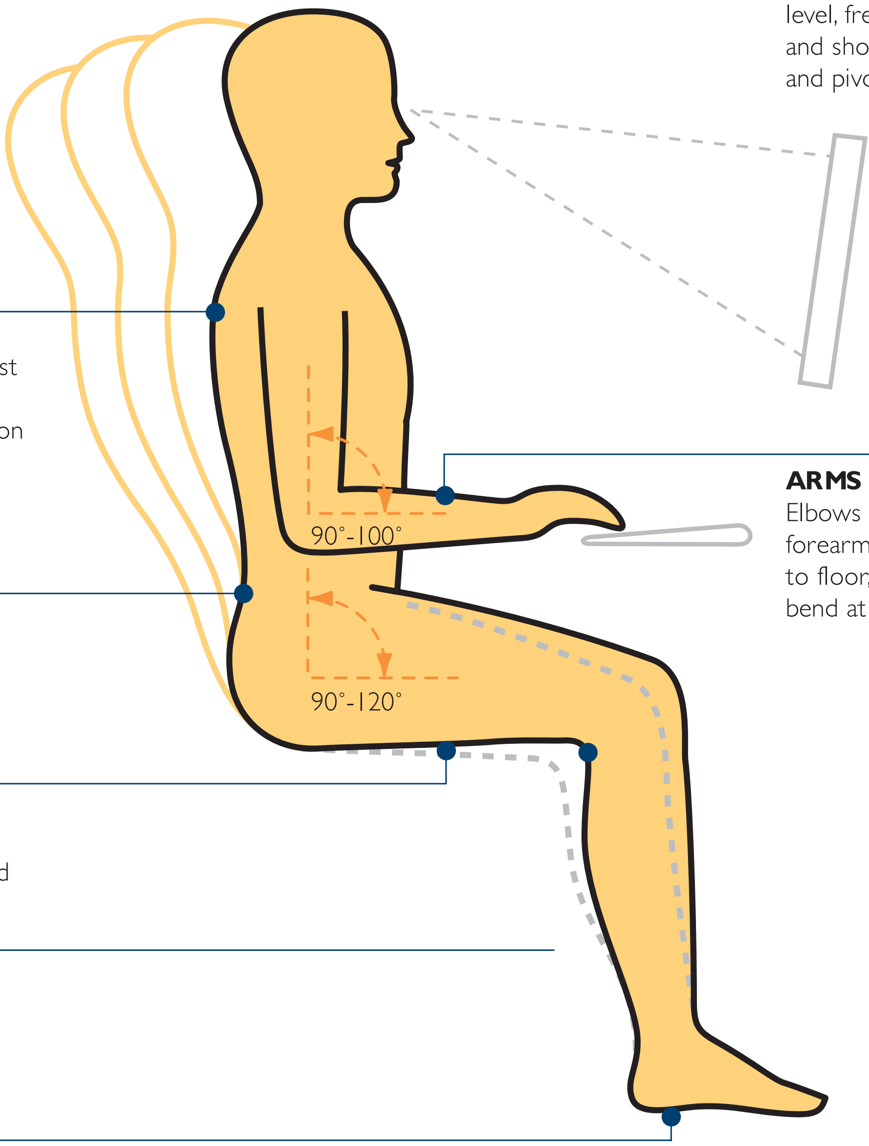
Guide to Healthy Sitting

POINTS TO REMEMBER FOR YOUR HEALTH AND COMFORT

SCREEN
Slightly below eye level, free of glare and should tilt and pivot

POSTURE
Change posture occasionally

UPPER BACK
Full contact with backrest in upright or reclined position with back tension adjusted for smooth even support



ARMS
Elbows at sides, forearms parallel to floor, minimal bend at the wrist

LOWER BACK
Fits into curve of the lumbar support

THIGHS
Parallel to the floor or angled slightly downward

BEHIND THE KNEE
Not touching the front edge of the seat

FEET
Flat on the floor or foot rest

Steelcase

UK-MKG-518-0403

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Steelcase

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The Human Component in the Healthy Office

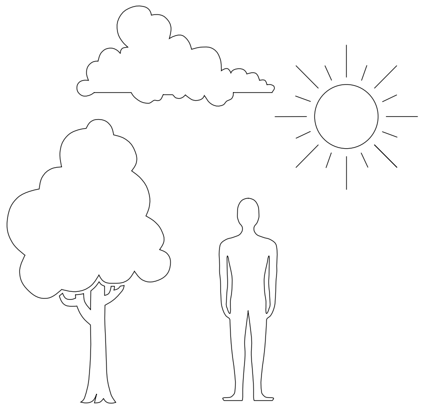
The Human Component in the Healthy Office

There is a delicate ecosystem — largely unnoticed over the decades — that has a profound effect on the contentment and quality of life for millions of workers.

It s the "ecosystem" of the office.

Just as ecosystems in nature occasionally suffer the ravages of inferior air and water quality, reckless land use, and careless waste management — so the ecosystem of the office can suffer from poor planning or indifference.

The office ecosystem is made up of many basic elements. Among them are air quality, lighting, ergonomics, worker demographics, psychological factors, acoustics, communications, waste handling, organizational influences, and workplace design. When any of these are disturbed or poorly managed, the impact on worker satisfaction and productivity becomes remarkably apparent.



The "ecosystem" of the office has a profound effect on the quality of life for millions of office workers.

Cause for Concern

Recent editions of American newspapers — both the front page and business section — carry an important message of concern caused by an imbalance in the office ecosystem. There is a growing incidence of employee sick leave, medical claims, and litigation, all related to health and safety in the office environment. Managers are becoming acutely aware of perils that lurk within the average office, and they are looking for ways to deal with them. The quest for health and safety has been taken up by conscientious business owners and office workers alike, who see the office environment as an area that should contribute to enriching the general quality of work life, not endangering it.

Office Health: A Shared Insight

Steelcase recognizes its responsibility to be knowledgeable about health-related issues, and to help do something about them. As the leader in products, services, intelligence, and systems designed to support office workers, Steelcase is prepared to collaborate with organizations interested in creating safe, healthy offices.

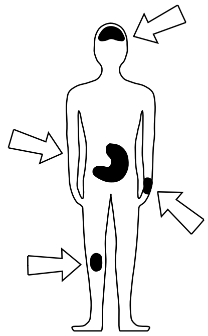
In some cases that may result in the need for furniture to meet special needs. In others, our objective is to help investigate the entire office environment, seeking solutions that may not involve furniture at all. But in all cases, Steelcase is committed to help find solutions that both contribute to a healthy quality of work life, and improve the effectiveness of people who work in offices.

