7.
Ergonomics and Human Factors

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Ergonomics and Human Factors

Neither workers, nor machines, nor workplaces exist apart from each other. To accomplish work, all come together, and injuries and illnesses sometimes result from their interactions. The study of these interactions is called "ergonomics," or "human factors engineering."

The term ergonomics was coined in the United Kingdom after World War II to describe a discipline created during the war. It had been noted that "bombs and bullets often missed their mark, planes crashed, friendly ships fired upon and sunk, and whales were depth charged" (471). In response to this situation, research on designing military equipment to match more closely the capacities of the users began on both sides of the Atlantic. Attention was thus devoted to the interaction between the human operators and their machines.

One name for this new discipline, ergonomics, is derived from two Greek words, ergo, meaning work, and nomos, meaning laws. Ergonomics is the science devoted to understanding the laws or principles that govern the design of work systems. A British professional group—the Ergonomics Research Society—was formed by the practitioners of this new discipline. An organization with similar aims, the Human Factors Society, was founded in the United States in 1957. The work of the original members was termed "human factors engineering," or engineering psychology. Whether they are called human factors engineers or ergonomists, the scientists who practice this discipline draw on a number of other disciplines, including medicine, physiology, psychology, sociology, engineering, and physics.

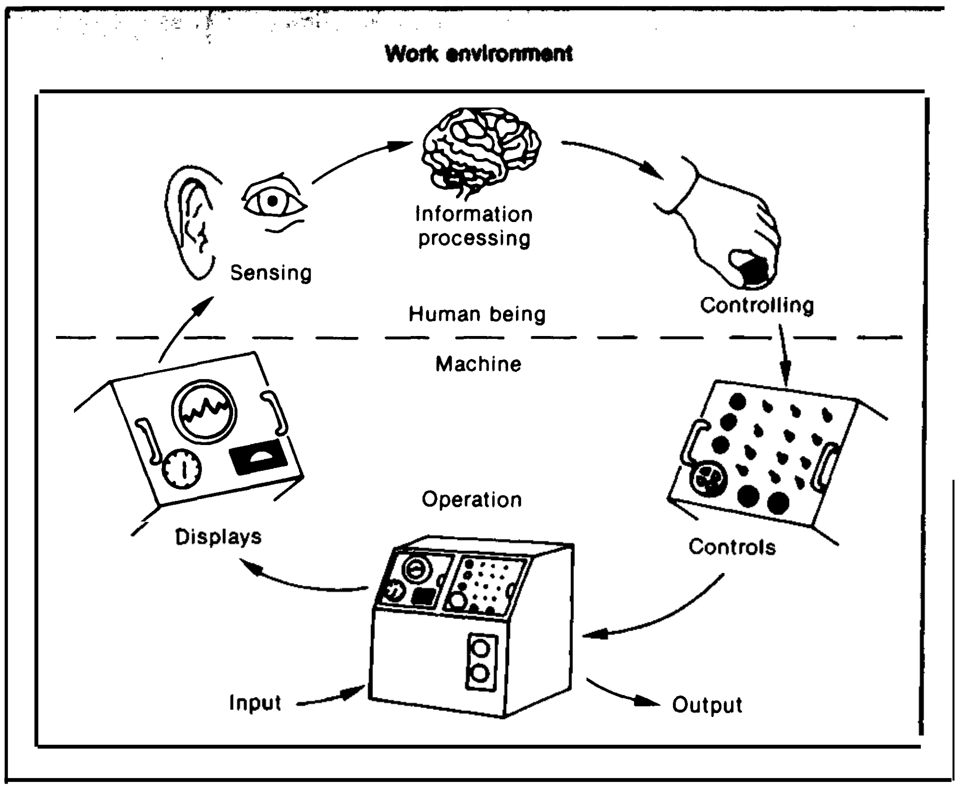
Ergonomists are concerned with safety, effectiveness, and efficiency wherever people are part of a system (380). The discipline is "an applied science concerned with the design of facilities, equipment, tools, and tasks that are compatible with the anatomical, physiological, biomechanical, perceptual, and. behavioral characteristics of humans" (250). The principle behind ergonomic design is that the machine should fit the worker, rather than forcing the worker to fit the machine. To quote from one ergonomics guide (655):

> Man's physical limits for bending, stretching, and/or compressing are such that the machine must be made to adapt to the man rather than the converse. Behavior characteristics are somewhat more flexible. Man can adjust his sensory-motor behavior to some degree, and . . . can utilize alternate procedures and make up for certain equipment inadequacies. However . . . as operator load increases due to task complexity, fatigue may reduce operator reliability; system performance could degrade at a critical time . . . Workplace layout should favor the man's physical and behavioral capability in all cases in which a likely error in human performance could affect . . . safety . . , The designer cannot assume that personnel selection and training will be a panacea for improper workplace considerations.

Figure 7-1 is a schematic representation of a human-machine system. The person processes information about the environment and acts on it by using the machine's controls. The important features of the machine include the controls used by the worker, the operations of the machine, and the displays used to feed information back to the worker. The task of the ergonomist is to analyze how the worker obtains the information needed to operate the machine, how that information is processed to reach a decision concerning the appropriate way to control the machine, and what worker actions are appropriate to control the machine in a fashion that is safe and meets production criteria (380).

Other considerations, especially improving the productivity of workers, fit easily into the goals of ergonomics. Opportunities exist for workplace designs that simultaneously improve production output and reduce the risks of injury. For instance, C. G. Drury reported that new handtools in the component-assembly department of a large computer company and changes in seating, lighting, and workbenches led to improved production and the elimination of repetitive motion injuries. The costs of the redesign" were earned back *4.3* times within one year through increased productivity and savings, and the number of rejected components fell to half the previous level. The workers involved expressed increased satisfaction with their jobs *(340).*

Figure 7-1.—Schematic Representation of a Human-Machine System



SOURCE (292)

CLASSIFICATIONS OF ERGONOMICS

Ergonomists usually subdivide the field into information ergonomics and physical ergonomics. Information ergonomics is concerned with the collection, display, sensing, and processing of information. Physical ergonomics is concerned with worker size, strength, capabilities for motion, and working posture.

Ergonomists use a number of techniques that include the evaluation of the transmission of information between the machine and the worker (link analysis), discovery and evaluation of system failures (critical incidence analysis), detailed examination of the sequence of actions taken by workers (task analysis), and analysis of situations that may arise from unprogrammed events or human errors (contingency analysis) (380). Ergonomists also make extensive use of anthropometric data concerning the physical dimensions and capabilities of the human population. In addition, the techniques of biomechanical analysis are used to measure expected physical stresses encountered by parts of the body while performing; work tasks.

