Strain on the back in concrete reinforcement work

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ABSTRACT To investigate the long term effect of heavy construction work on the back the occurrence of postures, lifting, carrying, and accidents in concrete reinforcement work and in maintenance house painting were measured. The 32 620 observations covering 272 work hours showed that reinforcement work necessitated stooped postures and heavy lifting more often than did painting. Reported minor back accidents were more than ten times as common in reinforcement work than in painting (1.3 compared with 0.11 accidents per man-year, $p < 0.001$). Accidents of the musculoskeletal system, registered by the insurance companies, were also several times more common in reinforcement work (81 compared with 25 per 1000 man-years, $p < 0.001$). The premature development of lumbar degeneration detected in the clinical study of the reinforcement workers was evidently due to the occupational strain on the back. The different types of hazardous back loads probably potentiate the effects of each other.

The determination of the load on the back in any specific trade is very demanding. Any trade includes many tasks each of which has several work phases, and each work phase entails its own characteristic static and dynamic loads and risks of injury. Today, not even a thorough survey of the back loads in all the work phases of a trade will yield an exact measure of the harmful back loads for that trade as we do not yet know how to distinguish harmful from safe loads.

In the present study we have analysed posture, lifting and carrying, minor accidents and accidents reported in one physically heavy trade (the reinforcement of concrete) and one physically light trade (house painting) to determine the physical load on the back associated with these trades. The results of this analysis have been compared with clinical and radiological back findings for workers active in these trades with the aim of evaluating the relations between physical work demands and back morbidity.

Material and methods

STATIC AND DYNAMIC LOADS

The postures, lifting, and carrying necessary in reinforcement work were determined through observa-

tions at the construction sites of two apartment houses, two office buildings, and two bridges. Those associated with painting work were clarified at two apartment houses under renovation. Observations, covering all work phases and tasks, were made for about 30 active workhours at each worksite.

The observations were made at 30 second intervals simultaneously by two observers. One observer was a civil engineer who recorded the work phase, the quality of the work surface, and the amount of lifting and carrying. The other observer was a physiotherapist who registered the postures of the neck, the back, and the limbs as well as the presence of static muscle load.

Back posture was recorded as follows: straight, if the angle of forward inclination was less than 15°; bent, if the angle was 15–90°; and double bent, if the angle was more than 90°. Back posture was recorded as bent backwards only when such inclination was clearly discernible. Rotation of the back was recorded if the shoulders were not in the same plane as the pelvis.

The posture was recorded as static if no movements were perceived. The back muscles were considered to be statically loaded when a bent or a bent and rotated posture was observed, whether with or without an extra load. Double bent postures were not considered to cause static loading of the back muscles because such postures strain mainly the ligaments. If the worker was leaning on something at

the time of observation static back load was not recorded.

Lifting and carrying were registered when the burden handled was judged to weigh 5 kg or more. Typical burdens were weighed so that the observer could judge their weight. The following characteristics were recorded for lifts: the weight of the load (5–20 kg, over 20 kg); the distance between the load and the trunk (<30 cm, >30 cm); the path of the load (toe, hip, and shoulder levels); and the posture of the back (unrotated, rotated).

For carrying, the level of the load was recorded (load over shoulder level, on the shoulders, at the side) as was the duration of carrying (in seconds).

The work surface was classified as good, intermediate, or poor depending on the quality of the ground and the number of obstacles on it. The work surface was recorded as intermediate if the worker was working on a stand of good quality and did not have to stretch out. If the stand was of poor quality or unstable, or if the worker had to stretch out, the work surface was classified as poor.

MINOR ACCIDENTS

A minor accident was defined as an event that differed from the normal course of work and caused sudden, unexpected strain on the musculoskeletal system. The minor accident may or may not have caused pain. It may have caused disability for the rest of the workday but for no longer. If it was still the cause of disability the next day it was considered an accident and not a minor accident.

We asked 96 reinforcement workers and 91 painters to report the loss of balance (slipping, stumbling, staggering, falling); sudden demands on their strength (movements demanding sudden strength, slackening grip on the load); the overloading of tissues through prolonged heavy exertions or awkward postures; and other minor accidents. The workers were interviewed by telephone every two to four weeks. As the workers were not able to report minor accidents immediately, they were asked to make notes at the end of the workday. The interviewer requested detailed information about all minor accidents reported by the workers, and on the basis of the responses the interviewer decided whether or not to classify an event as a minor accident. The winter months with snow and ice were included in the study. Altogether 440 men-months of reinforcement work and 429 men-months of painting work were covered.

