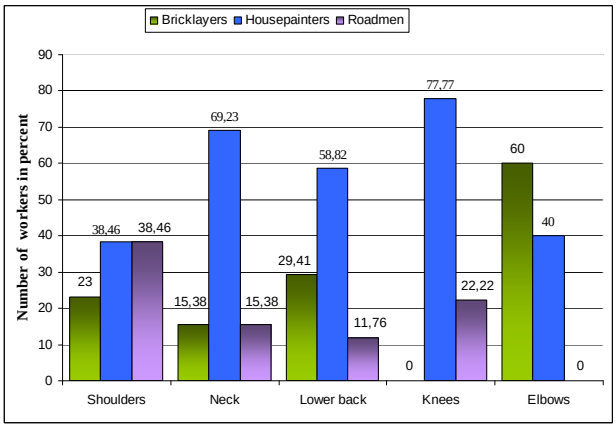

Fig 4. Frequency of ergonomic risk factors in bricklayers, housepainters and roadmen work places

Fig 3 shows that for all construction workers the most common location of pain and/or discomfort was the lower back which was different in all eight groups of year's in trade (range: 10.51 %–27.0 %). The complaint is considered the main reason for an awkward work posture, and high use of physical force. Very often, workers work leaned in static posture, running from 5 to 10 min. Workers also suffer pain and/or discomfort in ankles/feet (range: 12 %–22.99 %), in neck – (range: 6.25 %–19.63 %), in shoulders – (range: 12 %–16.61 %), and in knees – (range: 4.55 %–14.63 %).

It can be argued that the majority of respondents, according to their age are the maximum physical capacity stage (mean age is 37.07 years). The construction industry is often characterized by the one and the same person works on one site at one and the other site other employment, taking into account existing work demands.

Survey shows musculoskeletal symptoms prevalence in the five most affected body regions – low back, knee, shoulder, elbows, and neck – for all construction workers in tree trades (bricklayers, housepainters and roadmen) with the highest risk for each region (see Fig 4). Significantly elevated odds ratios (foreman reference group) were found for numerous trades in numerous body regions. For example, housepainters (4.81), bricklayers (1.22), and roadmen (1.22) had the highest odds ratio for neck pain. Lower back odds ratios were highest in housepainters (4.27) and bricklayers (3.1), while bricklayers (4.13) had the highest ratios for elbows and roadmen (3.52) had the highest ratios for shoulders symptoms.

This analysis relied upon questionnaire data from twelve different construction companies but not related populations.

Comparing profile data according to seniority of their trade these results indicate that in seniority of all groups of employees (painters, bricklayers, pipe fitters, road construction workers and others), especially for painters and bricklayers have a maximum load in the lower back, while the lowest – below the patella and thigh. Aged-workers feel the pain in the neck, whereas

Table 2. Tabulated data from the body-mapping exercise for construction workers according previous experience

Body parts effected	To 1 year	2–5 years	6–10 years	11–15 years	16–20 years	21–25 years	26–30 years	> 31 years /(Total in line)
Neck	1	2	4	10	10	6	16	13/(62)
Shoulder	2	4	6	9	12	6	11	11/(61)
Elbows	1	1	5	2	9	2	9	6/(35)
Wrists/hands	1	3	1	2	6	7	5	1/(26)
Lower back	4	11	12	18	10	5	14	7/(81)
Hips/thighs	1	4	3	1	4	3	4	1/(21)
Knees	2	1	6	9	11	5	7	5/(46)
Shin	2	3	5	7	6	1	9	7/(40)
Ankles/ feet	2	4	7	8	7	4	14	15/(61)
Total cases of discomfort or/and pain	16	33	49	66	75	39	89	66/(433)

the various works carried out in awkward postures (see Table 2).

Discussion and conclusions

This study offered the opportunity to analyze of different approaches to initiate ergonomic changes in construction over time at a single site. Efforts focused on introducing ergonomic concepts and recruiting contractors and crews to look at specific tasks that placed workers at risk of work-related musculoskeletal disorders and attempt modifications to reduce those risks. The intervention strategy might be only one of widely known. It was also pointed to the need for a more systematic approach to raise awareness about ergonomic risks and possible solutions among workers, contractors and construction managers. The researchers and general contractor, with owner support, should settle on a site ergonomics training module for all construction workers as a means of amplifying the crew-specific effects of the effort. Questionnaire and observational data suggest that this training program should be successful in heightening awareness of ergonomic risk factors and efforts to reduce such risks.

Our data demonstrate that construction workers and contractors recognize the risks of work-related musculoskeletal disorders in their industry, but how they act on this recognition is subject to multiple forces. The construction community is rooted in tradition and a sense of identify from its accomplishments, including how the work itself is approached. For example, a substantial reduction in the physical work demands on the lower back of bricklayers resulted from the adjustment of working height and powered scaffold. For one working day, the differences in physical work demands are 795 trunk bends less of trunk posture >60º, compared with the condition of bricks and mortar set out the ground floor. These our findings of reduction in frequencies of bending the lower back are in accordance with the Nederland researchers (Vink *et al.* 2002; Molen 2005) who observed a reduction in trunk flexion (>60°) of 830 and 920 respectively times over a whole working day while working with 50 cm raised bricks and mortar compared with working with bricks and mortar set out the ground floor.