Information Ergonomics

Information ergonomics is generally concerned with what the worker **senses in the workplace and how that information is processed by the worker, The two major sources of sensory information are visual and auditory.**

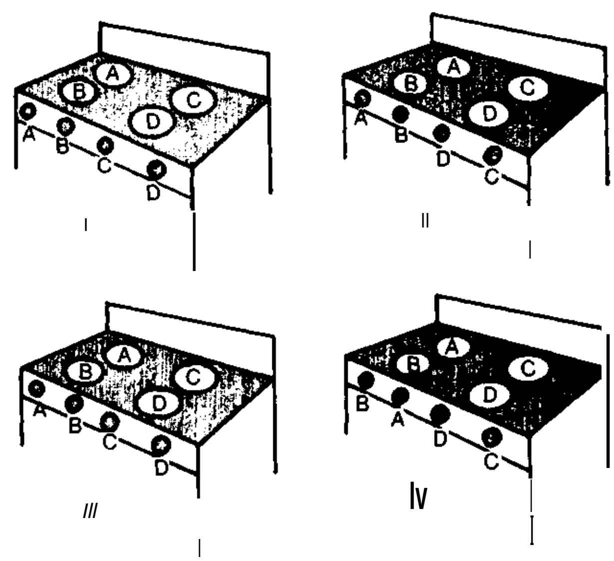
Visual displays in the workplace include meter scales, control labels, warning signs, cathode-ray tube (CRT) displays, and printed text. To this list can be added video display terminals (VDTs), which can be CRT displays, liquid crystal displays, or other technologies. Three factors important to the operator must be considered **in designing a visual display: the size of the critical detail in the display, its brightness, and the contrast of the display against the background. There are a number of techniques available to achieve these goals in design and to evaluate existing equipment. There are also many guidelines for special applications, including the special needs of groups such as older workers (23).**

Workers also receive information through sound. These can include tones (bells, whistles, beepers, etc.) **as well as speech. Designers and ergonomists often face the question of whether to provide information through visual or auditory means. In general, if the message is simple, short, or calls for immediate action, if the worker is already overburdened with visual messages, or if the workplace is too dark or too bright for visual displays, an auditory presentation is recommended. If the message is complex, long, and does not necessitate immediate action, or the auditory system of the worker is already overburdened, or if the workplace is too noisy, a visual display may be preferred** (23).

Finally, information ergonomics is concerned with the processing of information **by the** worker and the design of the workplace, including the de**sign of controls. Research that has measured the abilities of humans to accurately process information has shown that people often will not be able to make quick, accurate responses in complex or unexpected situations, Second, the studies have also shown that "compatibility" in display-control design is very important. Compatibility refers to the relationships between stimuli and responses, and generally falls into three categories: spatial (the compatibility of physical features or spatial arrangement for displays and controls), movement (the direction of movement of displays and controls), and conceptual (the associations people hold concerning the meaning of signals, such as in the United States the association of the color green with "go")** (292).

One example of an everyday problem **in compatibility will perhaps clarify this notion. Figure** 7-2 presents four possible arrangements of the burners and burner-controls for a stove. For several of these patterns, the relationships between burners and controls can be difficult to learn and hard to remember because the arrangements lack spatial compatibility. To examine this, researchers in the 1950s setup an experiment in which they told a group of subjects to turn on specific burners. The subjects' reaction times *were* **measured and the number of errors was noted. Design I, asso-**

Figure 7-2.–Control Burner Arrangements of Simulated Stove Used in Experiment About Logical Arrangements



Number of errors in 1,200 trials: arrangement

1	0
II	76
III	116
IV	129

SOURCE: (292)

ciated with both the fewest errors (zero) and the best reaction time, was considered to be the most compatible (292).

Many workplaces have dozens of incompatible control configurations, which often lead to operator errors and subsequent serious injury (23). The cherry-picker accident discussed in box C illustrates the importance of controls layout.

Physical Ergonomics

Physical ergonomics, concerned with the worker as a physical component of the work process,

Box C.—Cherry Picker Accident

Design as Related to the Accident.—The worker was painting the inside of a large industrial plant that was under construction. He was using a large mobile work platform—a cherry picker.

The worker stood in the "bucket" of the cherry picker. The control knobs for moving the bucket left or right and raising or lowering the bucket were identical. The painter, who did not use the equipment regularly, was found with a severe head injury adjacent to a beam with which he had apparently collided.

Application of Heinrich's Approach.—According to the dichotomous classification of accidents proposed by Heinrich (see ch. 4), the injury would have been reported as resulting from an unsafe act, i.e., the painter operated the controls in such a mannner as to produce his collision with the I-beam. (In fact, this was the classification used when the injury was reported under the workers' compensation system.)

Using the *ergonomics model*, the investigator would focus on the following questions:

- What was the worker's experience in using the lift?
- What was the worker's physical size? (Did he have limitations in his upper limb movement? What was the strength in his upper limbs?)
- What was the placement of the operating controls? Were they labeled to indicate method of operation? What protection was provided against inadvertent operation?
- What was the relationship between the method of control operation and movement direction and [illegible] of the lift?
- [illegible] strength was needed to operate the controls?

[illegible] found that the worker had no problems with upper limb movement or strength, but he had [illegible] experience and training in using the lift. No protection was provided against inadvertent [illegible] (a wire mesh cage over the upper perimeter of the two control levers would have [illegible] inadvertent operation).

[illegible] problem was found in the absence of compatability of control movement versus lift movement. [illegible] the lever forward, away from the body, caused the "bucket" to rotate to the left, [illegible], while pulling it toward the body caused the "bucket" to move to the right, clockwise.

[illegible] would therefore have concluded that two possible causes existed for the accident:

- [illegible] controls were not protected from inadvertent operation, one of the hoses of the spray [illegible] had become entangled with the control for rotary movement and had caused the [illegible] to collide with the beam, or
- [illegible] was inexperienced in using the equipment and control movement was not com[illegible] with the lift movement, he could have operated the control in the wrong direction and thrown [illegible] the beam.

often uses the techniques and equipment of anthropometry and biomechanics. Anthropometry is the measurement of the physical dimensions of the human body, including both the structure of the body in fixed positions and the extent of movement possible, such as reach or lifting capacity.

Biomechanics is the study of the mechanical operations of the human body. The muscles, bones, and connective tissue can be analyzed as **a** mechanical system using the fundamental laws of Newtonian mechanics. The forces acting on the muscles, bones, joints, and spine can be determined for the lifting of an object, for instance. Through such analysis, it is possible to calculate the size and direction of forces acting on the body. These can be compared with expected human tolerances to judge whether the activity in question will cause harm.

ERGONOMICS AND PREVENTION OF MUSCULOSKELETAL INJURIES

Ergonomic principles can be applied to prevent both overt and cumulative traumas. An example in the overt category is the risk of falling from a ladder, which can be reduced by considering the sizes and mobility of people when deciding how far apart to place a ladder's rungs **(250).** Cumulative traumas are not the result of single events or stresses; they stem from the repeated performance of certain tasks. Back problems are by far the most common cumulative trauma injuries. Evaluation and redesign of tasks to prevent back injuries is discussed later in this chapter.

Repetitive motion disorders are a type of cumulative trauma associated with repeated, often forceful movements, usually involving the wrist or elbow. Some 20 million workers on assembly lines and in other jobs that require repetitive, strain-producing motions are at increased risk of developing such disorders. Redesigning work stations, equipment, and handtools can significantly reduce the awkward, forceful movements common to many jobs on assembly lines, in food processing, in the garment industry, and in offices. Carpal tunnel syndrome, one of this class of disorders, illustrates the potential for prevention offered by the integration of ergonomics, medical surveillance, and treatment.

Carpal Tunnel Syndrome

A wide variety of workers (see table 7-I), from aircraft assemblers to upholsterers, are among those at risk for carpal tunnel syndrome (CTS), a progressively disabling and painful condition of the hand. Because the musculoskeletal strain from repeatedly flexing the wrist or applying arm-wrist-finger force does not cause observable injuries, it often takes months or years for workers to detect damage.