The Human Component in the Healthy Office

In the past, a safe work environment meant simply a place where the risk of accidents could be avoided. Today, concern for the physical characteristics of the workplace is only part of what constitutes a safe environment.

Over the past twenty years, technological advances have revolutionized the way office work is done. The quality of office work has improved; many businesses have been able to increase productivity and profits. But with all the enhancements brought about by computers and changing job designs, a new strain of health-related issues has also appeared.

Much is reported about new forms of *physical* injuries that result from uninterrupted work with computer terminals. Repetitive stress injuries such as carpal tunnel syndrome have been linked to the workplace. And in 1990, for the first time, the need for safety guidelines in the use of video display terminals became a matter of law in San Francisco.



In addition to physical discomfort caused by repetitive strain, office workers are affected by psychological stress caused by changing job demands.

But, in addition to these physical maladies, office workers report increased *mental* stress caused by job demands that are changing. Supervisors and their subordinates in the Information Age are engaged in new forms of "knowledge work." They toil in jobs that have less latitude than in previous eras; they face increased levels of abstraction, less variety, and greater pressure to perform.

Office automation has brought very significant changes to an office work environment that had been relatively unchanged for several generations. With automation has come fewer staff, heavier workloads, and tighter deadlines; that requires a faster pace of work, more task specialization, and greater autonomy of workers. As a result, many employees express concern over job descriptions they believe are too rigid to meet the demands of the new automated workplace.

It has become clear: When people are unhappy or uncomfortable in their workplaces, health problems escalate. Performance suffers. Absenteeism rises. Productivity drops. Profits decrease.

In Search of the Healthy Office

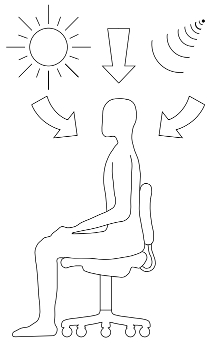
Understanding the healthy office requires substantial awareness of how an office functions. The concept embraces the ethical responsibility of employers to become advocates for the health and safety of their workers; and it urges considerable study and evaluation. In some cases, the search results in the redesign of work processes in order to assure the health of the people who work there.

People are the focus of the healthy office. The goal is to help people in offices work more effectively, while eliminating dangers to their health — either physical or psychological. Becoming aware of the source of the problems is a first step in finding solutions.

A Word about Ergonomics

The study of ergonomics has been a key factor in drawing attention to health aspects of the office environment. Ergonomics is a process by which the office environment is assessed and reshaped according to the capabilities of the people who work there. The physical health and safety of employees involves such issues as proper posture at computer keyboards; improved indoor air quality and circulation; adequate and proper lighting; noise control; and correct use of video display terminals.

Valuable solutions to most of these issues have come from office furniture manufacturers. The development of highly adjustable furniture has helped to enhance the overall comfort and health of workers. Modularity of systems furniture allows workstations to be redesigned to support communication within work groups, while controlling the level of office noise.



The study of ergonomics helps address issues like worker posture, air quality, adequate lighting, and noise control.

Concern about physical environment is only one aspect of the healthy office. Psychosocial factors and a company s organizational design also affect the comfort and well-being of employees; those are the factors that determine not only what jobs workers do, but how they do them.

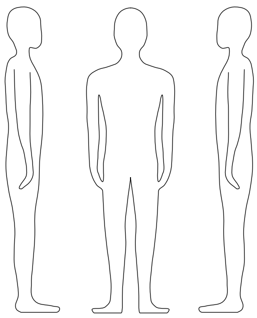
The Human Component

These "people issues" can create more subtle — but highly complex — problems in the office. They involve the psychological needs of employees as well as the structure of the organization itself.

Psychological Issues

Assuming a physical environment in which employees feel safe and comfortable, office workers are also in need of a sense of well-being:

Social climate. Health problems decrease when employees feel positive about time spent in the workplace. People are social beings who welcome interaction with their colleagues; most enjoy feeling part of a group. Opportunities to meet for discussion and support not only reduce conflict but help develop a sense of group cohesion and group control. In fact, research shows that one of the main topics of casual conversation among employees is their work... even when they re not working. And much of that talk is problem-solving.

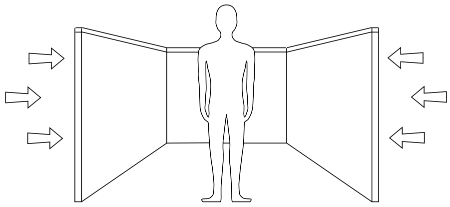


People are social beings who welcome interaction with their co-workers, and enjoy being part of a group.

Relationship with management. In "The Office Environment Index 1989," a Louis Harris and Associates survey, only 38 percent of office workers polled reported they were confident that their organization s management was "honest, upright, and ethical" with its own employees. Building trust and encouraging communication between management and workers is an investment which usually pays off in increased employee satisfaction and improved productivity.

Job pressures. People are able to handle pressure to varying degrees. Sometimes work demands are greater than worker capability; when employees become frustrated by a perceived inability to "get the job done," their stress is often manifested in a higher incidence of reported illness. Boredom from monotonous tasks is a common complaint voiced by office workers. Adequate time for breaks, along with adjustments in work pace, and flexible hours can help ease job pressures.

Privacy. The need for privacy in the office is best expressed as a "continuum." Appropriate levels of privacy change over the course of a day. Some tasks are nearly impossible to perform unless there is a near total absence of environmental stimulation or distraction — what psychologists call stimulus deprivation. Other tasks can be performed in a totally public and accessible space — even under conditions of stimulus overload. Individual workers should be able to choose the level of privacy that is appropriate for the moment.



Workers need some degree of privacy in order to manage the distractions around them.

The size of a worker s space is not a reliable indicator of privacy; work area, rather, is a factor of density or crowding. Almost total speech privacy is possible in the bleachers of a football stadium where people are packed closely to each other; while a player alone in the middle of the huge playing field has no privacy at all.

Organizational Issues

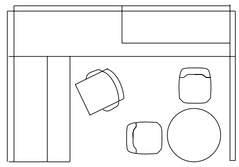
The way a business is organized can have an impact on workers. Even if the physical environment seems to be ideal, an unsatisfactory organizational structure can have a debilitating effect on employee health and well-being.

Job design. People today are asking for greater say in the design and performance of their jobs. Many employees want a job which is challenging, provides a variety of tasks, and includes opportunities for advancement. Workers who feel trapped in boring, dead-end jobs are likely to be less productive, and more likely to report in sick.

