

Repetitive Strain in Nonrepetitive Work: A Case Study

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In a Québec factory, a woman in a nontraditional job suffered from epicondylitis whereas her male coworkers were unaffected. A study was undertaken in order to enumerate the operations at risk for epicondylitis. Workers were interviewed in order to identify difficult operations and systematic observations were done over 4 work days. Although tasks were extremely varied, certain movements at risk for epicondylitis were repeated many times. Fifty-three valves were turned against resistance as part of this job, and one valve requiring a particularly difficult movement was turned 20 times in one day. There were at least 61 operations at risk for epicondylitis per day over a 4-day period. Strain on the elbow joint was particularly intense for the woman worker because the design of the workplace gave an advantage to taller workers with larger hands. Although this case study does not permit us to conclude that the worker's epicondylitis was due to her job, it enables us to suggest that it would be wise to adapt the dimensions of relevant equipment and worksites to a wider range of potential worker sizes. We also raise some questions about the definition of repetitive strain in epidemiological studies. We suggest that it may be necessary to consider not only the cycle time but also the total of forces exerted on a joint in order to study workplace injuries to the musculoskeletal system.

epicondylitis cumulative trauma disorder
nontraditional work women's work case study

1. INTRODUCTION

Recently, several studies have associated cumulative trauma disorders with repetitive movements and short cycle times in the microelectronics, food processing, and clothing industries (Brisson, Vinet, & Vézina, 1989; Luopajarvi, Kuorinka, Virolainen, & Holmber, 1979; Punnett, Robins, Wegman, & Keyserling, 1985; Silverstein, Fine, & Armstrong, 1987; Stock, 1991).

Among the pathologies thus identified are tendon disorders that occur when tendons are rubbed repeatedly against ligaments or bone and become inflamed, with local pain and swelling. It is thought that inflammation can arise through the occurrence of injuries that are not allowed to heal due to repeated solicitation of the injured structures (Snidjers, Volkers, Mechelse, & Vleeming, 1987).

The elbow is particularly susceptible to tendinitis because the forearm muscles can exert a large force on the relatively small area of tendon insertion on the humeral epicondyle. Epicondylitis, one of the most common industrial diseases, can result from overuse or strain of the tendons linking the finger and wrist extensors with the elbow joint (Kurppa, Waris, & Rokkanen, 1979; Luopajarvi et al., 1979). Epidemiological and clinical studies of epicondylitis have been reviewed by Kurppa et al. (1979) and Viikari-Juntura (1984). Epicondylitis has been

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attributed to forceful external forearm rotations such as those used in sports activities such as tennis (from which its nickname *tennis elbow* is derived), pitching, and bowling (Gardner, 1970; Putz-Anderson, 1988; Sanders & McCormick, 1987; Tichauer, 1976). Repetitive wrist motion, forceful wrist extension, wrist pronation, and ulnar deviation have also been characterized as being at risk for epicondylitis (Putz-Anderson, 1988).

Musculoskeletal problems are the most common health symptom among women in Québec (Guyon, 1990). Women have a particularly high prevalence of cumulative trauma disorders, including epicondylitis (Allander, 1974; Armstrong & Chaffin, 1979). In fact, lateral epicondylitis was once called "washerwoman's elbow" (Snijders et al., 1987). Dimberg and colleagues, for example, found in a study of 2,814 industrial workers that women had a higher probability of cervicobrachial symptoms; they attributed the higher prevalence to the fact that women were much more likely to work in jobs that exerted more strain on the neck and upper extremities. In addition, they noted a higher prevalence of pain among shorter workers, and they also noted that such workers (primarily women) may be forced more often to work with elevated arms and an extended neck. However, they also suggested that women might be disadvantaged by such extraprofessional factors as inferior force in the upper limbs, a greater ratio of body fat to muscle, which increases the force required to move objects, and stress and fatigue due to the combination of domestic and professional work schedules (Dimberg et al., 1989).

