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# An analysis of work postures of manual wheelchair users in the office environment

**Betty S. Troy, MS; Rory A. Cooper, PhD; Rick N. Robertson, PhD; Thomas L. Grey, MS**

*Department of Biomedical Engineering, California State University, Sacramento, CA 95819-6019; Rehabilitation Research and Development Center, Department of Veterans Affairs Health Care System, Palo Alto, CA 94304; School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, PA 15261; Division of Physical Medicine and Rehabilitation, University of Pittsburgh Medical Center, Pittsburgh, PA 15213; Human Engineering Research Laboratories, Highland Drive VA Medical Center, Pittsburgh, PA 15206*

**Abstract**—The goal of this project was to examine the difficulties manual wheelchair users experience in office activities and ascertain whether such problems may be due to poor relationships between the equipment and the users. Sixty adult manual wheelchair users completed a questionnaire about problems encountered in office activities. Filing and writing were the most problematic activities for this group. Phase II of this study consisted of videotaping four subjects performing each activity in their personal office environments, and having them complete a second questionnaire on body-specific locations of discomfort. Videotaped postures and reports of discomfort were matched to determine the existence of poor equipment-user relationships. In filing, low back pain may have been due to bending forward to access lower drawers while seated. For writing, an inappropriate desk-wheelchair relationship that required subjects to bend forward with their arms on a surface that was too high may have caused back, shoulder, and neck discomfort.

**Key words:** *discomfort, ergonomics, human factors, manual wheelchair users, office environment, work postures.*

## INTRODUCTION

Numerous researchers have studied nondisabled populations performing seated work in office environments: information of this nature is readily available. On the other hand, extensive literature searches of the last 15 years on Medline® and Index Medicus® revealed only two articles reporting research that specifically addressed work postures of wheelchair users in the office environment. Research in this area is extremely scant and it is warranted, particularly in view of relatively recent changes made by the U.S. legislature regarding work environments for persons with disabilities and of increases in the number of workers in the workforce with disabilities. It is possible that similarities may exist between seated work of nondisabled workers and wheelchair users in the office environment, yet researchers have found that physical anthropometric differences are apparent between these two populations (1,2). Such differences may affect the access to work of a wheelchair user in environments that are designed based on data from nonimpaired populations.

### Nondisabled Populations and Common Problems of Seated Work

Seated activities are classified into three types of positions: forward leaning, erect, and reclined. Forward leaning is typical during activities requiring reaching, writing, drafting, drawing, and small equipment repair.

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Address all correspondence and requests for reprints to: Betty S. Troy, MS, VA Palo Alto Health Care System, Rehabilitation Research and Development Center (153), 3801 Miranda Ave., Palo Alto, CA 94304-1200.

Erect postures are sometimes adopted during computer use and typing. Reclined postures are assumed for computer use, conferencing, television viewing, and driving. A person's posture within these positions is largely determined by the placement of the visual target, which affects the posture of the head and, therefore, the neck and trunk. If the arms are involved in the task, the arms and shoulders are also affected (3–5). Each of these postures is adopted variably during the typical workday.

Frequently sustained postures, particularly awkward positions, can cause discomfort and musculoskeletal problems. Surveys of 1,967 nonimpaired Federal Aviation Administration (FAA) air traffic controllers, who spend most of their work day in the seated position, revealed the following: overall, 29.7 percent reported discomfort in the lower back, 16.3 percent in the buttocks, 14.6 percent in the upper back, 9.9 percent in the back of the neck, 6.4 percent in the upper legs, and 5.4 percent in the lower legs and feet (6,7).

Different factors contribute to discomfort at each body region. Low back pain (LBP) is often caused by the tendency of the pelvis to tilt backward in the seated position, decreasing the natural lordotic curvature of the lumbar spine. This tilt has been found to be reduced by use of a lumbar support (4) or by tilting the seat pan forward 15 to 20° (4,5,8). Thus, the lumbar spine is encouraged to retain its natural lordotic curvature while sitting, thereby decreasing musculoskeletal stress in this region. In their study of workers in office chairs, Bendix, Winkel, and Jessen found that subjects preferred a freely tiltable seat as opposed to a forward or backward tilting seat in preventing LBP, as this provided them the freedom to change positions (9). Subjects tended to become more restless as sitting times increased.

In sitting, most of the body weight is supported by the buttocks, particularly through the ischial tuberosities. Pressure at these points is enough to occlude sufficient blood flow to the overlying skin, causing tingling, numbness, and discomfort. As a result, if the person is able, weight is shifted off these tissues to allow blood flow to resume (10).

Shoulder and upper back problems are often caused by performing work above the elbow level (11–15). The worker usually flexes the elbows or elevates and abducts the shoulders to be able to handle the work. For desk work, a shoulder abduction angle of 15 to 20° or less and a flexion angle of 25° or less should be attempted (4).