Desire for participation. In order to enjoy their work, most people need a sense of control over what they do and how they do it. Office workers want to provide more input into decisions affecting their workload and the pace at which tasks are performed. At the same time, they want to feel they are contributing to the good of the company.

“The Office Environment Index 1989” reports: “To office workers, ‘participation means more than simply teamwork and offering suggestions to management on how to do the job better; it means making a valuable and unique contribution and being recognized for it.” This study found that 81 percent of office workers rated “management recognizes my contributions” as very important in looking for a job. Recognition and personal attention can encourage a sense of ownership and enhance employee productivity.

Personalizing the workplace. People spend a significant amount of time at their place of employment; they want to feel at home. Employees are requesting more of a say in how their work spaces are arranged, furnished, and managed. This is an important opportunity for self-expression and control over the immediate environment which can add to the emotional well-being of workers. By allowing people to share in how their immediate work environment looks, management can expect increased personal involvement by employees.



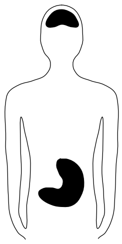
People want to “control” their environment... including how their workspaces are furnished and arranged.

Environmental control. More and more, workers are expressing the need to control more of their immediate office environment than just their furniture. Aware of potential hazards in the workplace, employees are asking for more control over temperature, lighting, ventilation, and noise in their immediate surroundings. While such direct control may not always be practical, the issue is one of growing concern to both workers and managers.

Symptoms of an Unhealthy Human Component

Stress is a fact of life. And it isn t always bad. At work, as in daily living, some stress is actually very useful. For instance, job stress may provide incentive to complete an assignment on time or encourage problem-solving. Stress may simply be a sign that an employee cares about the quality of his or her work.

But too much stress on the job can affect both the physical and psychological well-being of employees. The human body and mind function together and often become unhealthy together. Symptoms such as ulcers and migraine headaches may be more than physical complaints; asthma, psoriasis, alcoholism or other forms of chemical dependency may well be a signal to the employer that The Human Component of their business needs attention.



Ulcers and migraine headaches may be telltale physical signals that psychological needs of workers are not being met.

Whatever the cause, when a person feels that their “stress load” is too heavy, they respond in emotional, behavioral, or physiological ways that can be harmful. Too much stress over a long period of time almost always leads to health disorders.

A Bias Toward Prevention

In 1988, the Department of Health and Human Services of the United States published a study relating working conditions and psychological health. In "A Proposed National Strategy For The Prevention of Psychological Disorders" several "psychosocial" risk factors were identified. The study offers recommendations to guide the design of jobs in the interest of improving mental health, including a discussion of the following principles:

Workload and work pace. It is important to match physical and mental demands of the job with the capabilities and resources of the individual. Recovery from demanding tasks should not only be permitted, but encouraged. Individuals should be given increased control over the pace of their own work.

Work schedule. Work schedules should be compatible with demands and responsibilities outside the job. Such innovations as flextime, compressed work week, and job sharing offer possible solutions to the need to balance personal and workplace demands.

Work roles. Clearly defined roles and responsibilities at work are essential to avoiding undue psychological stress. Employees should expect clear explanations of job duties and job expectations.

Job future. Valuable employees must be kept informed about opportunities for their promotion and professional growth.

Social environment. A productive work environment allows time for some personal interaction on the job.

Content. Jobs should be designed so that they provide meaning and stimulation; workers should be given ample opportunity to use their inherent skills and develop new ones.

Participation/control. Individual workers should be involved in major decisions that affect their jobs and the performance of their tasks. One method — called "tactical autonomy" — leaves strategic decision-making in the hands of managers who determine what direction the company or group ought to take; the group or individual then determines how those directions are to be followed... in other words, how to get there.

Steelcase

Leap Seating Outperforms Other Leading Chairs

Michigan State University research study validates Leap performance claims.

Background

Recent research has given us a new understanding about how the human torso, spine and pelvis move and interrelate in a seated environment. We believe these findings will radically change the way chairs are designed for the workplace in the future. In an effort to provide a healthier way to sit today, the Leap chair incorporates new design concepts and new technologies, based on the new research, with features like the Live Back™, Natural Glide™ system, and separate upper and lower back controls.

But does the Leap chair really provide better fit, movement and support than other leading work chairs on the market today? Is it really a healthier way to sit?

To find out, Steelcase commissioned Tamara Reid Bush and Robert Hubbard, Biomechanical Design Research Laboratory, Michigan State University, and Steve Reinecke, Innovative Ergonomic Solutions, to evaluate the Leap design against three other leading work chairs on the market. Their findings (attached) were reported at the Human Factors and Ergonomics Society 43rd Annual Meeting in Houston, September 27 - October 1, 1999.

The Study: "An Evaluation of Postural Motions, Chair Motions, and Contact in Four Office Chairs"

The goal of this study was to use the most recent biomechanical models and tools to measure people and work chairs in terms of fit, movement, and support during changes in spinal inclination and curvature. Testing was performed with four office chairs in a simulated keyboarding workspace, with fourteen subjects ranging from petite, light women to tall, heavy men.

Equipment: A video-based system was used to measure the positions and motions of the subjects and the chairs. A Lordosimeter measured changes in lumbar (lower back) spinal curvature. A state-of-the-art pressure mapping system was used to measure the distribution of contact pressures between the subjects and the backs of the chairs. Torso positions relative to the keyboard and desktop were evaluated against changes in recline angle and lumbar curvature. Based on the contact areas between the subject s back and the seat back, the amount and quality of support was evaluated for all four chairs.

Bottom-Line: Leap has the best overall performance of all chairs tested.

Motion Results

- **Leap performed best in keeping users oriented to their work when changing postures**
  Because of the importance of maintaining contact with the work task, the movement of the hands and head when reclining were monitored. (Typically when users recline, they are pulled away from their work, which increases the likelihood of eyestrain and wrist strain.) Of the four chairs tested, Leap demonstrated a significant reduction in travel of the wrist and head while still achieving an equivalent range of recline. For example, Leap reduced the horizontal travel of the wrists by 78% compared to the other chairs. Thus Leap allows users to recline – taking pressure off the discs and pelvis – yet maintain contact with the work task.
- **Leap showed the highest correlation between chair movement and body movement, while providing a more even distribution of motion between the upper and lower back**
  How well the chair moved and provided support to the torso during movement was also monitored. Leap moved with people very well, showing the highest correlation between chair movement and body movement. The motions between the upper and lower regions of the back were also more evenly balanced.