The nature versus nurture argument persists when considering other cases of repetitive strain injury. Evidence from several studies suggests that working conditions are responsible for these symptoms. For example, women in the garment industry have frequent musculoskeletal problems, particularly in the back and upper limbs (Brisson, Vézina, & Vinet, 1992), an ergonomic study of sewing machine operators suggests that these workers are at risk for upper body injuries due to repetitive hand and wrist movements with short cycle times combined with static forces and cramped precise movements, conditions often found in women's jobs (Vézina, Tierney, & Messing, 1992). In another study, we found very different symptom profiles for men and women working in poultry slaughterhouses, but those of men in traditionally female jobs resembled those of women (Mergler, Brabant, Vézina, & Messing, 1987). However, other authors have suggested that musculoskeletal injuries have important emotional determinants (Lucire, 1986).

The question of women's excess susceptibility to cumulative trauma disorders was raised recently in a job involving very diversified tasks with a very long cycle time, which was always assigned to men. A woman newly assigned to this job was stricken with epicondylitis, whereas those men who preceded and succeeded her were unaffected. We report here a descriptive analysis of the movements and forces involved in this job.

2. METHODS

2.1. Subjects

Two workers were observed: Worker A, the woman who left the job due to bilateral epicondylitis and Worker B, the man who took her place and now occupies the position. Information on their physical and social characteristics was obtained through interviews or direct measurement.

2.2. Assigned Tasks

The factory makes light bulbs that must be coated with paint. The job studied involved two major activities: (a) mixing paints, a task that consisted of preparing components and mixing, testing, and adjusting solutions to the desired concentrations (6 hours, 30 minutes per day), and (b) "relieving of the oven attendant," which involved placing fluorescent tubes in an oven and inspecting them (40 minutes per day).

2.3. Interviews and Observations

A standard ergonomic methodology was used (Guérin, Laville, Daniellou, Duraffourg, & Kerguelen, 1991). Workers were interviewed to obtain information on worker characteristics and task descriptions. They were asked to identify operations they found difficult. In addition, workers were asked about changes that had occurred at the work station since Worker A had been transferred.

Preliminary observations furnished descriptions of the work cycle, working conditions, and task requirements. Certain movements were considered to be at risk for epicondylitis: forceful ulnar or radial deviation and wrist pronation or extension. Operations involving such movements and identified by Worker A as being difficult were valve opening and closing, turning mixing machines on and off, transport and emptying of containers, and loading and transport of containers using an overhead rail system. Systematic observations were done during the morning and afternoon during 4 workdays spread over 2 weeks. The oven-loading operation was observed and filmed for 10 minutes. The work activity as well as the frequency and the characteristics of movements of the upper limb were noted. Methods of data collection were adapted to the specific task conditions. In particular, the presence of dangerously high concentrations of solvent vapours at some sites prohibited the use of cameras and other devices. Thus mixing paints was observed using written notes, and oven attendant was filmed using a hand-held video camera for further analysis. In some cases (as noted later) where no camera could be used and the activity was too complex for all components to be noted at once, the activity was simulated and observed at a site where the relevant dimensions of the workstation and the task components were reproduced. Photographs were taken of the simulated activity and compared with the movements and positions during the real work. The simulation was repeated until the photographs of the simulated activity accurately represented the real situation.

Another methodological problem should be noted. Although the male worker was still on the job, the female worker had been transferred 18 months earlier. Because she was still suffering from epicondylitis, she was asked to perform the movements involved in the various steps of the task and to stop if she felt any discomfort.

2.4. Measurements and Recorded Information

All measurements were repeated three times and the mean was calculated. Forces were measured with a dynamometer that could measure to 68 kg. Some forces were estimated using visual cues (the valve did not turn for some time after exertion of the force, contortion of the wrist, etc.) as noted. Grip strength was measured with a grip dynamometer with a 100 kg capacity. Any weights manipulated during the observations were weighed using a balance with a capacity of 136 kg, and precision ± 0.5 kg.