Discomfort in the neck is often caused by increased muscular activity required to support the head while it is craned over to focus on objects on a flat surface. The need to hold the head in this position can be decreased by changing the position of the focal object, for example, by setting papers from which a typist is typing onto a document holder placed next to the typewriter (11,14).

Chair height affects the level of support provided for the thighs. If a chair is too low, the knee flexion angle becomes less than 90° and the thighs do not support weight, concentrating it instead on the ischial tuberosities. On the other hand, if a chair is too high and the feet do not touch the ground, increased pressure is supported by the popliteal region, decreasing circulation to the feet and causing swelling and discomfort. It is ideal to have weight distributed between the buttocks, thighs, and feet. Chair height should be adjusted so that the feet rest firmly on the floor or footrest, with thighs and buttocks evenly supported by the seat (4,9).

**Table 1.**
"Poor Postures" versus probable sites of symptoms.

| Poor Postures | Probable site of pain or other symptom |
|---|---|
| Standing (particularly a pigeon-footed stance) | Feet, lumbar region |
| Sitting without lumbar support | Lumbar region |
| Sitting without support for the back | Erector spinal muscles |
| Sitting without good footrests of the correct height | Knee, legs, and lumbar region |
| Sitting with elbows rested on a working surface that is too high | Trapezius, rhomboideus, and levator scapulae muscles |
| Upper arm hanging unsupported out of vertical | Shoulders, upper arms |
| Arms reaching upward | Shoulders, upper arms |
| Head bent back | Cervical region |
| Trunk bent forward; stooping position | Lumbar region; Erector Spinae Muscles |
| Lifting heavy weights with back bent forward | Lumbar region; Erector Spinae Muscles |
| Any cramped position | The muscles involved |
| Maintenance of any joint in its extreme position | The joint involved |

Note: Table 1 adapted from van Wely (17).

According to Graf, Guggenbuhl, and Krueger (16), work activities that have a higher incidence of musculoskeletal disorders require less frequent and less marked postural change. In their study, they found the following types of work to produce high-to-lower risk of musculoskeletal injury, respectively: video display unit operation, cashier operation, assembly of small devices, and office work.

Van Wely (17) studied 50 repetitive strain injury patients at their workplaces while performing their jobs. The patients had each been referred to the study by their physicians, of whom subjects had sought medical care for discomfort of specific body regions due to work. Van Wely developed a table of bad postures with corresponding probable sites of symptoms for each posture (**Table 1**). For example, sitting without a lumbar support would have been likely to result in pain at the lumbar region of the spine. A team of three experts on work postures, without prior knowledge of patient work discomfort, analyzed subject work postures, identifying potentially detrimental positions assumed by them. Findings verified that specific postures were likely to have been a probable cause of discomfort at specific sites, as matched in van Wely's table. Corlett and Bishop also reported that using van Wely's chart is an accurate method for identifying poor postures that give rise to discomfort (18), and Torner et al. found that discomfort is a better indicator of potential musculoskeletal injury than clinical methods (19).

## Wheelchair Office Environments

The American National Standards Institute (20) pointed out that when a person uses a wheelchair, his or her spatial requirements change and are no longer what is considered to be "the average." They become shorter, wider, and need a wider turning circle. Although an office may be designed for seated workers, it may not necessarily be accessible for workers seated in wheelchairs. Without accessibility, wheelchair users are unable to perform their work in their offices.

A multidisciplinary approach is essential in finding solutions for wheelchair users who would otherwise be hindered from performing their jobs in environments that are not appropriately modified (21). First, a seating technologist, an occupational therapist, or engineer specializing in wheelchair seating should recommend appropriate fitting with wheelchair seating and positioning equipment for the user, giving special consideration to stability, mobility, postural support, skin integrity, function and comfort (20). Second, a rehabilitation engineer or an occupational therapist specializing in workspace design should make appropriate modifications and prescribe assistive devices needed in the workstation. Third, an architect should provide the appropriate accessibility modifications that may be required in the office building and common areas.

Abdel-Moty and Khalil (23) have presented a computerized method capable of matching the needs of ambulatory people with disabilities, including wheelchair users, to the physical workplace. General information about the person, anthropometric measurements, wheelchair dimensions, and workplace information are entered into a computer. The application takes into consideration the wheelchair and its user, the tasks to be performed, and the physical workplace and outputs recommendations for workplace configuration.

A large part of workspace design is based on anthropometric data. However, anthropometrics of populations of people with disabilities have been reported to be significantly different from those of nonimpaired populations. Using 14 anthropometric measurements, Goswami, Ganguli, and Chatterjee compared 61 Indian men with spinal cord injury (SCI) or poliomyelitis to 140 nonimpaired men and found that growth of affected parts was reduced and some acquired deformity of the unaffected limbs was apparent (1). A significant difference was found between body dimensions of the persons with disabilities versus the control groups. Similar findings were reported by Nowak in a study of workspaces for subjects between the ages of 15 and 18 with disabilities of the lower limbs, who required wheelchairs (2). Because of these differences, it is important to design workspaces using anthropometric data from the appropriate populations (24).