Table 7.1.—Occupations and Activities Associated With Carpal Tunnel Syndrome

Aircraft assembly	Inspecting
Automobile assembly	Meat processing
Buffing	Metal fabricating
Coke making	Musicians
Electronic assembly	Packaging
Fabric cutting/sewing	Postal workers
Fruit packing	Textile workers
Gardening	Tire and rubber workers
Hay making	Typing
Waitressing	Upholstering
Housekeeping	

SOURCE (60)

The incidence and prevalence of CTS in the work force is not known. The National Institute for Occupational Safety and Health **(567)** reports that 15 to 20 percent of workers employed in construction, food preparation, clerical work, production fabrication, and mining are at risk for cumulative trauma disorders. The Bureau of Labor Statistics (603) reports 23,000 occupationally related repetitive motion disorders in 1980, although the number of CTS cases is not specified.

CTS is undoubtedly underreported in aggregate statistics. Research in particular high-risk plants provides some insight into the extent of the problem. In a study at an athletic products plant, **35,8** percent of workers had a compensable repetitive trauma disorder. In some jobs within the plant,

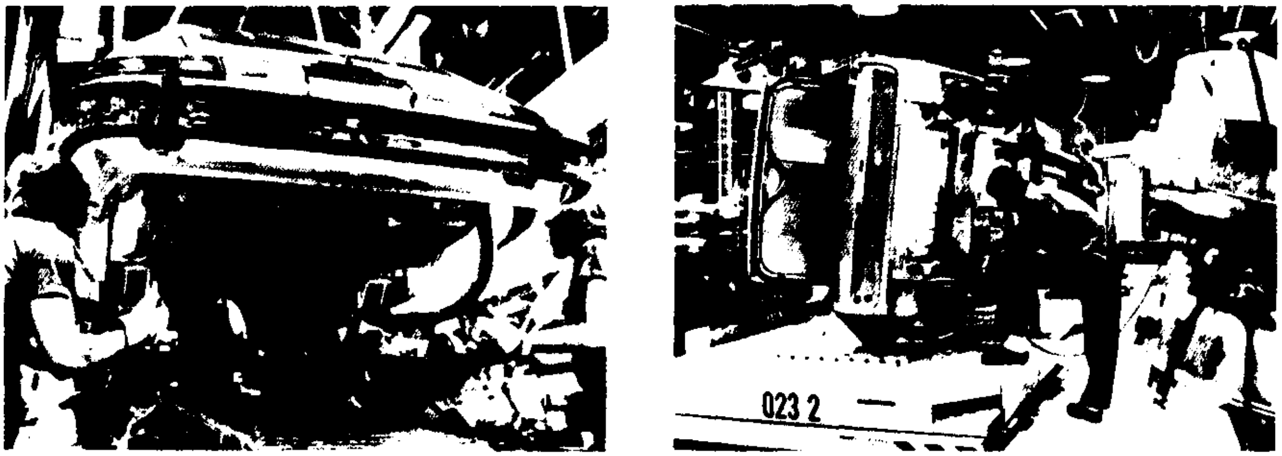


Photo credit: OSHA, Office of Information and Consumer Affairs

Work on an automobile assembly line can involve cramped working positions. A Volvo assembly plant in Kalmar, Sweden, uses "tipper trolley s." These trolleys hold the automobile bodies and can be tipped 90 degrees to allow work on the underside of the car

the rate was as high as 44.1 percent, and carpal tunnel syndrome occurred in 3.4 percent of the workers (21,23). Many industries claim that the incidence of CTS is increasing and is one of their most disabling and costly medical problems (60).

Symptoms

The onset of symptoms of CTS is usually insidious. Frequently, the first complaint is of attacks of painful tingling in one or both hands at night, sufficient to wake the sufferer after a few hours of sleep. Accompanying this is a subjective feeling of uselessness in the fingers, which are sometimes described as feeling swollen. Yet little or no swelling is apparent. **As** symptoms increase, attacks of tingling may develop during the day, but the associated pain in the arm is much less common than at night. Patients may detect changes in sensation and power to squeeze things but some people suffer severe attacks of pain for many years without developing abnormal neurological signs. Ultimately, in advanced cases, the thenar muscle at the base of the thumb atrophies, and strength is lost.

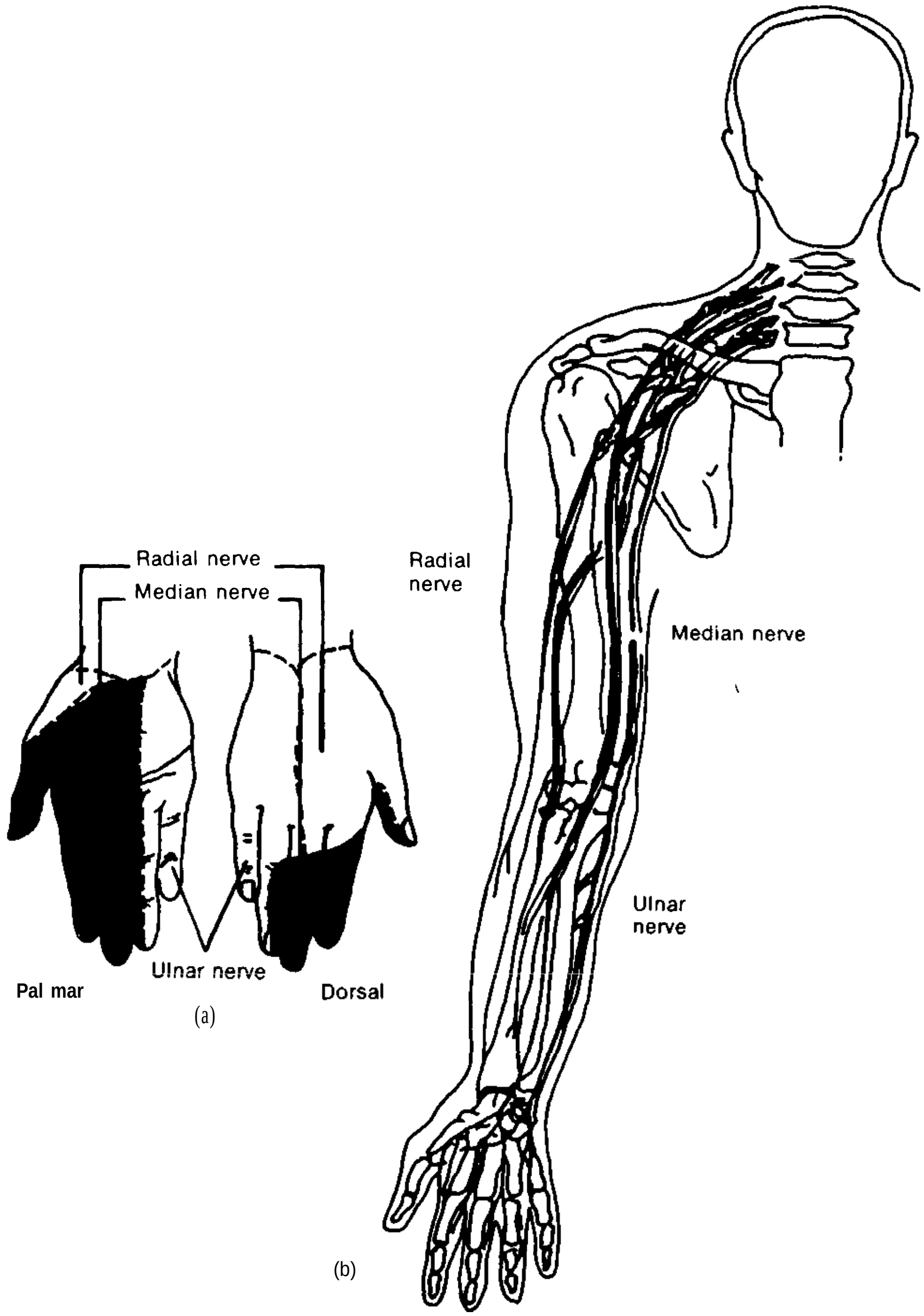
Compression of the median nerve is the immediate cause of CTS. The median nerve comes down the **arm,** through the wrist, then branches in the hand, supplying the thumb, forefinger, middle finger, and half the ring finger with nerves (fig. 7-3). The carpal tunnel itself, located in the wrist, is formed by the concave arch of the carpal bones and is roofed by the transverse carpal ligament (fig. 7-4). These structures form a rigid compartment through which nine finger tendons and the median nerve must pass. Any compromise of this unyielding space usually compresses the median nerve.