ACCIDENTS

All occupational accidents that occurred among Finnish concrete reinforcement workers and construction painters in 1978 were determined from the

register of the National Board of Labour Protection. The incidence of accidents was calculated for these trades by relating the number of accidents to the total number of active workers.

Accidents that had affected the musculoskeletal system were examined closely to determine the role of falling down, falling, slipping, sudden movement, or overloading in their origin. The original reports sent by the construction firms to the insurance companies in 1976–8 were analysed to ascertain the causes of the accidents and the types of injury in detail. In all, 424 accident reports in reinforcement work and 829 in painting were checked.

The significance of the differences in the distribution of minor accidents and accidents was tested by a χ^2 method with a Poisson parameter.

Results

POSTURE

The clearest difference between reinforcement workers and painters was in the use of double bent postures, which were common in reinforcement work but not used at all in painting. The painters worked more often with their back straight and rotated than the reinforcement workers (table 1).

Static load on the back muscles was more common in reinforcement work (24% of the observations) than in painting (11%). Static loads that lasted for more than 15 s after the intermittent observation every 30 s accounted for 9% of the observations of reinforcement work but for only 2% of the observations in painting. Static loads lasting over 1 min after the observation were recorded only in reinforcement work (table 2).

LIFTING

The reinforcement workers lifted burdens of 5 to 20 kg, on average, 13 times an hour compared with five times an hour for the painters. Weights over 20 kg were lifted five times an hour by the rein-

Table 1 *Back posture in concrete reinforcement work and painting*

Back posture	Concrete reinforcement work: 25 108 observations (%)	Painting: 7512 observations (%)
Straight, not rotated	61	71
Straight, rotated	4	10
Bent forward, not rotated	18	14
Bent forward, rotated	3	4
Double bent, not rotated	12	—
Double bent, rotated	2	—
Bent backwards	—	1
Total	100	100

Table 2 *Duration of static load on the back muscles in concrete reinforcement work and painting*

Duration (s)	Concrete reinforcement work: 25 108 observations (%)	Painting: 7512 observations (%)
No static load	76	89
1-14	15	8
15-29	5	2
30-44	2	1
45-59	1	—
≥60	1	—
Total	100	100

forcement workers compared with 0.4 times an hour for the painters.

In reinforcement work many of the lifts were made from hip to hip level (43%) but nearly as many were from toe to hip level (39%). In painting 76% of the lifts were from hip to hip level and only 10% from toe to hip level. While lifting, the back was more often rotated in reinforcement work than in painting.

CARRYING

Lifting was often combined with carrying a weight; two of every three lifts by the reinforcement workers entailed carrying whereas this was so for only one of every three for the painters. The duration of carrying was roughly similar in both trades; about one in five loads was carried for more than 20 s after the moment of observation.

WORK SURFACE

The work surfaces caused more difficulties in reinforcement than in painting. In reinforcement work the surface was classified as poor in 25% of the observations at construction sites for bridges and in 10-15% of the observations at construction sites for apartment houses and office buildings. In painting the work surface was classified as poor in only 5% of the observations.

MINOR ACCIDENTS

In the interview study the reinforcement workers

reported 138 minor accidents (in 440 men-months) and the painters 25 (in 429 men-months) ($p < 0.001$). Of the 138 minor accidents in reinforcement work, 49 affected the back. This corresponds to 1.3 minor back accidents per man-year in concrete reinforcement work. Four of the 25 minor accidents reported by the painters affected the back, corresponding to 0.11 minor back accidents per man-year in painting. The difference between trades was statistically highly significant ($p < 0.001$) in relation to the incidence of minor accidents affecting the back. In reinforcement work most minor accidents affecting the back occurred while walking, lifting, and during sudden, strong work movements. In painting the minor back accidents were associated with lifting (table 3). The final event behind the minor back accidents was mostly slipping, but stumbling and staggering were also common (table 4).

During the interview period 12 reinforcement workers and three painters had had accidents that caused sick leave for one or more days.