## Legislative Changes

Two legislative events have been instrumental in improving the rights of workers in the United States who have disabilities. First, Section 504 of the Rehabilitation Act of 1973 prohibits discrimination against qualified workers by any program receiving federal funds, by executive agencies, and by the United States Postal Service, based on handicaps (25,26). Second, Title I of the Americans with Disabilities Act of 1990 requires that employers provide reasonable accommodation for employees who need them to perform essential functions of their jobs (27). In addition, the percentage of workers in the United States with disabilities has increased from 8.6 percent in 1988 (28) to 12.9 percent in 1991[1].

[1]U.S. Department of Commerce, Bureau of the Census. 1991 Survey of income and program participation (unpublished data).

### The Need

Information on workers with disabilities in work environments is currently extremely scant. One reason may be due to the variability in the definition of performance between—and even within—disabilities. This makes it difficult to design work environments without information upon which to base modifications. Since employers are required to make modifications for employees with disabilities, there is a need for information on which ones would be most effective.

Many researchers have studied unimpaired populations performing seated office work. It has been found that a significant difference in anthropometrics exists between disabled and nondisabled populations (1,2). Accessibility and comfort needs of disabled populations may not necessarily be met in work environments of unimpaired populations. There is a need for further understanding of the relationship between the manual wheelchair, its user, the office environment, and the difference in work positions and discomfort imposed on the users as compared to those experienced in nondisabled work environments.

### Research Questions

The objective of this study was to answer the following questions:

1. Which office activity, if any, do manual wheelchair users feel is most problematic?
2. In what body regions do subjects experience discomfort due to performing this activity?
3. What kinds of physical problems are apparent in the relationship between office equipment, manual wheelchairs, and their users that are causing subjects to feel discomfort while performing this activity?

This study assumed that subjects are properly fitted in their wheelchairs and seating systems, and have sufficient architectural access to their workplaces. Workstation configuration was the area of focus.

## METHOD

### Phase I

A questionnaire was developed to determine whether any office activities (e.g., using the computer, writing, using a copy machine, reading, using the telephone, and filing) cause difficulty for manual wheelchair users. Subjects were asked how often they performed each activity and whether feelings of discomfort and fatigue were felt due to each. Questions were asked in several ways within the survey to verify the results (29).

Copies of this questionnaire were mailed to 140 potential subjects throughout the United States. Subjects were located via word of mouth, the Paralyzed Veterans of America (PVA), and random choice from the *Resource Directory of Scientists and Engineers with Disabilities* (30). Seventy responses were received; 10 were excluded from the study for one of the following reasons: subjects indicated that they transferred out of the wheelchair into an office chair at work, that they did not work in an office environment, did not use a manual wheelchair in the workplace (i.e., used a power wheelchair or scooter instead), or the subject was indicated as deceased. Sixty responses met the subject criteria for this study: all were from manual wheelchair users at least 18 years of age who worked in an office setting on a regular basis while seated in their wheelchairs.

More responses were obtained from those who were contacted through word of mouth and PVA (76.7 percent), as compared with those who were selected from the *Resource Directory* (23.3 percent). Fifty-two of the respondents were male and 8 were female; 57 percent were between 36 and 50 years old, 18 percent were under 35, and 25 percent were over 50. Half of the subjects indicated that they were diagnosed with paraplegia, 13.3 percent with quadriplegia, 15 percent postpolio syndrome, 1.7 percent multiple sclerosis, 3.3 percent amputation, 1.7 percent spina bifida, 3.3 percent cerebral palsy, and 11.7 percent had other diagnoses (nonclassified SCI, multiple sclerosis/amputation, neuropathy). All subjects had at least enough upper body strength and range of motion to propel a manual wheelchair on a daily basis.

According to van Wely (17), level of comfort is an indication of how potentially detrimental a posture can be. The more discomfort felt, the worse the posture is likely to be. If the posture is held repeatedly or intensely, severe damage to muscles, bones, or tendons may result. Also, prolonged, frequently sustained, static postures (particularly awkward ones) result in fatigue and discomfort and often contribute to various musculoskeletal disorders and work inefficiency (4,31,32). Based on these findings, five factors were chosen to be considered in determining which activities were most problematic from the responses to Questionnaire 1:

- performing activity at least 4 hours per day (perform activity for at least half of work day)

- feeling tired easily (feel they cannot perform activity for long periods of time)
- feeling physical discomfort (pain, headaches, numbness, dizziness)
- feeling that there should be an easier way to perform the activity (indicating a desire for change)
- identifying the activity that causes the most discomfort.