The present intervention focuses primarily on a reduction of trunk flexion (>60°), but it could be argued that an increase in the frequency of trunk rotation or lateral flexion could exist due to the intervention. In a more upright trunk posture it is possible to pick up bricks and mortar with medium trunk flexion in between 20º and 60º, but with lateral flexion or trunk rotation. Trunk rotation is considered a risk for developing work-related musculoskeletal complaints of the back.

The work is characterized by an unusual combination of conservatism, embodied in the traditional craft tools and work methods and sometimes radical change as new technologies are introduced, usually with the aim of improving productivity and sometimes quality. Both of these characteristics have strong implications for the application of ergonomics in the construction industry. Ergonomics attempts a systematic approach to the relationship between the worker and the tasks, tools, equipment and environment of construction. Workers and contractors alike must see some advantage to making changes to these elements of work system in order for measures to reduce ergonomic risk factors to succeed.

Painting ceilings and high walls are resulting in awkward neck and upper extremity postures. House painters also must frequently move heavy equipment and buckets of paint. The painting trades do the finishing work on drywall after it has been installed, sometimes using stilts to access high walls and ceilings. In this study all painters were used so named normal technique which may be described as holding the extension handle with both thumbs pointing upwards and moving the shaft by means of pivoting and rotating movements. Twelve (in survey participated 36) subjects reported symptoms of musculoskeletal disorders during the last 12 months. It may be argued that the subjects would change their work technique or work processes when they experienced disorders. For painting ceilings, a small flange on the pole should help the painter support the weight with his or her entire hand and not just his or her grip, thereby reducing muscle demand and fatigue.

Equipment operators (participated in survey 36 and indicated musculoskeletal disorders 16 subjects) have a

particular set of exposures different from most other trades. While they do not do the manual handling that many other trades do, they operate equipment (in many cases heavy equipment) all day and are exposed to vibration, awkward seating posture related in some cases to viewing their work and risks of injury while dismounting and maintaining the equipment. Study showed that newly deigned equipment significantly (22.5 %) reduced stress to the operators.

Diffusion of ergonomics through the construction industry requires considerable resources and attention to particular issues, including following:

1. The strategy in construction suggests that ergonomics be integrated into apprenticeship and vocational schools training programs. Apprentices constitute the most accessible audience for such training, but conflicts can arise in that what apprentices are taught in classes is not always accepted practice in the field by journeymen or contractors. The resolving this conflict is closer coordination between contractors and training centres to identify the real training needs of workers in ergonomics going into the field.
2. Training of workers is necessary but not sufficient to insure ergonomic change. Training in ergonomics needs to be supported with other resources at the owner and contractor level to assist in designing solutions in the field.
3. Many exposures to ergonomic risks have their roots in decisions in planning, scheduling and sequencing of work, which workers and even contractors often have little control over. Must be brought into the ergonomics discussions those who makes and influences these decisions.

The improving of working posture depends from selection of anthropometric data in design process. The application of anthropometric data from one occupational group to another or from the general population to a specific occupational group in the design of workplace and work systems can be inappropriate. When determining their sampling strategies, anthropometry research managers need to consider potential differences in body size and shape between occupational groups in order to obtain the most useful data for engineering applications. Researchers who use human databases to evaluate human-machine interfaces also have to be cautious in selecting adequate databases for their applications.

In contrast to many other work activities, construction work involves greater variation with regard to task and workplace conditions. For this reason, generalizing work related upper extremity musculoskeletal disorders (UEMSD) risks across trade classifications may not provide sufficient detail to identify varying levels of risk associated with common jobs and activities. Assessing construction workers' exposures using a task-based approach considers multiple risk factors known to be present in specific operations. The results of task-based assessments can be used with existing job analysis results to identify activities for intervention or to identify previously unreported high-risk jobs (Albers *et al*. 2006). Hierarchical taxonomies developed for the construction industry to describe types of projects, and the operations and activities necessary to complete the projects may be used to develop questions regarding task-based hazards

Exposure assessment in construction should primarily be used to demonstrate the efficacy of interventions and here the precision is not as important as the relative risk, e.g. showing a drop in exposure (Schneider 2006). More precise measurements are required in the grey areas where exposures may pose a risk, depending on the length or intensity of exposure. But in construction there are so many tasks posing a high risk, they can be attacked without a significant investment in exposure assessment to prove the level of risk, knowing that any exposure reduction will lower overall risk. There will always be residual risk in construction it will never be a risk free environment for WMSD. But we can reduce the risk significantly through interventions and demonstrate it through simple assessments. The cost of assessments must also somehow be related to the cost of the intervention.

The evaluation of workplace interventions for ergonomic risks reduction probably should adopt different criteria on which to base evidence classification. Until now these criteria are still lacking. Therefore, employers should not be reluctant to carry out preventive actions because of a lack of hundred-percent proof.

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