In reinforcement work about a third of the minor accidents affected the back (35%) and another third the legs (37%), whereas in painting less than a fifth of the minor accidents affected the back and about half affected the legs.

REGISTERED ACCIDENTS

The records of the Finnish National Board of Labour Protection (which cover all occupational accidents that lead to sick leave for three or more days) indicated that reinforcement workers had had 278 accidents and painters in construction work had had 722 accidents in 1978. National official statistics showed that there were 1750 active reinforcement workers and 10 750 active house painters in Finland in 1975. Assuming that the number of active workers was the same in 1978 as in 1975, the incidence rate for accidents (accidents $\times$ 1000/number of employees) was 160 in reinforcement work and 70 in painting ($p < 0.001$).

Table 3 *Posture or movement at the time of minor accidents in concrete reinforcement work and painting*

Posture, movement	Concrete reinforcement work	Painting
	No of minor accidents affecting back/all minor accidents	No of minor accidents affecting back/all minor accidents
Walking, with or without a burden	20/58	0/1
Getting on or off a work platform	1/6	1/8
Working on a platform	1/12	0/1
Standing bent forward	7/11	0/0
Kneeling or squatting	0/3	0/3
Lifting	10/16	3/4
Sudden work movement demanding strength	10/27	0/0
Difficult arm movement	0/5	0/8
Total	49/138	4/25

Table 4 *Final events behind minor accidents in concrete reinforcement work and painting*

Final event	Concrete reinforcement work	Painting
	No of minor accidents affecting back/all minor accidents	No of minor accidents affecting back/all minor accidents
Slipping	25/51	0/2
Stumbling	8/27	0/1
Staggering	5/22	0/0
Falling from platform	1/11	0/1
Moving on platform	0/3	1/8
Working surface not final causal factor	10/24	3/13
Total	49/138	4/25

The reinforcement workers experienced more slipping and more falls than the painters, who were afflicted more by falling from the work platform (table 5).

Accidents affecting the musculoskeletal system in 1976–8 were analysed in detail from the reports sent by the construction firms to the insurance companies. The incidence rate (accidents $\times$ 1000/number of employees) was 81 in reinforcement work and 25 in painting ($p < 0.001$).

Discussion

Methods for determining the loads on the lumbar spine in different occupations are not well developed¹ and few thorough field studies of the demands on the back in heavy physical work have been carried out. Earlier, physical work strain was often assessed by monitored energy consumption,² which is a rather crude measure of the strain on the lumbar spine. In recent years several techniques have been presented for assessing postures and movements,^{3–6} but none of these methods covers all types of occupation satisfactorily. The short term effects of lifting have been investigated in laboratory studies.^{7–9} A method for the analysis of physical strain in construction work¹⁰ has been presented, as well as procedures to calculate the loads on the lumbar spine.¹¹ Accidents have been studied retrospectively, but field registration and analysis of all minor

and major occupational accidents that potentially affect the low back has not been carried out. As Stubbs points out, clear qualitative and quantitative criteria for the determination of trunk stress are needed to deepen our understanding of the relation between work loads and back morbidity.¹²

The cumbersome determination of the average daily load on back tissues, however, is probably of little value in evaluating permanent harmful effects on the back. What should be determined is the occurrence of loads that exceed the physiological capacity of the tissues. The size of these overloads and their frequency determine the development of permanent harmful effects in the low back.

POSTURE

Working in awkward postures is known to cause temporary symptoms.^{13, 14} Steel workers who work in a bent posture for more than 150 minutes a day suffer from lumbago, lumboischialgia, and lumbosacral radiculopathy much more often than other workers.¹⁵ Although coal miners' prolonged stooping has been related to increased disc degeneration, it has been considered less important in mining than injury or heavy lifting.¹⁶ Postural fatigue has been thought to make the back liable to subsequent injury.¹⁷

Clearly the prolonged use of awkward postures causes both fatigue of the back muscles and reversible back pain. There are also indications that prolonged working in bent postures induces an enhanced occurrence of painful lumbar syndromes. Whether working in bent postures as such contributes to disc degeneration (by impairing the nutrition of the discs, for example) is not clear. At present it seems more plausible that the permanent adverse effects of prolonged stooping are due to subsequent injury.