The responses to Questionnaire 1 were then tabulated and evaluated based on these characteristics. Two activities, filing and writing, received a very high response rate in four out of the five characteristics and were chosen to be analyzed further in Phase II.

## Phase II

Fifteen of the 60 subjects who completed Questionnaire 1 volunteered to participate in the second phase of the study. Seven (A, B, C, D, E, F, and G, respectively) were chosen as subjects, based on tasks that were indicated to be problematic, the geographical location of the subjects, and their availability. Due to limited funds for travel, only those within a reasonable driving distance of the researchers were chosen. Three subjects (E, F, and G) indicated feeling physical symptoms due to writing, three (A, B, and C) due to filing, and one (D) felt symptoms from both. Therefore, with D performing both tasks, we studied four subjects at each activity, filing and writing, during Phase II (see **Table 2**).

**Table 2.**
Summary of subjects tested in Phase II.

| Subject | Diagnosis | Lower Limb Sensation & Motor Control | Activities Tested | Regions of Discomfort Reported |
|---|---|---|---|---|
| A | Cerebral Palsy | Yes | Filing | Lumbar Spine |
| B | Post Polio Syndrome | Yes | Filing | Lumbar Spine, Erector Spinae, Outer Thighs, Trapezius, Rhomboideus, Levator Scapulae, Shoulders, Upper Arms, Wrists |
| C | T5 Complete Spinal Cord Injury | No | Filing | Trapezius, Rhomboideus, Levator Scapulae, Shoulders, Upper Arms, Left Elbow, Ventral Side of Right Elbow |
| D | T10 Complete Spinal Cord Injury | No | Filing | Lumbar Spine |
| | | | Writing | Upper Back, Neck, Erector Spinae, Trapezius, Rhomboideus, Levator Scapulae |
| E | Multiple Sclerosis | Yes | Writing | Lumbar Spine, Upper Back, Neck, Shoulders, Sides of Back at Lower Ribs |
| F | Multiple Sclerosis/ Amputation | Yes | Writing | Lumbar Spine, Left Shoulder, Left Elbow, Left Hand, Neck |
| G | T12 Incomplete Spinal Cord Injury | Yes | Writing | Lumbar Spine, Knees, Legs |

In this portion of the protocol, the relationship between discomfort of body regions and poor work postures was studied.

We used a combination of observation and a second questionnaire to locate sites of discomfort. The subjects were videotaped performing their designated activities for approximately 15 minutes at their worksites. A video camera was placed on a tripod approximately perpendicular to the subject's plane of action, roughly 25 ft (7.6 m) from the subject, or as space permitted (**Figures 1** and **2**). Since the intention of this study was to examine postures of the subjects and not to take measurements, restrictions in the office environments precluded precise camera placement. Following videotaping sessions, the subjects were asked to complete Questionnaire 2 (**Figure 3**), in which they identified locations of discomfort that they felt were due to filing or writing. The videotaped postures were matched with the results from Questionnaire 2 to determine whether there were poor postures that subjects had been manipulated into adopting as a result of poor equipment-user relationships.

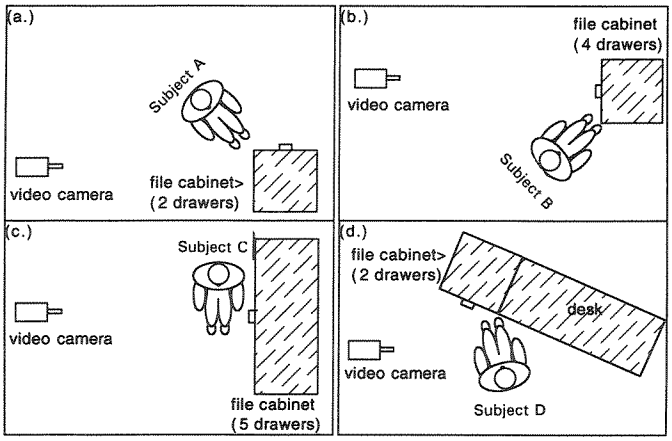


**Figure 1.**
Camera setup for videotaping of four subjects filing.

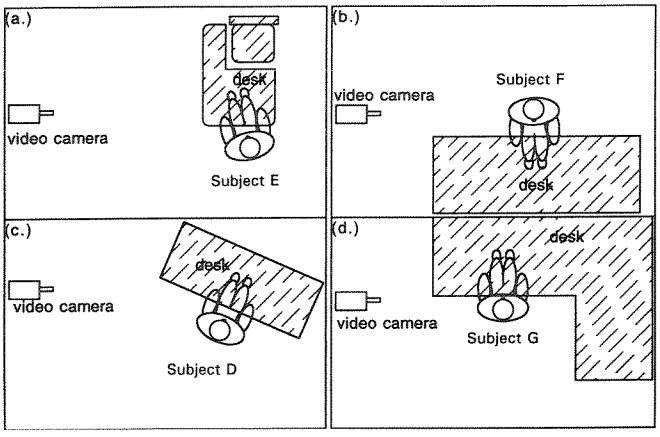


**Figure 2.**
Camera setup for videotaping of four subjects writing.

## RESULTS

### Phase I

The three activities that received the highest percentage of responses from Questionnaire 1 for each of the