Dimensions of the workstation, distances through which the weights were carried, and the three rooms in which the work took place were measured with a tape measure.

For 4 consecutive days, Worker B noted each time he opened or closed a valve and each time he carried a bucket. For 2 consecutive days, he noted the number of times he turned the mixers on or off.

3. RESULTS

3.1. Worker Characteristics

The workers' characteristics are presented in Table 1. Age, seniority, and experience of the two workers were similar. However, there were great differences in their physical characteristics: Workers were both taller than the mean for their sex (between 80th and 95th percentile for North Americans), and Worker B greatly outweighed Worker A, but the other characteristics were near the North American means for each sex. The average weight difference for women and men is 12 to 13 kg, the median hand spread 19.0 cm for women

Dimensions of Job Control in Computerized and Traditional Office Work and Its Health Effects

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This study investigates whether a consistent relationship exists between computerization and job control. It also examines the role of job control as a predictor of stress symptoms typical for data entry and word processing (VDU) work. Two groups of VDU users and two comparable non-VDU-user groups took part in this study. A special questionnaire made it possible to assess global job control and four indexes of control related to specific aspects of work (control over choice of tasks and methods, control over time frame, control related to one's skill, and control related to participation in the decision-making process). Results did not show an unequivocal relation between computerization and the latitude of control. The latitude of control depends on the task performed and the aspect of control we are considering. Regression analyses showed that global control is a good predictor of job satisfaction, some mood disturbances, and visual complaints. The other aspects of control are related in a variety of ways to stress symptoms. The role of a Type A behavior pattern in the relationship between job control and stress symptoms varies depending on which aspect of control is being considered. It was concluded that because of the high functional differences between various aspects of control, it is better to avoid using the concept of global control and, when possible, apply specific indexes of control.

job control VDU work stress

1. INTRODUCTION

The ability to control one's own environment is very important from the psychological point of view. A key role is attributed to such control in many psychological theories (e.g., Rotter, 1966; Seligman, 1975). Much empirical evidence points to the negative psychological effects of insufficient control over one's situation (e.g., Karasek, 1989; Kohn & Schooler, 1986).

Because VDU operation is one of the fastest growing types of occupation, it is being studied here. There is a twofold purpose to the present study: (a) it seeks to determine the possibilities of control VDU operation offers, and (b) it seeks to contrast these possibilities with the possibilities offered by more traditional ways of performing comparable work.

Results obtained from early studies indicate that the computerization of office work decreases the level of control exercised by the employee. Smith, Cohen, and Stammerjohn (1981) found that clerical VDU operators exercise significantly less job autonomy and experience more control by their supervisors than clerical groups not using VDU. Similar results were reported by Bradley (1977) and Stellman, Klitzman, Gordon, and Snow (1987). However, in other studies an inverse relationship between computerization and degree of job control was not found (Turner & Karasek, 1984).

There are reasons to believe that this variability of results exists because in many of these studies various aspects of job control were not adequately separated. The complexity of the job control concept is widely recognized (see Aronsson, 1989; Frese, 1989; Ganster, 1989). For

We thank our colleague Ms. Joanna Bugajska for giving us the results of a medical interview that she carried out with one group of subjects (data entry with VDU). This group participates in the Polish part of the MEPS project (Musculoskeletal, Visual and Psychosocial Stress in VDT Operators in Optimized Environment: An International Study) initiated by Aaras, Westlander, and Shahnavaz (Aaras, 1991).