Risk Factors

Repetitive motions, such as those required in many jobs, is one of a number of risk factors for CTS. It is probably the most readily controllable cause, however. Certain diseases, acute trauma, congenital defects, wrist size, pregnancy, oral contraceptive use, and gynecological surgery all may contribute to the likelihood of developing CTS. Overall, the incidence of CTS is higher in women than in men, perhaps because of some of these risk factors.

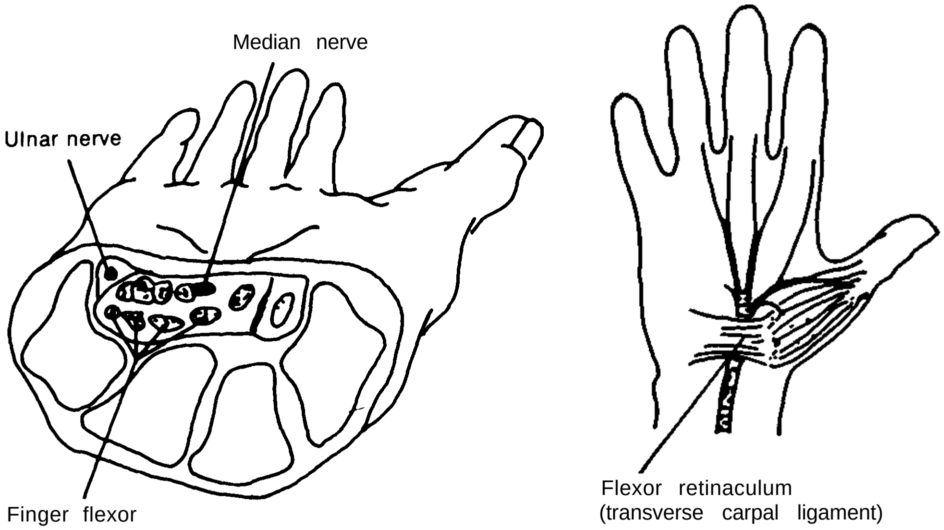
Occupational tasks responsible for the development of CTS include physical exertions with certain hand postures or against certain objects, and exposures to vibration or cold temperatures. Repeated and forceful up-and-down motions of the wrist (flexion and extension) (fig. 7-5), cause the finger tendons to rub on the structures forming the carpal tunnel. This constant rubbing can cause the tendons to swell (tenosynovitis), eventually putting pressure on the median nerve inside the carpal tunnel. The nerve itself is stretched

Figure 7-3.—Major Nerves in the Arm and Hand



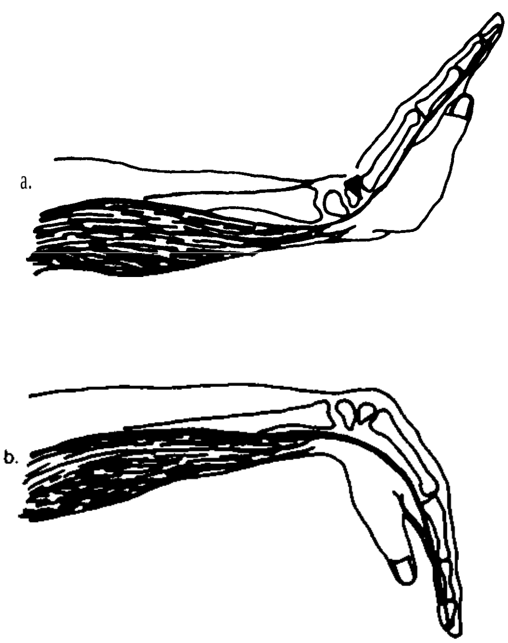
SOURCE (60)

Figure 7-4.--The Carpal Tunnel



SOURCE (60)

Figure 7-5.—Flexion and Extension of the Wrist



Bending the wrist causes the finger flexor tendons to rub on adjacent surfaces of the carpal tunnel.

SOURCE' (60)

by repeated exertions, and compressed between the walls of the carpal tunnel.

Forceful movements and the direction of the movement are only two of the underlying causes of tenosynovitis that can lead to CTS. The speed of movements and incorrect posture while working also are important (275). Median nerve compression also can be caused by tasks that require a sustained or repeated stress over the base of the palm (247). Examples include the use of screwdrivers, scrapers, paint brushes, and buffers.

Although the mechanism is not yet understood, low frequency vibration is a recognized risk factor for CTS (405). Vibration exposure may result from air- or motor-powered drills, drivers, saws, sanders, or buffers. Cannon (95) examined medical records at an aircraft company and found a strong association between CTS and use of vibrating tools.

Control of CTS

Control of CTS requires a two-pronged approach. The primary strategy to prevent cases is the use of ergonomic principles to modify handtools and to improve work-station design and work practices. Even a successful ergonomic program will not prevent all cases of CTS, however. The second important element, therefore, is a medical surveillance program. This is particularly important now when so little is known about the individual factors that cause some people to develop CTS. Thus far, no programs focusing on the medical evaluation of CTS seem to exist (60).

Ways are needed to identify the earliest sign of CTS, to evaluate progression of the disease, and to examine the role of predisposing risk factors. The purpose of such a medical surveillance program is prevention of advanced disease by instituting therapy at early stages.

Although medical surveillance for CTS is still in very early stages, ergonomic interventions have been remarkably successful where they have been instituted. Armstrong (21) describes the steps involved in developing appropriate controls. First, plants and specific departments within plants in which there is a documented high rate of CTS should be identified. Then each job should be systematically analyzed. Traditional time-and-motion studies, in which each movement or act is recorded, can be used. Each element of the job can then be checked against factors known to be associated with CTS development. These include posture of the hand and wrist, strength, stress concentrations over the palm, vibration, cold temperature, and the presence of gloves.