Pressure Results

- **Leap provided the most consistent pressure distribution for all test conditions, and reduced shoulder pressure when reclining.**
  Users were able to maintain contact with the chair and the upper and lower back while maintaining constant lower back support. Unlike other chairs which showed high pressures along the spine and shoulders, Leap showed the most consistent pressure mappings for all test conditions. The patterns showed a wider, nearly square shape pressure map, stretching from the shoulders to the buttocks, vs. a tall thin rectangular shape. More consistent pressure distribution minimizes stress, fatigue and discomfort to the individual.

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An Evaluation of Postural Motions, Chair Motions, and Contact in Four Office Seats

Tamara Reid Bush and Robert Hubbard, *Michigan State University, East Lansing, MI*
Steven Reinecke, *Innovative Ergonomic Solutions*

The goal of this study was to use biomechanical procedures and models to measure people and office chairs in terms of fit, movement, and support during changes in recline and spinal curvature. Testing was performed with four office chairs in a simulated keyboarding workspace with fourteen subjects ranging from petite, light women to tall, heavy men.

Postures, body motions and chair motions were measured with a video-based system. A Lordosimeter measured changes in lumbar spinal curvature. Torso positions relative to the keyboard and desktop were evaluated for changes in recline angle and lumbar curvature. Pressure distributions were measured on the back of the chairs and related to changes in torso posture (back inclination and lumbar curvature). Based on the contact areas between the subject s back and the seat back, the amount of support was evaluated for changes in recline angle and lumbar curvature.

Chair D, the LEAP chair had the best overall performance. LEAP was found to move with people as they moved their spine from flexion to extension. During recline motions LEAP demonstrated a reduction in travel of the wrist and head as compared to the other chairs and a reduction in the pressure necessary to recline the seat, specifically in the shoulder region. The LEAP chair also provided a consistent pressure map for all test conditions, confirming that the chair maintained contact with the torso.

Introduction

The design and evaluation of seating has been limited by the available technologies to measure the mechanical interaction between a chair and its user. For many years, measuring the torso, while sitting, has been performed by two standardized measurement manikins provided by American National Standards Institute (ANSI)[1] for office seating, and the Society of Automotive Engineers (SAE)[2] for vehicle seating. Most office and automotive seat backs recline about a single point; this motion can be measured with the available manikins. However, both the ANSI and the SAE manikins do not represent the natural anatomic movements of the upper torso (thorax) relative to the lower torso (pelvis) that occur with spinal articulation.

Current tools that are useful for seat design and evaluation include the biomechanical models[3, 4], that have been developed at Michigan State University (MSU). In addition to the reclining of the entire torso, these biomechanical models also represent the motions of the thorax relative to the pelvis, which occur with spinal articulation.

For product evaluation in terms of biomechanical models and manikins, it was necessary for new measurement protocols to be developed. Bush, et al.[5] developed measurement methods for human seated postures associated with reclining and spinal articulation. These measurement methods of human movement in seated positions were used to obtain data from people for the evaluation of product performance, specifically office seats.

The goal of the present study was to use the recently developed procedures and models to measure people and office chairs in terms of fit, movement, and support during changes in recline and spinal curvature.

Experimental equipment

The equipment used in the study included three primary systems:

1. Qualisys video-based motion system that measured the positions and motions of the subjects and the chairs.
2. Tekscan pressure measurement system that measured the distribution of contact pressures between the human subjects and the seat backs.
3. Lordosimeter that measured the spinal curvature in the lumbar region of the subjects.

Data collection from all three systems was synchronized and data acquisition occurred for a duration of eight seconds at twelve data samples per second (12 Hz).

Motion System. The positions and motions of the subjects and the chairs were measured using a five camera Qualisys video system. Reflective targets were attached using a medical adhesive to skeletal landmarks of the subjects and to reference points on each of the chairs.

Pressure Mapping System. Contact pressures between the seat backs and the subjects torsos were measured with a Tekscan pressure system. Two pressure mats were used during the testing with each mat used for about half of the subjects. The mats were equilibrated and their calibration was checked before testing with each subject. The calibration was always stable within less than 5 pounds. There were pressure readings at the edge of the mat due to the attachment of the mats to the seat back. These pressures were eliminated in data processing.

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43rd Annual Meeting, 1999

Lordosimeter. The Lordosimeter consisted of several thin layers of material with an overall thickness of 5 mm. It was 25 mm wide and 230 mm long. A lycra covering was used to minimize any adhesion to the subjects backs. The lower end of the Lordosimeter was attached to the sacrum at the level of the posterior superior iliac spine (PSIS) with medical tape. The top portion of the Lordosimeter was held in place against the back by a strip of lycra fabric attached to the skin on both sides. As the subject s lumbar curve changed, the Lordosimeter, held close to the back, measured the change in spinal curvature.

Methods

Subject Sampling. The subjects were sampled based on height and weight criteria. Six categories were developed including petite (short), light females; petite, heavy females; mid-sized females and males by height and weight; tall, light men; and tall, heavy men, Table 1. These categories were based on a combination of Natick Data[6] and Steelcase criteria. Two subjects were tested within each of the anthropometric categories. A total of fourteen subjects were tested for this project with an age range between 20 and 51. Two of the subjects did not acceptably fit a height and weight category. The chairs, Figure 1, were selected by Steelcase to include the LEAP chair and three competing chairs. The following is a brief summary of the unique features of the chairs that were significant to this study:

Chair A. The seat back of the Chair A was a stiff shell, covered by a layer of foam, while the other three chairs had seat backs that were more compliant. Chair A had an adjustable seat back height and adjustable seat pan depth. The armrests were attached to the seat pan base and could be adjusted vertically and translated laterally.

Chair B. Chair B was the only chair that allowed a side to side rocking motion, this motion was not evaluated in this testing. The seat back of Chair B was a flexible plastic grid covered by a layer of foam. Chair B armrests were attached to the seat pan base and only adjusted vertically. The height of the seat back could also be adjusted vertically.

Chair C. Three sizes of Chair C were used to accommodate the range of subjects according to the sizing guidelines from the manufacturer. This resulted in the medium size Chair C chair being used by all of the subjects except the petite, light women who used the small size and the tall, heavy men who used the large size. Among the tested chairs, C chairs were unique with their mesh material for the seat pan and seat back. Chair C s armrests were attached to and moved with the seat back. The Chair C armrests were adjustable in and out by rotating about a pivot located near the seat back and they were adjustable up and down by slides on the sides of the seat back. The seat pan and seat back had a 2:1 ratio when reclining, so the seat back moved twice as much as the pan during recline.