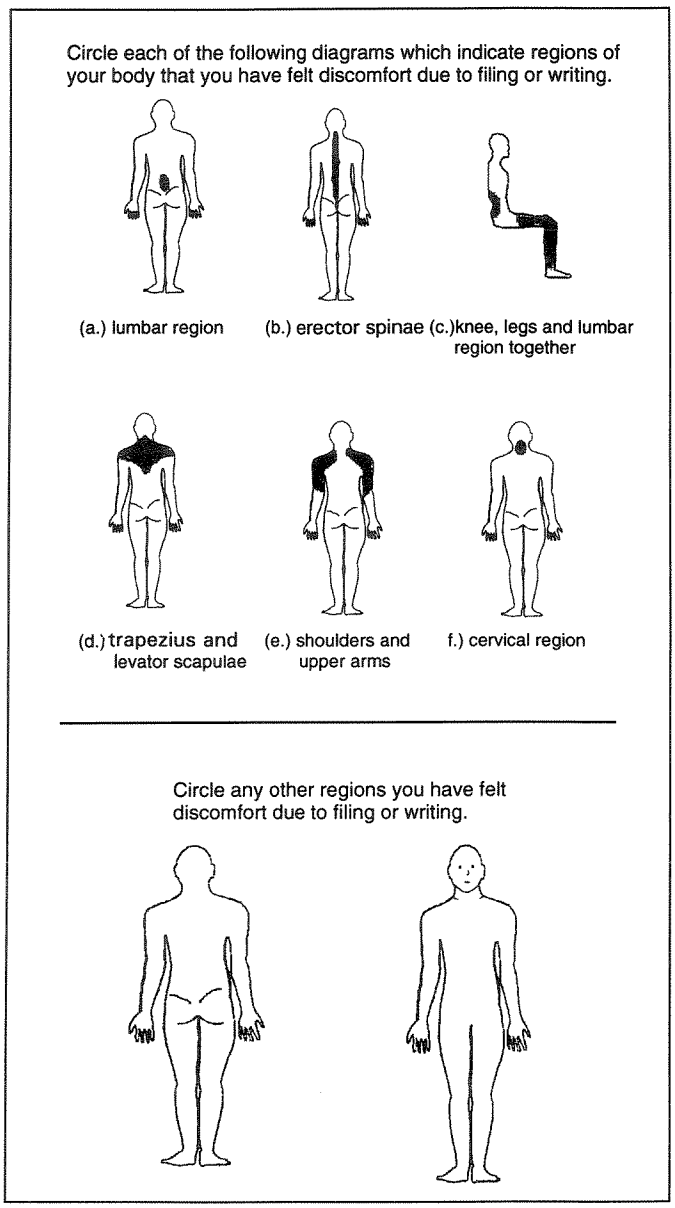


**Figure 3.**
Relevant sections of Questionnaire 2.

five potentially detrimental characteristics mentioned above are listed in **Table 3.**

Filing and writing were two activities that contained the greatest number of potentially detrimental characteristics (listed in four out of five) and were chosen to be studied in more detail in Phase II. Both activities were ranked among the highest in the following four characteristics: causing physical discomfort, causing subject to feel tired easily, activity that causes the *most* physical discomfort, and subject feels the activity is performed in an awkward manner, indicating that there should be an easier way to perform the activity. The only characteristic for which filing and writing did not rank among the top three was "being performed for at least 4 hours per day."

Although frequency of performance of activities is an important factor in the potential for cause of musculoskeletal damage, some researchers have reported that it is possible for repeated exertions of short duration, as short as even a few seconds, to produce muscular fatigue of shoulder muscles when work requires motions of the arms in elevated positions (33). In nonimpaired young males, holding a weight of 2.5 pounds (1.13 kg) at about head level is found to cause significant muscle fatigue in the shoulders within 1 minute (4,34). Therefore, we chose the activities of filing and writing to be studied further in Phase II even if they were not indicated to be performed by the subjects for more than 4 hours per day.