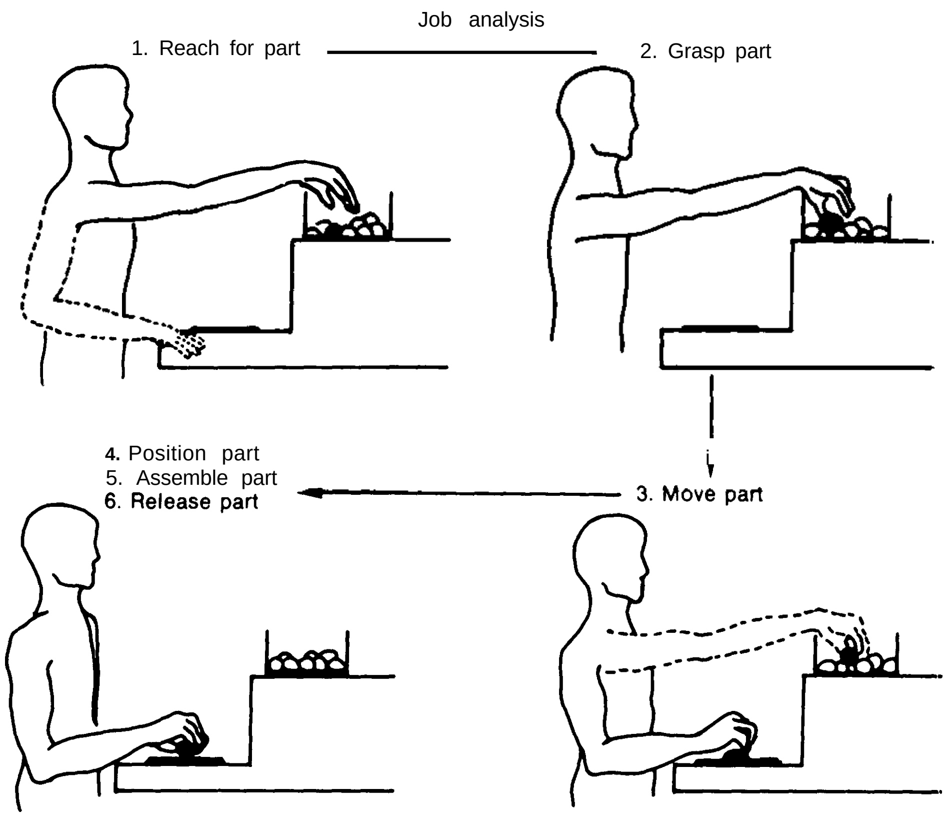
Armstrong presents a typical work task as an example. Figure 7-6 shows a worker taking parts out of a container and placing them on a conveyor. The six elements involved in this task are reach, grasp, move, position, assemble, and release. Reaching into the container involves wrist flexion and pinching, during which the worker's wrist is likely to rub on the edge of the box. The forearm is also likely to rub on the edge of the work bench while the part is positioned. The redesigned work station should reduce stress on the hand and wrist, and eliminate sharp edges. Good and bad designs for the container and the workbench with jig in this hypothetical case are illustrated in figure 7-7.

Powered handtools can also be designed and used to minimize stress. As illustrated in figure 7-8, good designs allow the work to be done with little or no flexion or extension of the wrist.

Armstrong and his colleagues have investigated cumulative trauma disorders in a poultry processing plant using the procedures described above. They discovered that workers in the "thigh boning" section had the highest incidence of cumulative trauma disorders of all departments. Thigh boning involves grabbing the thigh with one hand on a moving overhead conveyor, then making four cuts with the other to separate the meat from the bone. Each worker makes an estimated 15,120 cuts per shift. Ergonomic improvements to the process recommended by Armstrong and colleagues include training workers in the "proper work methods and knife maintenance to minimize the time and, hence, the distance that must be reached and force that must be exerted on the thigh." The work station could be modified to minimize the distance to be reached. The workers wear wire mesh gloves with rubber gloves underneath, which increase the force necessary to grasp the thigh and pull the meat away. Gloves should fit well, and the addition of barbs on the palm of the wire mesh glove might facilitate the hand actions. A new knife handle design, to reduce the force required to hold the knife and make the cuts—e.g., that pictured in figure 7-9—is suggested (22). Such a design would also minimize wrist flexion.

A high incidence of repetitive trauma disorders, including carpal tunnel syndrome, in a telephone assembly plant prompted management to consider how to prevent future cases. McKenzie and colleagues (299) noted the highest rates in areas using vibratory air screwdrivers, and in jobs requiring repetitive grasping, squeezing, or clipping motions. Ergonomic changes recommended included modifying the screwdrivers with sleeve guards and changing work positions to minimize hand and wrist stress. The changes were instituted with almost immediate results: from 2.2 percent annual incidence of repetitive trauma disorders in 1979

Figure 7-6.-Job Analysis: Assembly Tasks



• **Assembling parts on a moving conveyor can be described by a series of six elements,**

SOURCE (21)

to 0.79 in 1981. Lost and restricted workdays fell from 5,471 in 1979 to 1,111 in 1981, and further reductions were expected in subsequent years.

Back Disorders

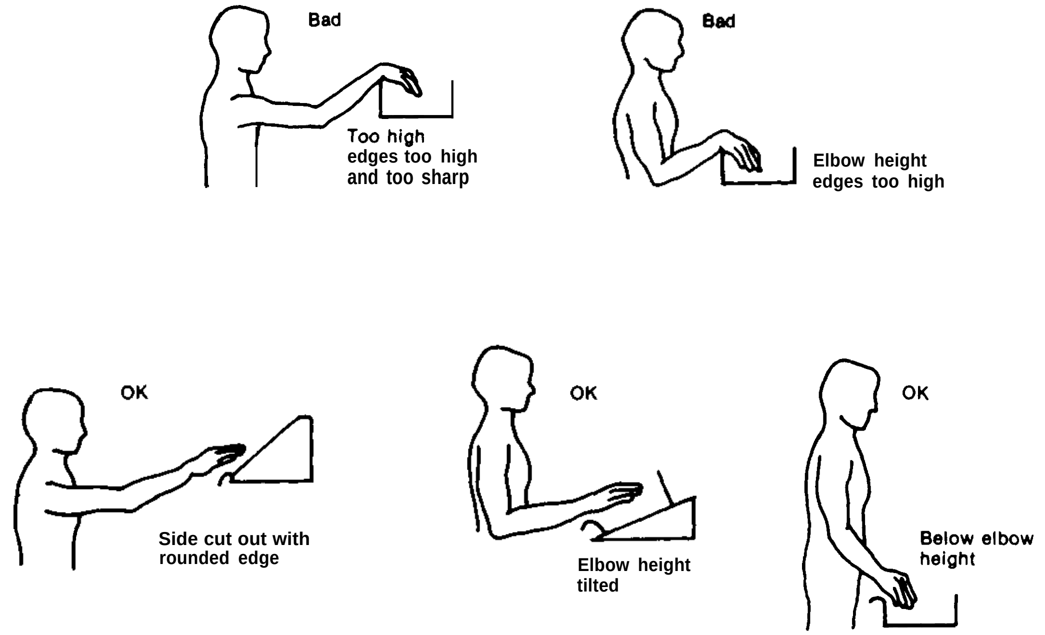
The Bureau of Labor Statistics completed a survey of workers who had incurred back injuries while lifting, placing, carrying, holding, or lowering objects (605). Of the 900 workers included in the tabulated results, more than 75 percent were lifting at the time of the injury, Surprisingly, the back injuries were concentrated in younger workers; almost 75 percent occurred in 20- to 44-year-olds. Both the weight and the bulkiness of the lifted objects were often associated with injuries. About half the injured workers had received some instruction about proper lifting.