Chair D, the LEAP. Chair D had a unique reclining motion in which the seat pan glided forward as the seat back reclined. Chair D had a foam-covered, flexible plastic back with a lumbar tension adjustment. Chair D seat pan depth was adjustable. The armrests were attached to the seat pan base and were the most adjustable, combining translation (found with Chair A) and rotation (found with Chair C) in addition to height adjustment.

The construction of the seat backs of all of the chairs, except the Chair A, allowed the measurement of seat back deflections that resulted from contact with the subjects back.

Testing protocol

The subjects went through an orientation where the terminology of recline and lumbar lordosis (erect posture) and kyphosis (slouched posture) were demonstrated and explained. Chair stations were set up with instruction boards on the operation of each chair. For testing and reference purposes, each chair was assigned a letter (A, B, C, D) and the manufacturer and chair name were not disclosed to the subject.

A qualified individual assisted the subject with the chair functions and demonstrated each of the chair adjustments. As the subject was rotated through chair stations (every ten minutes), the subject gained familiarity with each chair. After rotating through all four chairs, the assistant readjusted each chair and the subject was asked to repeat the chair adjustments on their own. The second adjustment typically occurred in less than five minutes for each chair.

After the orientation period, the subject was asked to change into the testing attire. This attire consisted of a pair of athletic shorts, a tight fitting tank top and a pair of low-heeled shoes such as tennis shoes.

Table 1: Subject categories.

Category	Approximate Percentile	Stature (cm)	Weight (kg)
Short Light Female	2%-5%	147-152	50.0-54.5
Short Heavy Female	2%-5%	147-152	72.3-76.8
Average Female	50%	160-165	59.0-63.5
Average Male	50%	173-178	75.5-80.0
Tall Light Male	95-98%	185-190	70.5-75.0
Tall Heavy Male	95-98%	185-190	98.0-102.5

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Chair A Chair B Chair C Chair D: LEAP

Figure 1: Test chairs selected by Steelcase.

Definition of Test Trials
Upright Recline (UR) - The subject was seated in the test chair and the seat back was locked in the full forward position. The subject was then instructed to move from lordosis to kyphosis, repeating the motion for the entire test period of 8 seconds.

Mid Recline (MR) – The seat back was in the unlocked condition (allowed to move freely) and the subject was positioned at a recline angle that was half of the full range of recline of that chair. The subject was then instructed to hold that recline angle and move from lordosis to kyphosis, repeating the motion for the entire test period of 8 seconds.

Full Recline (FR) – The seat back was in the maximum recline position that could be maintained by the subject. The subject was then instructed to hold that recline angle and move from lordosis to kyphosis, repeating the motion for the entire test period of 8 seconds.

Dynamic Recline (DR) – The seat back was in the unlocked condition. The subject began with the seat back in the most upright recline position and then reclined to the maximum recline attainable and then back to the upright position. The reclining motion was repeated for the entire 8 second trial.

Data Collection
After the subject was fitted with the lordosimeter and the targets, the test chair and desk and a simulated computer monitor and keyboard were brought into the calibrated space. The subject was seated in the test chair, (A, B, C, or D) and was asked to adjust the chair for a keyboarding task. In some cases, such as adjusting the armrest height of Chair C or the lumbar tension in Chair D, a test assistant helped the subject make the adjustments.

The order of test chairs was randomized and within each chair, the test conditions were randomized. The subject was given a chance to readjust the chair before each test condition. For example, many subjects lowered the chair slightly for the tests that occurred in the full recline position.

The lordosimeter, pressure and motion data were synchronized and all data were collected at 12 Hz for 8 seconds. Each condition was performed two times; due to the lengthy test procedure, the first and second trial were performed one right after the other to reduce the test time.

Results
Selecting subjects from the different anthropometric categories assured that a wide range of individuals would be tested. However, the test data were not analyzed by different anthropometric categories, rather the data from all subjects were pooled. Eleven of the twelve categorized subjects were analyzed in terms of the motion data. One subject was a petite heavy woman and the chest targets were lost for the majority of tests due to the chin obscuring the targets from the cameras, therefore the majority of these data were lost. All fourteen subjects pressure data were analyzed.

Dynamic Recline Test Conditions: Motion Results
In the dynamic recline test condition, each subject was asked to start in an upright recline position and then recline the chair to the maximum recline position and repeat this motion for the duration of the test.

The total recline range of each chair was measured for each subject and then averaged. The recline ranges were as follows; Chair A, 14˚, standard deviation (std) 1˚, Chair B, 21˚, std 3˚, Chair C, 21˚, std 4˚, Chair D 20˚, std 1˚. Chair A had the smallest range of recline, 6 to 7 degrees less than that of the other chairs. Thus when comparing the motion of the wrist and head, it must be noted that Chair A pro-vided smaller overall body movements because of the restricted recline range.

Because of the importance of maintaining contact with the work task, the movement of the hands and head during seat recline were monitored. Compared to Chair B and Chair C during dynamic recline, Chair D reduced the horizontal travel of the wrists by 78% (from 175 mm to 38 mm) and reduced the vertical motion of the wrists in half (from 30 mm to 15 mm). Figure 2 shows wrist movements for a single subject in Chairs C and D. The offset in the horizontal direction is due to differences in the initial starting points.

The horizontal motion of the head was reduced in Chair D by 15% to 25% compared to Chairs B and C. The vertical motion of the head was reduced between 32% and 41%. The subjects achieved an average recline range of 20 degrees in all three chairs; it was the design of Chair D, including the seat pan glide mechanism, and the location of armrest attachment, that provided the reduced head and wrist motion.

Thus, of the three chairs with similar recline ranges, Chairs B, C and D, Chair D (LEAP) performed the best in maintaining reach and vision zones so contact was not lost with the keyboard or desk, and the focal point was not disrupted.

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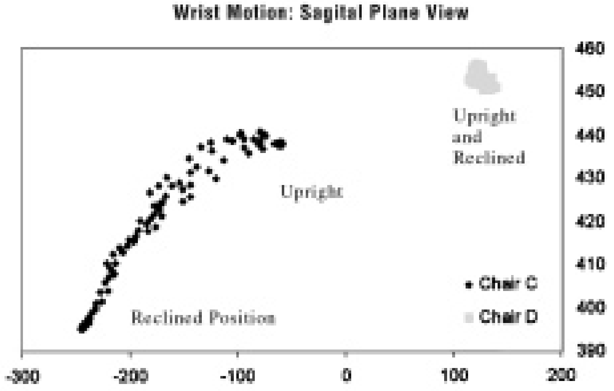
43rd Annual Meeting, 1999

Figure 2: Motion of wrist in side view, a comparison between Chair C and Chair D. Subject 6.