**Table 3.**
Top activities with potentially detrimental characteristics (N=60).

| Potentially Detrimental Characteristics | Top 3 activities with highest percentage of YES answers from Questionnaire I |
|---|---|
| physical discomfort | 1) writing (33.9%)<br>2) reading (28.6%)<br>3) filing (25.5%) |
| tired easily | 1) writing (27.6%)<br>2) filing (26.4%)<br>3) reading (26.3%) |
| performed for 4 or more hours per day | 1) reading (19.6%)<br>2) using the computer (16.4%)<br>3) telephone (13.6%) |
| activity that causes the most discomfort | 1) filing (30%)<br>2) none (16.7%)<br>3) writing (13.3%) |
| should be an easier way (indicates desire for change) | 1) filing (58.7%)<br>2) writing (42.9%)<br>3) copy machine (39.6%) |

## Phase II

Four subjects were videotaped filing and four while writing. Discomfort in body regions indicated by subjects from Questionnaire 2 were matched to postures viewed in the videotapes, and probable causes are discussed.

*Filing*

Subjects A, B, and D indicated feeling discomfort in the lumbar region. Viewing the videotapes revealed that they bent forward at the lower back to reach drawers of the filing cabinet (**Figure 4**). The lower the drawer, the more they had to bend. Bending forward in this position forces the lumbar spine to adopt a kyphotic posture, increasing the disc pressure in this part of the spine significantly (35). Both A and B have sensation and some motor control of the lower body and limbs, but subject D (T10 complete SCI) should not have sensation or motor control there, Yet D indicated feeling discomfort at the lower back, below the site of injury to the spinal cord. The reason for this is not known. However, it has been reported that SCI patients have said they experience pain below their site of injury (36).

Subject B indicated feeling discomfort in the erector spinae muscles, which was possibly due to bending forward at the lower back while having to support the head to access the lower drawers of the filing cabinet (**Figure 4**). This requires use of the erector spinae muscles to be active in order to support the body in a forward bent position. She indicated that the knees, legs, and lumbar spine, particularly the outer thighs and lower lumbar spine, produced problems for her during filing. What is likely to have been the cause of discomfort is that this subject

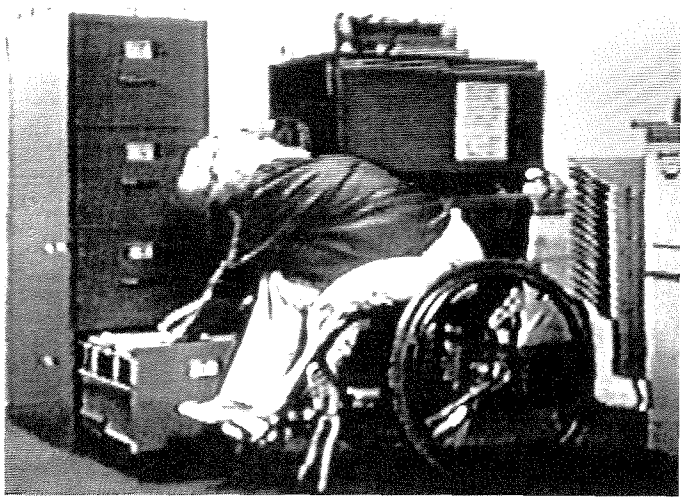

**Figure 4.**
Subject accessing the lowest drawer of a filing cabinet.

tended to brace herself by abducting her legs onto the wheelchair footrest struts as she tilted her upper body forward or to the sides, sustaining pressure in those regions. This was done in order to access the file drawers without falling out of the wheelchair.

The trapezius, rhomboideus, levator scapulae regions, shoulders, and upper arms were uncomfortable due to filing for B and C. The videotapes revealed that they frequently reached upward with both arms to access the upper drawers of the filing cabinet. Subject B used a filing cabinet four drawers high, while subject C used one five drawers high. For both, the top drawers required that they reach overhead to flip through and pull out or put in files, not being able to actually see the contents of the drawers.

Subject B also felt discomfort in the wrists. This was possibly due to the need for her to flex them to grasp files in the upper drawers of the filing cabinet.

Subject C felt discomfort in the left elbow and ventral side of the right elbow. The left elbow was frequently in flexion to pick up papers carried on the lap. Although papers are relatively lightweight and this movement pattern appears unlikely to cause elbow discomfort, no other movement pattern during filing was identified that might have caused this discomfort. It may have been injury-related or caused by other activities. This subject used the right arm, braced around the seat back post, to keep from tipping out of the wheelchair while tilting over to the side to access the lower drawers. The flexed elbow and pressure from being wrapped around the seat back post for stabilization while reaching was likely to have been the cause of pain felt in the ventral side of the right elbow.

*Writing*

Subjects E, F, and G indicated feeling symptoms in the lumbar region during writing. All three have some motor control and sensation of the lower body and limbs. The videotapes showed that these three subjects were bent forward at the lower back in order to get closer to the desk and see their work on the desk top. In this position, the back is left unsupported, in which case a lumbar support would be ineffective.