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TABLE 1. Physical Characteristics of Two Workers in a Light Bulb Factory

	Worker A Female	Worker B Male
Age (yrs)	41	40
Seniority in factory (yrs)	22	20
Seniority in task (yrs)	1.5	1.5
Height (cm)	170	190
Weight (kg)	59.6	93.2
Grip strength (kg)		
dominant hand	27.0	57.3
nondominant hand	20.8	55.0
Hand breadth (cm)	18.5	21.5

and 20.6 cm for men (Pheasant, 1986), and the average grip strength 26 kg for women and 51 kg for men (Aghazadeh & Dharwadkar, 1985). Worker A was right handed and Worker B was left handed.

3.2. Work Activities

The work was composed of operations that varied in duration and type. Some operations were repeated several times per day, others a few times per week or per month depending on production requirements. The amount of paint needed varied with the length of tubes and the number produced. Because the quantity of paint mixed at one time was constant, a rise in production or product diversification resulted in an increase in the number of mixing operations required of the worker. The production level at the time of the study was considered by workers to be normal.

Since Worker A was transferred, a mechanical aid for weight-lifting was added. However, Worker B did not use it, saying that it was unnecessary.

3.3. Mixing Paints

The worker emptied ingredients from storage containers into barrels using either a hose or a smaller container. Every 20 minutes, the worker tested the density and specific gravity of the solutions and adjusted them by adding components from containers.

3.3.1 Valve opening and closing

Fifty-three valves were manipulated as part of this job, at an average rate of 61 such operations per day over the 4 days of the study. Four types of valves were used: round, flat, pressure, and ring valves. Round valves opened counter-clockwise in the horizontal or vertical plane and varied in diameter from 5 to 10 cm (Figure 1). Flat valves opened downward or from left to right. Ring valves opened vertically downward and were difficult to hold due to the small size of the ring. Pressure valves were always vertical and pressure had to be exerted constantly during operation. One pressure valve also required operation of a lever at the same time as pressure was exerted on the valve; the palm and index finger were under pressure during this operation. This valve was operated 20 times a day.

Valves were usually hard to access; those above the paint canisters were usually 121 cm (midarm height for Worker A, elbow height for Worker B) from the floor and those below at 66 cm from the floor, and at 61 cm from the edge of the canister. Thus, workers were often forced to open and close them while in awkward unbalanced or stretched positions. Static effort was exerted at the elbows, wrists, and fingers. Forearms rotated inward and outward to close or open valves, wrists are often extended and in cubital or radial deviation. The amplitude of these movements was greater for Worker A than Worker B; due to the difference in height,

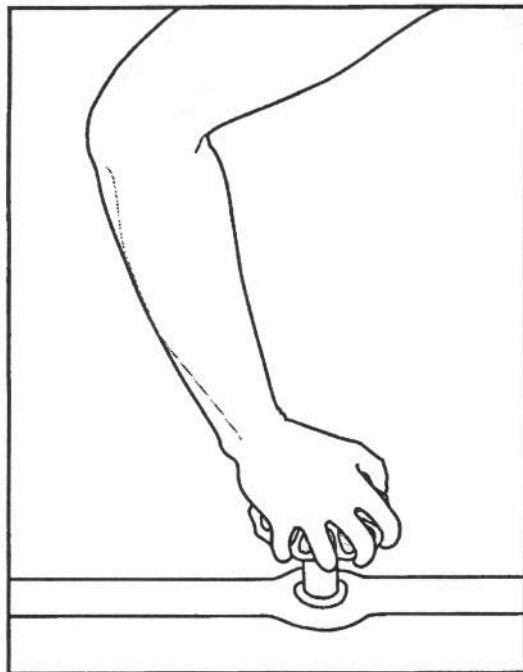


Figure 1. Opening or closing a valve. Note passage from cubital to radial deviation when valve is opened or closed.

Worker A often worked at the limit of her reach and her elbow was often maximally extended. The difficulty of access was the same whether the worker was right or left handed.