LIFTING

Weight alone is an inadequate measure for assessing the severity of lifting tasks, as the distance of the burden from the body is another crucial factor.¹⁸ Bending sideways¹⁹ and rotating spinal movements²⁰ place especially high strain on the lumbar tissues.

Table 5 *Causes of registered occupational accidents in concrete reinforcement work and painting in Finland in 1978*

Cause	Concrete reinforcement work: 278 accidents (%)	Painting: 722 accidents (%)
Hitting an object	33	30
Slipping, falling	29	15
Sudden movements, overloading	20	14
Falling object	8	11
Falling down	5	23
Others	5	7
Total	100	100

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Torsional strain probably contributes more to the development of disc degeneration than compressive loads.²¹

Repeated compressive stresses due to lifting have been considered capable of causing microfractures in the cartilaginous end plates and the subchondral bone of the vertebrae.²² Possibly, however, some or most of the permanent harmful effects of lifting result from minor and major accidents associated with lifting. Tichauer related low back injuries to unanticipated movements,²³ which in turn often accompany lifting and carrying.

Among miners, incapacity for work has been shown to be many times more common for workers who have done lifting for more than 30 years than for workers who have done lifting for less than 25 years. Radiological signs of lumbar disc degeneration increase with the amount of heavy lifting.¹⁶ According to Frymoyer and Pope degenerated vertebral units are less able to withstand mechanical stress and will fail more rapidly when stressed.²⁴

MINOR ACCIDENTS

The opinion that long standing stress plays an important part in disc tissue changes is meeting with growing acceptance.²⁵ It seems logical that degeneration may be hastened by a series of slight injuries to the vertebral bodies and epiphyseal plates that ultimately cause irreversible damage.²⁶

Microtrauma has been defined as a macroscopically unnoticeable lesion that in time induces diminished function.²⁷ Necropsies have shown microfractures in lumbar vertebral bodies adjacent to the subchondral osseous plates.²⁸ The stereoscopic radiographic technique has made it possible to identify small fractures in the posterior elements of the spine also in living people. The clinical significance of these small fractures (which are probably due to repeated minor stress in the bone with eventual fatigue failure) is still not clear.²⁹

Some empirical evidence for the theory that minor accidents may accelerate spinal degeneration may be obtained from a study by Lawrence.¹⁶ Radiological signs of lumbar degeneration were found to be more common and more severe in coal miners with a history of injury than in miners with no such history, but the latter group still had more radiological changes than manual and office workers. The higher prevalence of degenerative changes in miners with no history of injury than in office workers was considered possibly due to frequently repeated minor injuries.

REGISTERED ACCIDENTS

It is important to distinguish between injuries in which a true accident leads to trauma and injuries in

which there is no disruption of the ordinary work pattern.³⁰ True accidental injuries, falls in particular, are followed by long periods of absence.³¹ Industrial back injuries are three times more common in dockers than in shipbuilders, probably because of the heavy lifting in the dockers' work.³² In the construction industry workers in trades with heavy physical strain have been found to have the highest risk of back injury.³³ An analysis of accidental lumbosacral injuries in a gear box factory during a one year period showed that most of the injuries resulted from the sudden onset of pain while lifting, straining, stooping, and slipping, and others were caused by sudden unexpected loads, attempts to avoid injury, movement of the surface under foot, and tripping or stumbling.³⁴

PRESENT STUDY

The present study aimed to determine the loads on the back in one heavy and one light trade in order to compare the occurrence of symptoms and signs from the musculoskeletal system in workers active in these trades.

In our first analysis of the loads on the back in concrete reinforcement work we observed the work postures used and the weights handled.³⁵ In this renewed study on the effects of reinforcement work on the back we also measured the occurrence of minor accidents and registered, compensated accidents to obtain a comprehensive measure of harmful loads. In addition we studied another construction trade for comparison. We chose the work of maintenance painting, as we thought it exerted fewer demands on the back than concrete reinforcement. The maintenance painters were investigated not only for musculoskeletal but also for psychological and neurophysiological findings to determine the possible effects of occupational exposure to solvents; in this evaluation the reinforcement workers in turn served as a reference group.