Manual lifting presents a risk of overexertion injuries and cumulative damage to the soft tissues around the spine. Overexertion injuries to the back constitute the largest single category of workers' compensation claims, amounting to 25 to 30 percent of all disability cases Lower-back injuries are often extremely painful and significantly diminish the quality of life of the afflicted workers. Many of these can be prevented by job and equipment redesign.

The conventional wisdom about how to lift something is to squat, pick up the object, and, while keeping the back straight, lift straight up

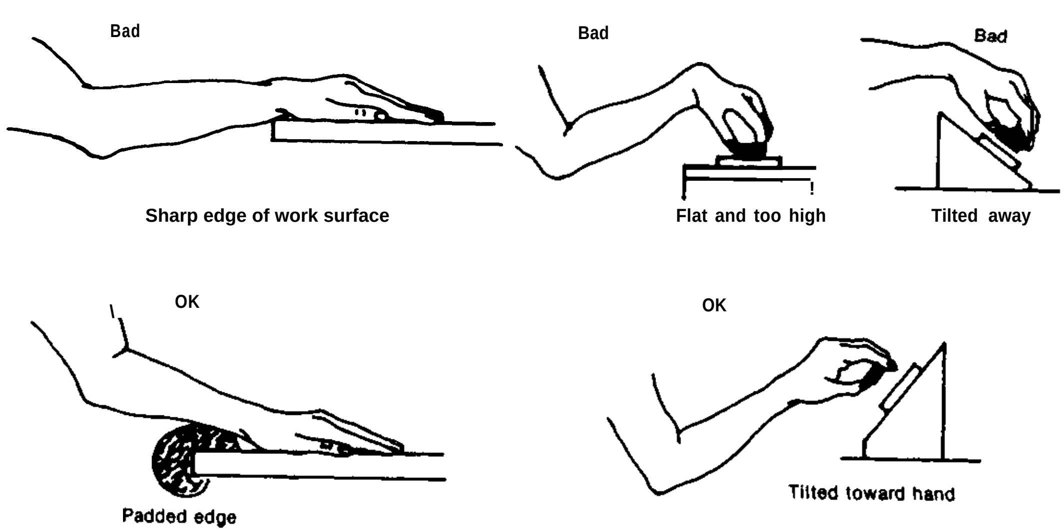
Figure 7-7.—Good and Bad Designs for Containers and Workbenches

a. Container



Containers should be designed so that workers can reach all locations without flexing their wrist. All edges that come into contact with the worker should be well rounded.

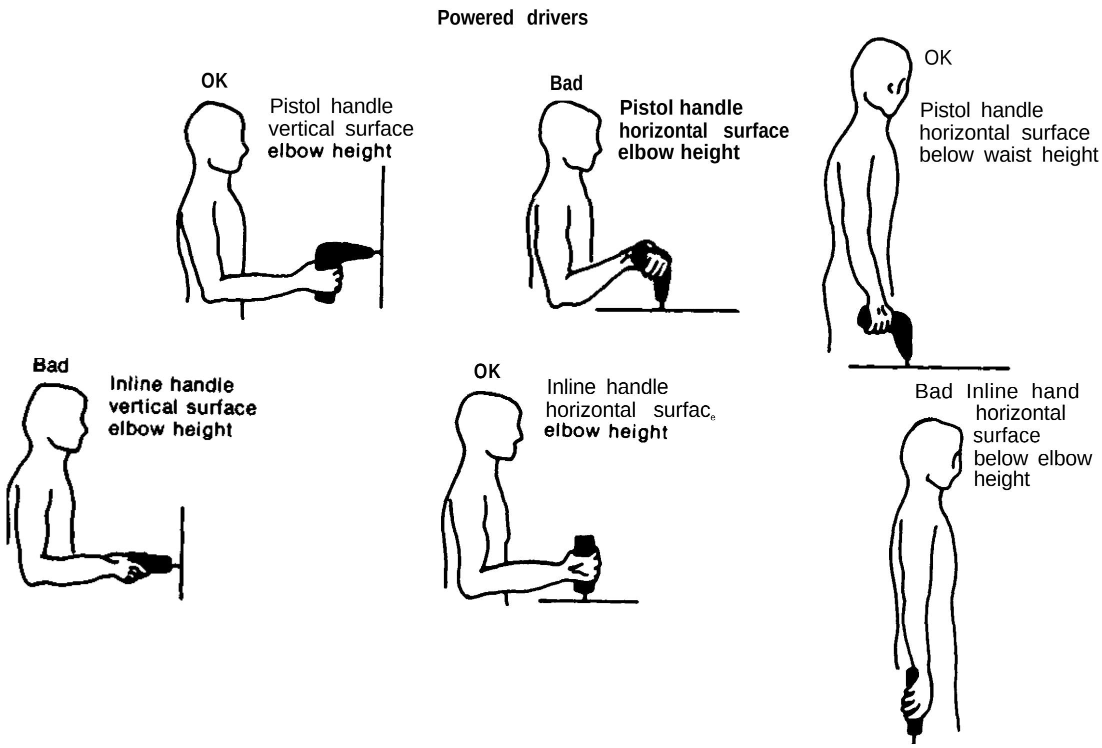
b. Workbench and jigs



Jigs should be located and oriented so that parts can be assembled without flexing the wrist.

SOURCE: (21)

Figure 7-8.—Good and Bad Designs for Powered Drivers



Wrist posture is determined by the elevation and orientation of the work surface with respect to the workers and the shape of the tool.

SOURCE: (21)

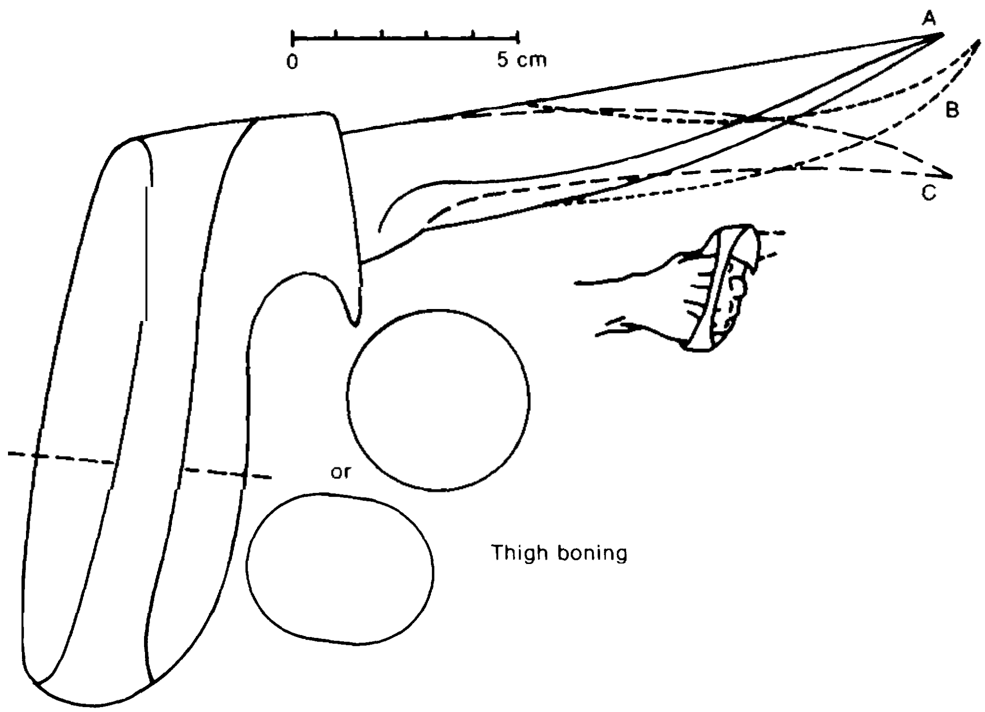
with the legs. This procedure is thought to prevent injury to the back. In many cases this procedure is justified, but there are many other situations where it is not.