Certain valves were particularly difficult because chemicals or glassy deposits had accumulated in the opening. For some round valves, more effort was necessary when opening than when closing valves and the effect was therefore somewhat different depending on the handedness of the worker. With many valves, the contrast between Worker A and Worker B was striking. Worker A was obliged to use both hands and appeared to exert considerable effort, whereas Worker B used one hand and did not appear to force. Several valves required a combination of positions at risk for epicondylitis (regardless of the handedness of the worker): internal rotation of the forearm, wrist extension combined with deviation, and finger extension. The difficult positions were often combined with static effort required of the hand, forearm, or arm, because of the difficulty of access.

3.3.2. Operating mixers

The paint containers were fitted with helical mixers to keep the paint mixed. The mixer motors were turned off before solutions were prepared, checked, and adjusted, and were turned on at the end; mixer motors were turned on or off 48 times per day. Turning on the motor involved pushing a pin into a switch. Turning the motor off was more complicated: The pin was pulled down while pushing a button. This could be very difficult in a situation that occurred frequently where the switch was behind a paint container and two hands could not be used because of the difficulty of reaching around the containers (although the switch could be reached with either hand, making handedness irrelevant). These manipulations involved external rotations, maximal elbow extension, and wrist extension with cubital deviation while exercising a force. A sudden flicking motion had to be exerted to pull the pin down, exerting a force through the wrist and forearm. All these manipulations were more difficult for Worker A because her hands were smaller and her arms were shorter. It was therefore harder for her to reach around the paint containers and she could less frequently use two hands to operate the valves.

3.3.3. Carrying and pouring from containers

Ingredients came in various heavy containers that had to be transported to the paint reservoirs and emptied (Table 2). When carrying containers, and especially when pouring from the heavier containers, the forearms were rotated while exerting a large static effort. The shape of the buckets require them to be carried far from the body: The shoulder was in flexion and abduction, the arm was stiff and the elbow was extended, and the wrist was flexed and in cubital deviation.

In order to empty the containers, the worker had to lift them to a height of 157 cm (eye height for Worker A, shoulder height for Worker B) because the reservoirs were at that level. Worker A had to lean on the edge of the reservoir and push the container with the other hand. The muscles of the arm that held the container were required to contract while the forearm and hand muscles exerted static forces and the wrist was extended and the forearm rotated. The other arm exerted similar forces with the forearm externally rotated. These postures were simulated with an empty bucket for Worker A, but even under those conditions some postures were at risk for epicondylitis. Worker B, on the other hand, being taller, rarely was obliged to exert effort with the arms in greater than 90° abduction. In general, his movements were of smaller amplitude (Figure 2).

3.3.4. Transporting and loading reservoirs onto the overhead transport rails

The 264-liter reservoirs were transferred from one room to another by rails that hung from the ceiling. At least five times per day, the worker had to pull chains varying in height from 152 cm to 185 cm from the floor in order to connect the rails, where the reservoirs were stored, to the transport rails. Worker A took the handle of the chain with two hands and swung her weight backward to dislodge the rail. She then turned and walked while pulling the chain with the right hand. Her position during this operation was maintained for several seconds: the shoulder flexed at more than 90°, the elbow flexed at 90°, internal rotation of the forearm, the wrist extended with cubital deviation, and the thumb extended. The pushing force was 8 kg if the reservoir was empty, and 24 kg when it was full. Similar demands on the upper extremities occurred during other manipulations with the rails. All these efforts were easier for Worker B because of his height than for Worker A. Also, his greater weight permitted him to push the reservoirs more easily.