In Finland the reinforcement of concrete is a special trade. The tasks of the concrete reinforcement workers are: cutting (the disentanglement of steel rods from stacks, pulling rods to cutting machines, and cutting); bending (bending the rods with electrical or manual machines, tying bent rods up in bundles, carrying the rods to intermediary storage); and binding (bringing cut and bent rods from intermediary storage, putting the rods in places, binding the rods together with iron thread). The use of prefabricated wall and floor elements and steel nets increased in the 1970s, but this did not affect the physical load of concrete reinforcement work done at construction sites to any considerable extent.

The three types of construction sites (apartment houses, office buildings, highway bridges) covered

by this study represent the vast majority of all concrete reinforcement work. The reinforcement workers work on contract, mostly in groups of three to ten men. The worker responsible for reading the blueprints does less manual work than the rest, but all the others pull, carry, cut, bend, and bind the steel rods. All the work is done out of doors, at times under temporary cover.

About one third of the painting work done "in the field" nowadays is maintenance painting. The work comprises cleaning old surfaces, filling holes and grooves, smoothing, brush or roller painting, or hanging wallpaper. The work is nearly always done indoors, often on platforms of scaffolds. The maintenance painters work on contract, either alone or in small groups. The two worksites (an apartment house and an office building) covered by the observation study were chosen as representative of maintenance painting. They were somewhat larger than maintenance painting worksites on average, but the tasks performed and the methods used were similar to those used at smaller worksites.

The data on postures and on lifting and carrying were gathered by extensive observation in the field. One may ask if it was appropriate to go to so much effort to gather statistical data on all work loads, as only excessive loads are of real interest. As the borderline between "excessive" and "not excessive" load remains difficult to distinguish, however, we decided to determine all loads. Even if we thus obtained thorough data on postures, and on lifting and carrying in general, we were still not able to register personal differences in postures and ways of lifting and carrying between workers performing the same tasks. Neither was it possible to determine the occurrence of accidents by objective observation. Even the occurrence of minor accidents was found to be so small that gathering objective data on their occurrence would have been extremely time consuming.

Thus we decided to gather data on minor accidents by interview. As we could not find any suitable published definition of "minor accident," we had to define our use of this concept. We enlisted the help of 96 reinforcement workers and 91 painters. These workers were asked to record all possible minor accidents at the end of each workday and to report them in detail when telephoned at home in the evening at two to four week intervals. Although recording and classifying minor accidents by telephone interviews entail difficulties, we are confident that the results of our interview study provide a reasonable estimate of the occurrence of minor accidents in the trades we studied. It would, however, be valuable to develop further the techniques for recording minor accidents in the search for occupational

causes of musculoskeletal morbidity.

There are also some weaknesses in the survey of registered occupational accidents. Even though it is obligatory to report all occupational accidents that lead to sick leave of three or more days, reporting is sometimes neglected. From the reports it is not always possible to determine whether an accident has affected the musculoskeletal system or not. As the diagnoses used and the sick leaves prescribed are the decisions of hundreds of physicians, and the descriptions of how the accidents took place are given by hundreds of foremen at construction sites, there is clearly variation in the reporting of causes, effects, and disability. Nevertheless, we have no reason to assume that the practice of reporting occupational accidents differs between the concrete reinforcement and painting trades.

Summing up the results of our analysis of the load on the back in concrete reinforcement and maintenance painting, the study showed that reinforcement work places greater demands on the back than painting in every major load category: posture, lifting, minor accidents, and registered occupational accidents. In the clinical part of the study we found that back symptoms and degenerative changes of the back were more common in reinforcement workers than in painters. There was no factor other than the considerable difference in physical work demands which could sensibly explain the reinforcement workers' higher prevalence of back findings. Thus we concluded this to be an effect of the strain on back in reinforcement work.³⁶

Which factor in reinforcement work is then the culprit? This question is more difficult to answer. The physical loads in reinforcement work differ in many ways from those in painting. Our study design does not make it possible to determine which factor or factors are decisive for the observed premature development of degenerative changes in the lumbar spine. It may well be that the common occurrence of minor and major accidents is the cause, but heavy lifting or prolonged stooping could also be responsible for the findings. It may be conjectured that all these factors potentiate the effects of one another. Further studies in other physically heavy trades are needed to define more accurately the importance of the various occupational factors, both alone and in different combinations.

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