The upper back between the shoulders and cervical region of the spine were regions where E and D felt pain. The videotape of them writing showed that they were bent forward at the neck with a kyphotic upper back. Subject E was writing on a desk with a decline of approximately 5°, which required this subject to bend forward in order to see what was being written. Subject D was writing on a slant board with an inclination of 7.5°. This reduced the amount the subject needed to bend forward; however, a board inclined to a greater extent would reduce the need to bend forward even more: a 15 to 30° slant is recommended (31).

The shoulders were also a problem area for two of the subjects. Subject E reported discomfort in both and F felt discomfort in the left shoulder, elbow, and hand. It appears that E was writing on a surface that was too high: both arms were abducted and the shoulders raised. Subject F's symptoms may have been caused by the cramped position of the left (writing) arm and hand. That arm was nearly hanging horizontal, occasionally being supported on the edge of the desk; the elbow was in extreme flexion while the wrist was in extreme extension. Occasionally, this subject was required to write with increased pressure on a carbon copy tablet about 2 in (5 cm) high. This raised surface did not allow support of the arm.

Subject E felt discomfort on the sides of the back at the lower rib region. This subject's torso was twisted toward the right, which required sustained contraction of muscles at the sides of the back.

The sides of the neck were regions where D and F felt discomfort. The videotapes showed them with their heads tilted away from, and twisted toward, their writing arm. Sustaining this position while writing could cause stresses at the sides of the neck and result in discomfort.

Subject D indicated discomfort in the erector spinae muscles. The videotape showed that the head was bent over with a kyphotic upper back. The trapezius, rhomboideus, and levator scapulae regions were also sites of discomfort, and the tapes revealed that the elbows were supported on a surface that was too high, requiring the subject to maintain the shoulders in a slightly raised position.

Subject G indicated feeling discomfort only in the knees, legs, and lumbar region, but reported that numbness was felt at the legs even while not writing. Thus, the discomfort at the legs was not necessarily caused by the activity of writing, and the possible cause of discomfort in the lumbar region could have been due to the lack of a lumbar support.

## DISCUSSION

A poorly designed activity possesses potentially detrimental characteristics. Each activity studied in Phase I was evaluated according to whether it caused physical

discomfort, how easily it caused fatigue, how frequently it was performed, how it ranked among discomfort-producing activities, and how great a desire for change it generated. The two office activities that ranked high in the "most potentially detrimental characteristics" were filing and writing.

The body regions where subjects predominantly felt discomfort due to filing were the lumbar region of the back, upper back, shoulders, and arms. The videotapes demonstrated that subjects accessed lower file drawers either by positioning their wheelchair in front of the drawers and bending forward or sitting angled at the side, bending and twisting the torso forward. Lower drawers did not allow enough knee clearance, forcing them to bend forward at the lower back and stretch to reach files. The lower the drawer, the more they needed to bend forward. Such postures are probable causes of discomfort in the lower back. Subjects were also observed to brace themselves by holding onto part of their chairs to keep from falling out while reaching for files. Higher drawers, such as the fourth and fifth drawers above the floor, allowed enough knee clearance but were so high that subjects had a difficult time accessing them. Subjects had to reach upward and tilt their heads up, and were frequently not able to see the contents of the drawer. Reaching upward is a probable cause of discomfort in the shoulders and arms. The drawer requiring fewest potentially detrimental motions to access was the third up from the floor, generally about 24 in (61 cm) from the ground to the bottom of the drawer. Although this height still did not provide enough knee clearance, it was the only drawer at a height that minimized forward bending or upward reaching. Ideally, subjects need a filing system with enough knee clearance so that they can reach the files without bending forward, twisting, or stretching.

From writing, most subjects felt symptoms at the lumbar region, upper back, shoulders, and neck. Three variables between desk and chair predominate in determining a writer's posture. A desk that is too high will cause a writer to sit with the shoulders in a raised position, while a desk that is too low or too flat will require one to bend the upper body and head forward. Desk inclination between 15 and 30° has been recommended to reduce the need to bend forward while writing (31). And a desk top height of 28.35 in (72 cm) is recommended for office work (4). When the distance between the desk and the chair is too great, the writer will also bend the upper body forward.

The subjects in this study were observed to bend forward at the neck and lower back and twist the torso away from, with the head facing toward, their writing arm while writing because of a combination of inappropriate relationships between the desks and wheelchairs. The recommended floor-to-bottom-of-desk height for nondisabled persons is 25.59 in (4), based on their average knee height of 20.67 in (37), which will fit under a normal desk with 4.92 in of clearance (65, 53, and 12.5 cm respectively). However, the average knee height for wheelchair users is 25.67 in (65.2 cm), which is 0.08 in (0.2 cm) more than the recommended desk opening height (38). To compensate, wheelchair users raise the desk opening by placing it on blocks. Three out of four subjects in this study who performed writing had raised their desks from 1 to 2 in (2.5–5 cm) to facilitate knee clearance. In so doing, they raised their desk tops from 30.3 in (77 cm) on average to 32 in (81.3 cm), resulting in their writing with elbows and shoulders in an elevated position. Desks with larger openings for wheelchair access and thinner desk tops to avoid raising the writing surfaces are recommended. Also, working on desks with inclined surfaces could have decreased the need to bend the upper body and head forward. Subjects also appeared to sit too far from their desks. This may have been a secondary effect from the need to bend forward in order to see what they were writing on a surface that is flat.