3.4. Oven Loading

For two periods of 20 minutes each per day, Worker A was required to replace another worker assigned to loading painted light bulbs into an oven. During the 20 minutes, 1,533 fluorescent tubes were fed into an oven to be baked. This task consisted of removing seven tubes at a time from a box of tubes and placing them on a conveyor to go into the oven. Because the box contained 63 tubes, this operation was repeated nine times before the box was emptied and

TABLE 2. Containers Transported and Emptied During Solution Mixing in a Light Bulb Factory

Container	Liquid	Weight of Container Plus Liquid (kg)	Distance Transported per Carry (m)	Frequency/Day
Can for density test	Paint	2.8	3-5	18-20
	Solution	15.2		1
Carboy	Lacquer	22.9	3	1
	Solvent	9.4		3
Bucket	Solution	8.2	3-20	3
	Solvent A	22.3	0	1
Large carboy	Solvent B	18.0	(carried on cart)	1

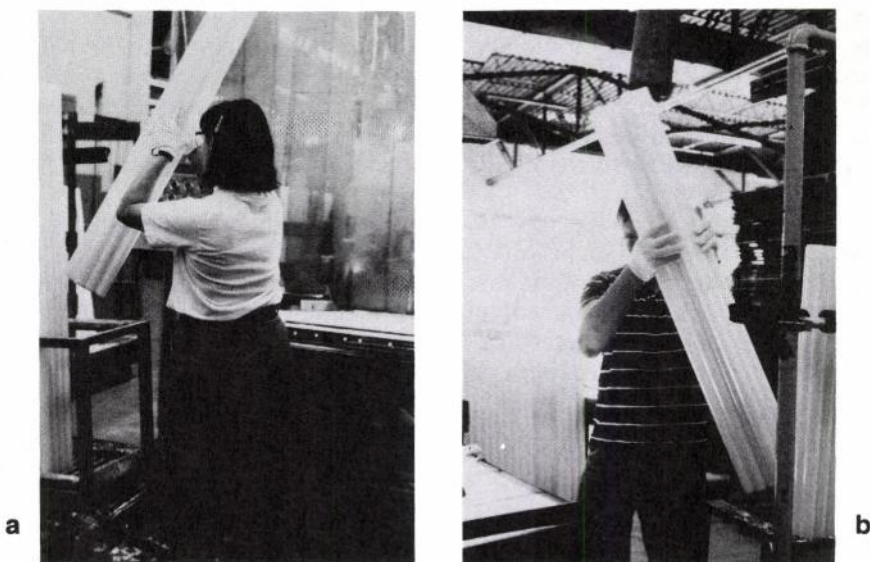


Figure 2. Lifting light bulbs. Note position of workers' wrists relative to bin height, and size relative to light bulb size.

placed on another conveyor. It took Worker A an average of 5.3 seconds and Worker B 5.5 seconds to place each group of seven tubes (average of 90 groups). The tubes were 58 cm, 118 cm, or occasionally 235 cm long and weighed 131 g, 277 g, or 549 g each. Thus, when the medium-sized tubes were being produced, workers turned 1.94 kg of tubes every 5.3 seconds, for a total of 425 kg of tubes every 20 minutes. (Since completion of this study, a machine has been installed to accomplish this task.)

Many of the manipulations involved turning the forearms with flexed or extended wrists while holding the light bulbs, positions that placed tension on the elbow tendons. The fact that the fingers were spread in order to hold the bulbs increased the tension on the finger extensors and therefore on the tendons that anchor these muscles to the elbow joint. The degree to which the fingers had to be spread apart was greater for Worker A than for Worker B (Figure 2).

4. DISCUSSION

On average over the 4-day period, Workers A and B manipulated valves 61 times and motor switches 48 times, respectively poured from heavy containers 24 times, and performed 5 manipulations of the rail system. Thus, workers did an operation associated with risk of epicondylitis once every 4 minutes during the supposedly diversified part of the task (92 operations during the 390 minutes), plus another 340 such operations during the 40 minutes of oven loading.

Differences in the size and grip strength of Workers A and B were similar to average male-female differences in these parameters, except that Worker B was heavier than average for his height. In almost all of the 92 diversified operations and in all of the 340 repeated operations, Worker A was required to exert larger forces, either because her shorter stature required her to work in disadvantageous positions or because her smaller hands affected the way she held materials and equipment. The difference in strength sometimes meant that Worker A was obliged to exert forces during longer times.