Work-Load Evaluation

There are at least four basic sets of criteria for determining acceptable work loads: biomechanical, physiological, psychophysical, and epidemiological (453). Biomechanical criteria are based on pressures and stress exerted on the body, particularly on the spinal column. Limits of tolerance have been developed by observing damage to cadavers when pressure is applied. Physiological criteria are primarily metabolic, e.g. oxygen consumption and heart rate. The psychophysical method incorporates workers' perceptions and sensations into the assessment of work load for both static and dynamic strength. Epidemiologic criteria are derived from aggregate data concerning the incidence, severity, and distribution of low back pain. These four approaches can be integrated and guidelines established with input from each. The National Institute for Occupational Safety and Health has developed recommendations in this way.

Maximum acceptable work loads are often expressed in terms of the weight and frequency of lifting. For instance, 75 percent of the industrial male population can lift a 13-kilogram box of fixed proportions every 5 seconds, and a 34-kilogram box every 30 minutes without triggering or aggravating low-back injury symptoms.

Figure 7-9.—A Knife Designed to Reduce Cumulative Trauma Disorders in Poultry Processing



One possible knife handle with three blades for reduced wrist deviations. The handle is designed to reduce the tendency for the knife to fall out of the hand in thigh boning.

SOURCE (22)

There is great practical significance to having very specific work-load recommendations. They can be used both for determining that a task is unacceptable and as guidelines for redesigning the task. Recognition of a problem often occurs only after a number of compensation claims have been awarded, triggering investigation. Insurance companies have a direct incentive to cut down on compensable back problems. For **case** histories of task evaluation and redesign carried out by the Liberty Mutual Insurance Co., see boxes D and E. According to Snook (453), "most industrial tasks with unacceptable work loads can be modified for less than the average cost of a single low back compensation claim."

APPLYING ERGONOMICS TO VDT DESIGN

The first reports from Europe concerning potential adverse health effects associated with video display terminals included accounts of many reported musculoskeletal and visual problems. Early U.S. studies of potential VDT hazards also concluded that there were no known radiation hazards and that the real hazards were ergonomic problems: musculoskeletal problems, visual problems, and fatigue. Poor design of equipment or poor job design may produce such problems.

Box D.—Ergonomics—Task Evaluation and Redesign

This case history involves back injuries sustained by employees of a drywall contractor. About eight employees work on an average job undertaken by this contractor. They are required to manually lift and carry Sheetrock (96" x 4') to the area where it is installed. There were five compensable back injuries reported during the year preceding the installation of control measures.

The task was evaluated at several job sites. From observation and weight measurements it was determined the exposure could be reduced through the use of carts to carry the drywall. For evaluation purposes a cart was fabricated, which would hold up to 20 sheets, with 2 fixed and 2 swivel wheels of 4-inch diameter. Measurements of initial and sustained forces were made, using 9, 15, and 20 sheets. This revealed that each load should be limited to 15 sheets, which could be handled by 85 percent of the male population without overexertion. Further study showed that by increasing the wheel diameter to 6 inches the population percentage would be increased to a point where employees could handle up to 20 sheets (fully loaded) on the cart. It was also determined that all wheels should be of the swivel type, which would allow the cart to turn corners much more easily.

Management, who actively participated in the [illegible], agreed to fabricate carts with 6-inch [illegible]. The exposure to back injury was [illegible] of the task increased. [illegible] of the carts during October [illegible] back injuries have been reported.

[illegible] (675).

Box E.—Ergonomics-Task Evaluation and Redesign

This case history involves back injuries to material handlers in the packing department of a metal office equipment and desk accessory manufacturer. The six female material handlers are required to manually lift boxes of various sizes and weights from a conveyor and stack them on wooden pallets. There were six compensable back injuries reported between February 1980 and September 1982, with a cost of $131,415.

Boxed products are transported by belt conveyors to the position of the material handler, where they are taken off the line and lowered and/or lifted onto pallets. Due to the wide variety of Sire, shapes, and weights, the boxes handled vary in weight from a pound to large bulky boxes weighing 50 pounds. Full pallets are taken by forklift to a warehouse.

A task evaluation was completed. The product being handled at the time of the evaluation weighed 45 pounds, measured 5' x 1' x 2', and was lowered a maximum of 31 inches or lifted 29 inches; the task was performed once every 1.2 minutes. It was determined that less than 10 percent of the female population could be expected to perform this task without overexertion.

The recommendation was to eliminate the manual handling task through the use of an automatic palletizer. The palletizer would automatically remove the boxed products from the conveyor belt and stack them on the wooden pallets.

Management agreed to this approach and installed automatic palletizers during December 1982. As the manual material handling task has been eliminated, there have been no compensable back injuries reported.

Source: (675}.

Musculoskeletal problems among office workers range from discomfort to pain and medical disability. The back, neck, and shoulders are the most frequent sites of problems. Table **7-2** summarizes the results from several studies of VDT workers. There is general agreement that musculoskeletal problems are associated with poor working positions, repetitive motions, and the length of work time without a break.

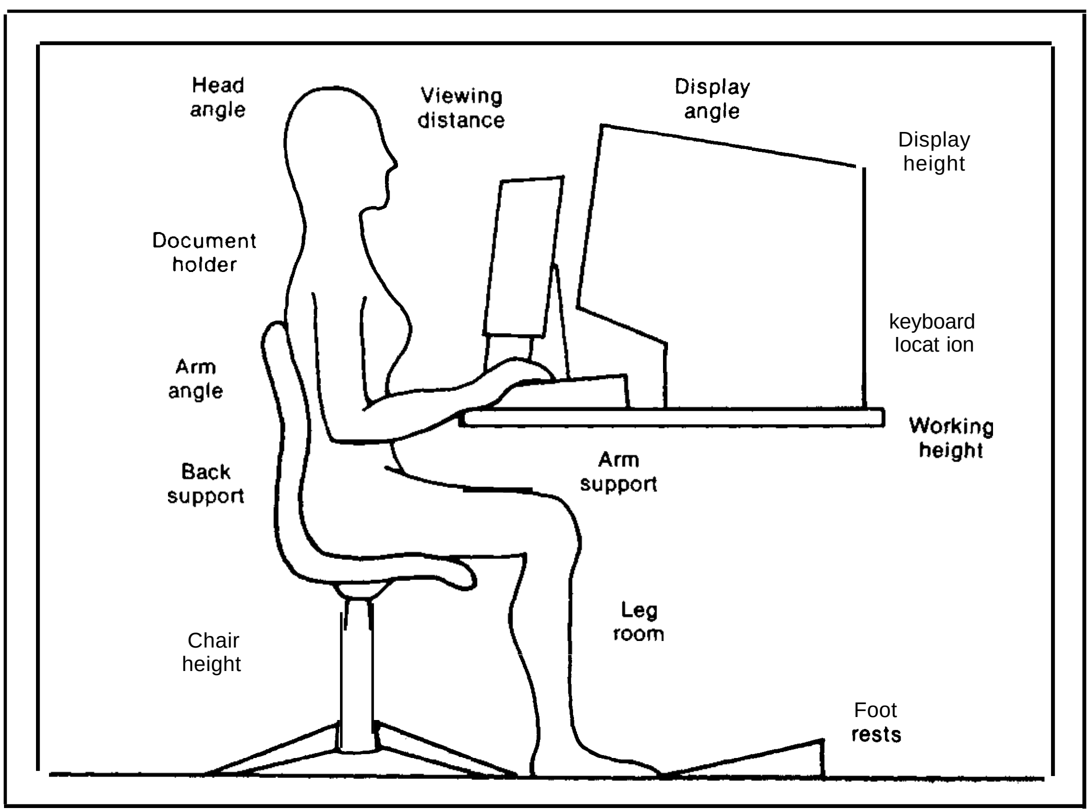
Figure **7-IO** illustrates risk factors contributing to musculoskeletal problems associated with VDTs, including equipment design (VDTs, work stations, and chairs) and job design (constrained working positions, repetitive work, and inadequate rest breaks). Any of these can be changed. The keyboards and screens of many early VDT work stations were fixed relative to each other and the height of the work station was not adjustable.