Movement Between Lordosis and Kyphosis: Motion Results

Three recline positions were selected, upright, mid and full recline. The subject was placed in one of these conditions and then asked to move from a kyphotic position to a lordotic position, repeating the motion.

When comparing the curve traces of the lordosimeter, the thorax motion, and the number of cycles over the 8 second test period, the subjects were consistent in their movement patterns across all four seats. Since the motion pattern and ranges were consistent, particularly between Chairs C and D, comparisons could be made between seat back responses and posture changes.

The comparisons were made between all four chairs to establish how well the seat moved and provided support to the torso during movement. Since Chair A had a rigid seat back, it did not provide a measurable amount of seat back flexibility or motion when the subjects changed their posture from lordosis to kyphosis.

Chair B showed a decrease in the average range of spinal articulation as the seat moved from an upright position to either a mid-recline, or fully reclined position. This decrease in spinal motion range was due, in part, to the difficulty the petite subjects had trying to maintain contact with the floor.

Not only was the flexion of the spine measured, but the motions of the thorax and pelvis were also measured. The motion of the thorax and pelvis, when combined were relatable to the amount of spinal flexion from lordosis to kyphosis. This combined measurement of the thorax and pelvis was termed postural openness.

Changes from lordosis to kyphosis were then compared to the response of the chair. The ability of the seat back to flex and follow the motion of the back was measured at the upper and lower regions of the chair for Chairs C and D, and measured in the upper region of Chair B. The lower region of Chair B could not be measured and appeared to be stiffer than the upper section.

The seat back flexibility was measured by creating two vectors between three targets and measuring the angular deviation from a reference position over time. For Chairs C and D, there were four targets on the seat back. This calculation was performed twice, once with the upper three targets and once with the lower three targets.

Almost twice as much chair flexion occurred in the upper region of Chair C as compared to the lower region. In Chair D, the motions between the upper and lower regions of the chair were more evenly distributed, with the bottom portion of the chair showing a slightly larger angle change.

Table 2: Correlation coefficients between chair movement and body movement.

Upright Recline	r^2 Chair B	r^2 Chair C	r^2 Chair D
Average	0.27	0.62	0.88
STD	0.28	0.27	0.10
Mid Recline			
Average	0.19	0.67	0.66
STD	0.21	0.24	0.25
Full Recline			
Average	0.44	0.83	0.88
STD	0.15	0.12	0.11

A linear regression was performed on these data and a coefficient of determination was obtained. This coefficient provided an assessment of how well the subject and seat back motions correlated. Table 2 lists the coefficients of determination for all three recline angles and the three chairs that had a flexible back.

In all recline conditions Chair B showed the lowest correlation. In the Mid and Full recline positions Chair D and Chair C provided similar correlations. However, in the Upright recline, Chair D was able to move with the body with a higher correlation, 0.88 as compared to 0.62 from the Chair C.

Chair D and Chair C performed well with regard to the ability to move with the back during spinal articulation from flexion to extension. Chair B had some ability to flex and move with the back, but to a lesser degree as compared to Chairs C and D. Due to the rigid back, there was no measurable ability of the seat back to flex with the body for Chair A.

Pressure Results

Three investigators, Bush, Hubbard, and Reinecke, independently assessed the pressure distribution mappings of all the test chairs during the various test conditions. While each subject moved through the test condition, pressure patterns of 96 still frames made up a dynamic pressure support movie. To evaluate the maps each investigator reviewed the maps and noted changes in the support patterns as the subject moved. Observations were made on the magnitude of force, amount of support contact area, and location of support to the subject s anatomical locations.

The following describes the overall trends seen in the pressure distributions for all chairs.

Chair A: Pressure Map Overview. Chair A had the least consistent pressure readings and the most asymmetrical patterns for all test conditions. These readings typically did not exhibit uniform continuous contact with the seat, but rather a “spotty” localized contact. This seat back displayed the most contact with the sides of the buttocks, resulting in a pear shaped pressure mapping for some individuals. When the subjects were in kyphotic postures, there was a round contact zone in the lower region of the seat back and when the subjects moved into a lordotic posture, this contact zone shifted to the upper portion of the seat back. Thus, in an erect posture, there was little to no contact with the seat back in the lumbar region.

Chair B: Pressure Map Overview. Chair B consistently displayed high pressure zones at the top edge of the seat back along the subjects upper thoracic regions, specifically in the reclined condition and in the lordotic postures. Several subjects showed high pressures across the lumbar region of the chair where the contour break line was in the seat back. In the fully reclined condition and the dynamic recline condition, the petite subjects showed contact only at the shoulder region, this is because their buttocks were pulled away from the seat back to maintain contact with the floor.

Chair C: Pressure Map Overview. Chair C showed a uniform pressure map in all test conditions. The subjects were able to maintain contact over the thoracic and lumbar regions of the back. Chair C showed symmetrical mappings laterally, although the pressures were primarily concentrated at the midline of the body with a narrow lateral distribution. High pressures were seen along the spine, which suggested a hammocking effect of the mesh seat fabric. The overall shape of the pressure map was a tall thin rectangle.

During the dynamic recline test condition, high pressures were seen in the shoulder region of the chair, especially for the lighter subjects.

Chair D: Pressure Map Overview. Chair D consistently provided uniform, symmetrical pressure distributions. The subjects were able to maintain contact with the chair and the upper and lower back while maintaining lumbar support constantly. The pressure mappings did not show high localized pressure zones, but rather uniformed even distribution. The patterns showed a wider, square shape pressure map stretching from the shoulders to the buttocks. The pressures were laterally similar with minimal pressures on the spinous processes.

During the dynamic recline conditions high pressure spots rarely appeared in the shoulder region across the subject sample.

In addition to the independent analysis made by the three investigators, quantitative measures of contact between the human subjects and the seat backs were developed based on the pressure readings. The pressure maps were analyzed with the following goals in mind.

1. The center of pressure (COP) was interpreted as the location of the resultant force that supported the subject s back. As the subjects changed spinal curvature from lordosis to kyphosis, the range of movement of the center of pressure indicated whether the seat back maintained contact with the subject s back. The center of pressure moved away from areas where support was lost and if the pressure patterns shifted large amounts, the COP would have a larger travel path.
2. The total area of the pressure distribution was interpreted as a measure of the compatibility between the seat back shape and the subjects backs. The greater the contact area, the better the fit. As the subjects changed their spinal curvature from lordosis to kyphosis, the change in the area indicated the ability of the seat back to provide distributed support for these changes of posture.

Table 3: Averaged vertical movement of Center of Pressure.