Another source for low back, upper back, and neck discomfort may have been the inclination of wheelchair seats from 1 to 4° to keep the users in their chairs during propulsion (39). Although this position provides more trunk stability for wheelchair seating and propulsion, writing requires a forward sitting posture (40), and when subjects lean forward to write, their pelvises remain tilted backward while their torsos bend forward. The lumbar and cervical spine become unnaturally kyphotic, causing discomfort in the lower and upper back and neck. This may be due to the inclination typical of wheelchair seats or because of lack of motor control of the lower body.

As stated previously, Kleeman (6) and Kleeman and Prunier (7) reported that FAA workers who perform various types of seated work activities throughout their work day experience discomfort in the lower back, buttocks, upper back, back of the neck, upper legs, lower legs, and feet (in the order of high-to-low prevalence). Our subjects reported discomfort in these same body regions with the exception of the buttocks. It is possible that subjects in our study did not report discomfort in the buttocks region because specialized cushions typically used by wheelchair users distribute pressure at the buttocks better, or

they may have limited or no sensation due to partial or full paralysis at the buttocks and not feel discomfort. Low back discomfort was most prevalent in both groups. In addition, subjects in our study reported discomfort in the arms and hands.

## CONCLUSION

In summary, the activities of filing and writing were found to be the poorest office activities for the group of subjects in this study. Filing produced discomfort in the lumbar spine, upper back, shoulders, and arms. Writing produced discomfort predominantly in the lumbar region of the back, shoulders, upper back, and neck. These are the same regions nonimpaired seated workers reported, with the exception of the buttocks. Arm discomfort was also a problem for subjects in this study.

Lower back discomfort was likely to have been caused by the need to bend forward either to reach the bottom drawers of filing cabinets during filing or to see what they were writing. A slant board of 15 to 30° has been recommended to allow workers to write in a more upright position (31). Also, the typical 1 to 4° backward tilt of wheelchair seats may have caused the pelvis to rotate backward as the subject was bent forward to write on desktops, causing the lumbar spine, upper back, and neck to become excessively kyphotic.

The shoulder, upper back, and arms were problem areas for filers, while the shoulder and upper back were problem areas for writers in this study. Wheelchair users obviously are at a lower height than an average person standing, and the upper drawers of filing cabinets four or more drawers high are designed for standing use. Therefore, filing from a wheelchair requires much upward reaching into upper drawers for contents that cannot be seen. This action was likely to have been the cause of shoulder, upper back, and arm discomfort. For writing, subjects had raised their desks for knee clearance, thereby also raising the desktops, so their shoulders were sustained in raised positions, causing discomfort in this region.

The buttocks were not a problem area for subjects in this study. Lack of discomfort in these regions may have been due to adequate seat cushion weight distribution or lack of sensation in these areas.

It was noted that, in order to keep from falling out of their wheelchairs, subjects needed to cling to a part of the chair when reaching for lower drawers of the file cabinets. Two subjects complained about discomfort due to such bracing, one at the sides of the legs and the other on the ventral side of the elbow. The first was revealed in the videotape to be abducting the legs along the footrest struts to keep from falling out of the chair, while the second wrapped the affected part of the arm tightly around the seat back tubing while reaching into lower drawers.

This preliminary study revealed some interesting information regarding wheelchairs and their users in the office environment. We conclude that some general modifications are required in offices to provide appropriate access for wheelchair users. Filing systems that are comfortably accessible from seated height, and larger desk knee openings, without increasing the height of the desktop, are modifications likely to provide manual wheelchair users adequate access with more comfort and therefore more work efficiency. The effectiveness and appropriateness of such modifications need to be studied further in future studies. In this study, it was assumed that paralyzed parts of the lower body and limbs would not be used in specified activities and, therefore, should not be affected by overuse. Yet one subject indicated discomfort below the level of a complete SCI. This leads the researchers to believe that further investigation is needed on disabilities and their effect on the perception of pain. Also, because most subjects were obtained through word of mouth in Phase I and partially chosen by convenience in Phase II, responses may have been biased toward a particular group of wheelchair office workers on the West coast of the United States. Seven of the eight subjects were male, which may also have biased the results. This study was also limited by the assumption that subjects were positioned correctly in their wheelchair seating systems, the possible effects of variability in physical disability of the upper body and limbs between subjects, and the postural variables that were not measured. A study that addresses these factors with a larger number of subjects, taken from a more random sample is needed to determine representation of the true population.

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