A case study such as this does not allow us to decide whether women in general are more likely to suffer from epicondylitis than men, or to attribute the cause of Worker A's

epicondylitis to her job or her individual susceptibility. For example, Worker B's left handedness and concomitant strength of the nondominant hand may have given him a further advantage over Worker A. It may also be, for example, that the exposure to organic solvents affects some aspects of nerve conduction that may be related to the worker's injuries. The interest of this study comes from the detailed observation of the tasks done by the two workers. This enables us to identify some factors that should be considered when integrating a new population into jobs that have usually been done by a population of different average size.

Men average 10 cm taller and 13 kg heavier than the average woman, and when any randomly selected man and woman meet, 90% of the time the man will be taller. Men and women differ in shape, and size differences vary according to the body segment considered. The average man's hand is 10% longer and broader than that of the average woman (Pheasant, 1986).

Workplaces and tests may interact differently with people of different physical size and shape. It has been shown in the laboratory and in field studies that male-female relative strength depends on the test used to reveal it. Stevenson and coworkers have shown that women are disadvantaged by design characteristics of some strength tests (Stevenson, Greenhorn, Bryant, Deakin, & Smith, 1994). Fothergill and coworkers studied a variety of positions and movements and showed that male-female differences in strength for a given task depended on the details of the orientation of the force (Fothergill, Grieve, & Pheasant, 1991). Similarly, a Swedish group pointed out that the impact of gender differences on grip strength varies with the distance between the handles of a pair of pliers (Franson & Winkel, 1991). Similar problems have been identified in field studies. In a study of mechanics, we found that a woman in a nontraditional job was forced to exercise her strength in disadvantageous positions due to the fact that tools and worksite arrangements were not suited to her size (Courville, Vézina, & Messing, 1991). In a study of municipal workers, interviews done with 113 male and female blue-collar workers in a series of jobs with a manual components, women report more pain than men in most parts of the body, particularly in the upper limbs (Messing, Courville, Boucher, Dumais, & Seifert, 1994). Differential task assignment by gender was responsible for some difference in exposure to conditions at risk for musculoskeletal pain, but an important component could be attributed to tools and equipment poorly adapted to the size and shape of the average woman. Thus, if workplaces are badly designed, problems that should in fact be attributed to deficiencies in tools or equipment may be attributed to gender or ethnicity.

We were also struck by the fact that the job we studied was much more diversified than traditional female jobs on assembly lines; there were many operations that exerted force on the same structures. This leads us to question current practices and definitions in regard to cumulative trauma disorders (CTDs). In Québec, compensation is usually allowed for CTDs only if repetitive work is involved. Repetitive work is defined as work involving repetitions of the same operations. Tasks with many repetitions are most often defined as those on assembly lines, and injured workers doing even slightly more varied tasks may be contested or even refused compensation.¹

The job analyzed here involved repetitions of the same movements during only 40 minutes per day. However, although the other tasks were not repetitive, force was repeatedly exerted on the same tendons and joint. Currently, epidemiologists are trying to devise ways of predicting CTDs; their efforts have centered around the classification of levels of force and repetition

¹In Dorval and Dominion Textile 1990 Commission d'appel en matière de lésions professionnelles (CALP) 18, a textile worker was refused compensation because she repeated operations during only 70 minutes per day. A cashier was initially refused compensation on the grounds that she interrupted punching the cash register to give change to customers; this was reversed on appeal (Coderre & Supermarché Dunant 1990 CALP 1042). A librarian who stamped books many times but also accomplished other tasks was also refused (Dubois & Ville de Drummondville, 1990 CALP 269).

(Moore & Garg, 1991; Silverstein, Fine, & Armstrong, 1986). Nevertheless, it may be necessary not only to evaluate the repetitive nature of tasks but also to examine the physiological effects of the tasks and to identify diversified operations having similar effects.

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