	Chair A	Chair B	Chair C	Chair D
Recline	mm	mm	mm	mm
Upright	305	330	305	203
Mid	254	254	254	203
Full	305	229	305	203

Table 3 shows the vertical movement of the COP. Chair D had the overall lowest movement of the center of pressure. Chair D data is significantly different at a 95% confidence level using a paired t-test when compared to the mean from Chair C. Thus, between Chair C and D, the COP has a smaller vertical travel path in Chair D. This relationship means that the pressures in Chair D were consistently and continuously being provided during postural changes, more so than in the Chair C.

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Table 4: The average maximum and minimum contact area during movement from lordosis to kyphosis. (cm²)

	Chair A		Chair B		Chair C		Chair D	
	Max	Min	Max	Min	Max	Min	Max	Min
Upright	690	380	658	393	710	426	722	464
Mid	716	535	761	535	819	613	806	581
Full	793	581	780	548	922	651	851	651

The second method that was used to analyze the contact of the seat back with the subject was the evaluation of the overall contact area. Table 4 displays the average maximum and minimum contact areas for all four chairs and all three recline angles. All the seat backs provide an increasing amount of contact area as the seat is reclined. Chair C and Chair D provide the largest contact areas for both the maximum and minimum values, which is congruent with the comments from the reviewers. These numbers indicate that Chairs C and D are consistently providing support to the subject through postural changes, however data from Table 3 shows that Chair D is providing more stable pressures patterns during postural changes.

Summary

Chair D (LEAP) allowed sufficient ranges of movement in terms of spinal flexion and extension, and recline. Of the four chair tested, the LEAP provided the least amount of disturbance to the hand and head position while still achieving an equivalent range of recline. The LEAP also provided the most consistent pressure mappings across all trial conditions and reduced shoulder pressures during recline, specifically for the petite, light, and mid-sized women. Overall the LEAP and Chair C both provided the ability to move with the subject during spinal articulation from lordosis to kyphosis. However, the LEAP provided a more consistent COP position with smaller vertical travel than Chair C. The LEAP also allowed equal motion in the lumbar and thoracic regions of the seat back while Chair C primarily allowed motion along the thoracic region of the seat back.

Acknowledgments

The authors would like to acknowledge Paul Allie, Kurt Heidmann and Noe Palacios from Steelcase for their assistance in the development of the test protocol. We would also like to thank Clifford Beckett, Phaedra Paul, Emily Daligga and Jocelyn Roy for their help with data collection and processing.

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Supporting Natural Human Motion While Seated

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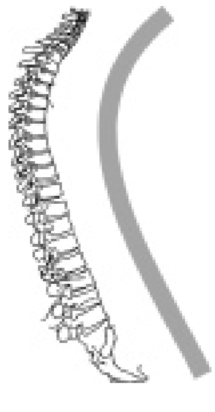
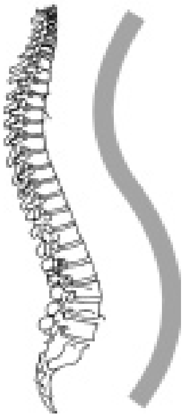
The changing shapes of the human spine
When you are seated, your spine changes shape with every movement. When leaning forward, the spine s shape becomes rounded. When sitting in a relaxed posture or when you sit upright the curve of your lower spine can flatten. And, as you recline against the chair s backrest the curve of your lower spine increases.



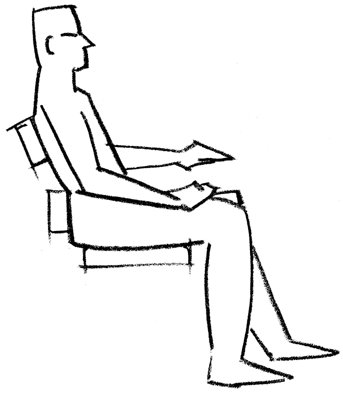
The spine's shape can range from a rounded "C" shape known as Kyphosis…



… to a more stress-free "S" shape when lumbar lordosis is maintained.

As you settle into a chair to find support, the shape of your spine is forced to conform to the shape of the chair s backrest. Because your spine s fit against the backrest is imperfect, there are gaps and you use the backrest less than you should. But shouldn t the chair support your back in any of the ways you want to move, instead of dictating a fixed shape for your spine?

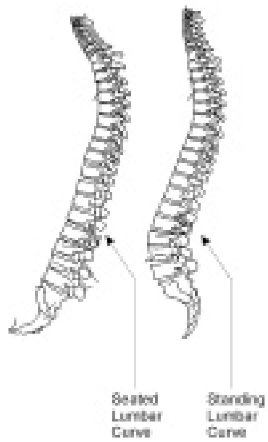
Intelligent Support — Supporting the Body
The study of human physiology and kinesiology is providing insight into the biomechanics of seating. We are finally learning the basis for seating that is comfortable for long periods…seating that reduces back pain. Chairs that really support people while they work and move have very complex functional requirements. Recent research has increased our understanding and is radically changing the way chairs will be designed for the workplace. In the future, chairs will support by moving with the body. This paper focuses on new findings about the back, spine and pelvis as an interrelated system, challenging many long-accepted ideas about seating in the work environment.



When you sit down, most chairs force you to adjust your body to the chair. Each model of office chair demands a slightly different posture. In order to develop a chair that can provide support to encourage the natural movements and changing shapes of the spine, we need to understand how a chair can do two conflicting things simultaneously. The chair must support the body, yet provide unrestricted natural movement. Good support requires stability. Good movement requires flexibility.

To better understand human movement while sitting, and how to support a range of movement, we need to take a closer look at the individual structures of the back and buttocks and look at how they work as a system.

The Biomechanics of the Back – Losing the Curve
The spine is a column made up of 24 vertebrae, separated by fluid filled discs that act as shock absorbers. The spinal column is like a tall radio tower, unstable on its own, but made extremely stable using "guy wires" to triangulate support. The "guy wires" in the human back are the muscles and ligaments. Unlike a radio tower (that is perfectly straight), the muscles and ligaments in the human back have the more difficult job of supporting the spine in its S-shaped, natural curve (cervical, thoracic and lumbar curves). Sitting changes the natural curve of the spine, increases strain on the muscles and ligaments as well as the pressure in the fluid filled discs. What s more, when seated, the pelvis rolls backward adding to the stress on the muscles and ligaments. This position (with pelvis rolled backward) causes us to sit with a flattened lumbar curve known as lumbar kyphosis. These strains exerted over time can be harmful to the discs, ligaments and muscles.