Table 7-2.—Frequency of Reported Musculoskeletal Problems From Various Studies of VDT Workers

	Percent reporting frequent or daily problems[a]		
Study/type of worker	Neck-shoulder	Back	Arm-hand
Arndt, 1980:			
Telephone operator[b]	8-17	15	12
Service assistant	9-14	14	6
Accounting clerk[b]	7-1o	10	5
Laubli, et al., 1980:			
Data-entry VDT operator.	11-15	N.A.	6-15
Accounting machine operator	3-4	N.A.	8
Conversational VDT operator.	4-5	N.A.	7-11
Typist.	5	N.A.	4-5
Traditional office worker	1	N.A.	1
Hunting, et al., 1981:			
VDT operator	6-12	6-10	6-12
Typist , ... ,	6-12	6-10	6-10
Traditional office worker , ...	2-5	2-5	2-5
Canadian Labour Congress, 1982:			
VDT operator	10-12	10-15	2-3
Non-VDT operator	7-8	9-14	4
Sauter, et al., 1983:			
VDT operator	24-34	27-35	3-4
Non-VDT operator	19-28	22-29	4-6

[a]Results include percent reporting almost daily, frequent, often constant Ranges represent multiple Questions
[b]Approximately 33 percent use VDT
N A = Not available
SOURCE (25)

Figure 7-10.— Potential Ergonomic Risk Factors Associated with VDT Design



SOURCE (25)

Equipment can be redesigned and made to fit the various sizes of people. Many manufacturers now **offer, usually at a higher price, office furniture and equipment that has been "ergonomically de**signed." Although **this equipment has** been **advertised as being vastly superior** to **ordinary office equipment,** its **biggest advantage from an** ergono**mic perspective** is the **simplest—it** is **adjustable. Job redesign** to **reduce repetitiveness and** to **alleviate constrained postures** is also **possible. Finally,** rest **breaks can** be **instituted** to **reduce fatigue** from working in one **position for long periods of time. Rest breaks often result in increased productivity** as well as **fewer musculoskeletal complaints (25).**

Visual problems reported among VDT users **include eyestrain, burning/itching eyes, blurred** vision, double vision, color fringes, and deterioration of acuity (table 7-3). A recent review by a National Research Council panel (321) concluded, however, that there was no evidence that the use of VDTs led to visual system problems different from symptoms reported by workers engaged in other tasks involving intensive close work.

The problems reported are related to the visual demands of VDT work. The intensity and duration of visual demands, the quality of the VDT image, and illumination are important. VDTs have often been manufactured and introduced in workplaces without sufficient attention to the these factors. The National Research Council (321) report notes that "[i]n many instances . . . VDTs have been designed without attention to existing scientific data on image quality, and many VDTs on the market do not provide the legibility of high-quality printed material." Snyder (454) has estimated that nearly half of all VDTs now in use are improperly designed for intensive office use.

VDTs have usually been placed into workplaces without consideration of the available lighting. There has been a tendency to believe that more light creates a better environment for office workers. The result is that many offices are overlit or too bright for certain activities. This is a particular problem in offices with VDTs, Increasing the light level, up to a point, improves contrast and visibility for most office tasks. VDTs, however, **emit** their own light and increasing illumination

Table 7-3.--Frequency of Reported Visual Problems From Various Studies of VDT Workers

	Percent reporting frequent problems[a]		
Study/type of worker	Eyestrain	Burning, itching, irritation	Blurring, double vision
Holler, et al., 1975:			
VDT user	**21**	**N.A.**	**7**
Arndt, 1980:			
Telephone operator[b]	**8**	**N.A.**	**1-5**
Service assistant	**9**	**N.A.**	**1-4**
Accounting clerk[b]	**6**	**N.A.**	**1-3**
Laubli, et al., 1980:			
Data-entry VDT operator	**20**	**N.A.**	**N.A.**
Conversational VDT operator	**28**	**N.A.**	**N.A.**
Typist	**18**	**N.A.**	**N.A.**
Traditional office worker	**5**	**N.A.**	**N.A.**
Canadian Labour Congress, 1982:			
VDT operator	**N.A.**	**9-17**	**13-16**
Non-VDT operator	**N.A.**	**7-8**	**8-9**
Sauter, et al., 1982:			
VDT newspaper editor	**40**	**43-46**	**N.A.**
Non-VDT newspaper editor	**17**	**17-22**	**N.A.**
Sauter, et al., 1983:			
VDT operator	**24**	**19-27**	**5**
Non-VDT operator	**20**	**21-23**	**5**

[a]Frequency of problems reported daily, constantly, often, very often, frequently.
[b]Approximately 33 percent used VDTs.

N.A. = Not available.

SOURCE: (25).

levels actually reduces the contrast and visibility of the screen image.

It is frequently suggested that the general lighting level in a room be somewhat reduced for screen-based work. An alternative recommendation is to provide even lower levels, with supplementary task lighting for reading text from paper and for other non-VDT work. Other illumination problems that must be addressed concern reflections off the VDT screen, glare, and contrast. There are techniques for reducing and eliminating most of these problems and for enhancing the ability of each worker to adjust the environment of the VDT to fit his or her needs. Unfortunately, these techniques have very often been ignored by manufacturers, vendors, and employers (25).

SUMMARY

Ergonomics —techniques for examining worker-machine interactions and design of machines to fit workers better—can be important in reducing injuries and discomfort from repetitive motions and other work activities. Information ergonomics involves workers' receipt of sensory information and how it is processed; physical ergonomics deals with worker body size, strength, and stresses while working. Generally, when faced with a problem in the workplace, ergonomists systematically analyze the job using biomechanical, physiological, psychophysical, and epidemiological analyses; each job element is compared with factors known to be associated with overt or repetitive trauma injuries. Changing work practices, tools, and machine design and redesigning plant layout are among the principal ergonomic solutions. There are many examples of the incidence of carpal tunnel syndrome and back disorders, two common repetitive trauma injuries among industrial and office workers, being reduced through the use of ergonomic designs. In addition to preventing overt and cumulative trauma injuries, ergonomic design has been shown to increase worker productivity and efficiency by making the machine or tool more closely fit the worker and the worker's capabilities.