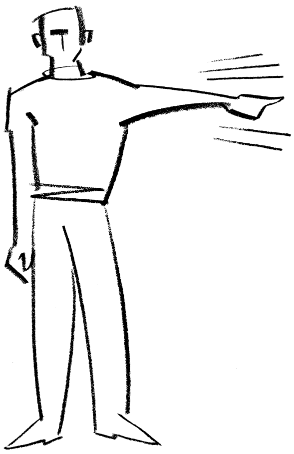


Everyone has felt muscle strain caused by inadequate support. For example while sitting, relaxing for an evening of watching TV you place your legs straight-out on the footstool. Your legs are supported only by your feet. At first it feels good, but if you remain in that one position too long, your knees begin to ache and soon, you can barely bend your knees. The same thing happens to your back when one position is maintained for too long. The answer is to frequently change the shape of your back so that muscles and ligaments don t become tired and stiff.

Why is Movement Important? Sharing the Load

We all have experienced the importance of movement without realizing it. When you sit in a chair, you are constantly changing positions as some muscles tire and other muscles take over. With some seats, getting comfortable is almost impossible. Long airplane flights can be uncomfortable as you constantly readjust yourself to find a tolerable position. The problem is that in the confined space of a plane, you are unable to change your position or the shape of your spine. The seat dictates a confined posture and few variations.

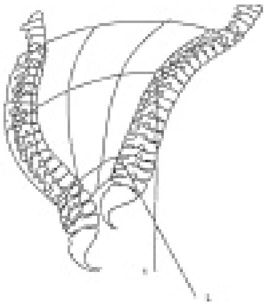
Motion is important for two reasons: The first involves stress distribution or what happens to the muscles and ligaments that act as “guy wires” for the spine. When we remain in one position, a small number of muscles and ligaments support the back and become tired and strained. Every movement transfers the support of the upper body to new muscles and ligaments allowing the strained ones to relax and recuperate.



As an experiment, hold your arm out in front of you, motionless. After a very short time your arm gets tired. Now hold your arm out but move it slowly up and down. Surprisingly, even though you would think you are using more energy, you will find that you can hold your arm up much longer. You are simply transferring the load to a larger number of muscle and ligament groups. We refer to this as “sharing the load.”

The second reason motion is important involves nutrient distribution in the spine. Between the vertebrae are fluid-filled disks. Spinal disks acquire nutrients through a process of continuously loading and unloading. Similar to a sponge transferring liquid in and out through compression and release, when you change the position of your body, exhausted fluids are pushed out of your spinal disks and fresh nutrients are drawn in.

Components of the Spine and Movement



Body movement is good. But what is the ideal posture (or range of postures) for the human back? Two studies conclude that the spine and its supporting muscles and ligaments prefer to move in ways not allowed by most chairs. The studies carried out at Steelcase Inc. and the University of Vermont, Department of Orthopedics, Low Back Pain Center, show that the curves of the back do not move as a single unit, but move independently.

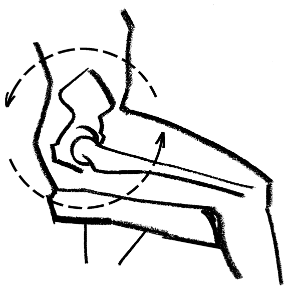
Recording images of the shape of the back as one moves forward or backward showed that the back moves in two independent regions. As you recline in a seat, the mid-back or thoracic region becomes more convex. At the same time the lower back or lumbar region becomes more concave (a posture known as lumbar lordosis). The problem with chairs today is that they recline as a fixed surface. A fixed surface can t conform to the varying shapes of the back. What this means is that the backrest must provide a flexible support surface that allows independent motion and the ability to change the shape of the back.

To make matters more difficult, each individual s spinal motion is unique. Even within a single user, as that person repeats a movement, the spine assumes a different curvature with every repetition.

Not only is the linear movement during reclining complex, the forces required to support the back are not consistent from top to bottom. The level of support required by the thoracic region is considerably different from that required by the lumbar region, and the two types of support should be independently adjustable to satisfy the comfort and posture needs of each user. Another related finding is that women tend to select a higher force level for lower back support than men.

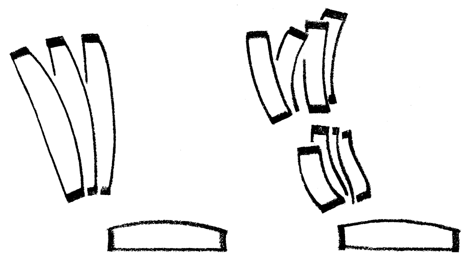
Pelvis Motion and the Spine

Currently, there are virtually no chairs that help control hip rotation (and consequently, the lumbar curve of the back). This is a direction for new chair design. The goal is a reclining mechanism that offers a biomechanically sound relationship between seat and backrest. An ideal chair will have a mechanism that coordinates the motion of the seat pan and buttocks while the back is reclined.



To understand this motion, Robert Hubbard developed a new biomechanical model, which describes the geometry and motions of the human torso, and supports the findings of other researchers. The model proposes that to support an increased lumbar curve, part of the backrest should move forward in the areas of the pelvis, lumbar spine, and lower rib cage, and part of the backrest should move backward, allowing for backward rotation of the upper rib cage. More than simply moving backward and forward in a simple linear path, these backrest segments should “float,” allowing some rotational movement.

In short, to properly support the human back, the backrest should provide a motion that is more complex than simply reclining with a fixed ratio to the seat pan. The new model suggests that a chair s backrest should change its contouring relative to the user s back in order to provide optimal lower and upper back support.

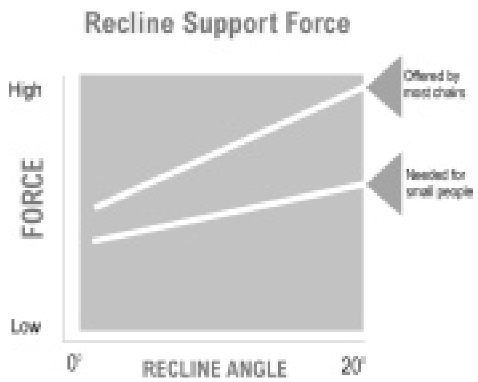


Current office chairs feature a single-plane backrest that makes a simple movement through a fixed arc. The arc has a single, fixed pivot point. The future design goal for office chairs will be to create a dynamic backrest with a changing surface contour. This will allow the backrest to mimic the shape of the human back in all natural seated postures and move with the back during changes of spinal curvature.

Chairs of the future will offer a backrest with nearly the same flexibility as the spine. The shape of the backrest will change to fit the user s posture no matter what the user s physiological uniqueness. This innovative backrest design encourages postural changes because whatever shape the body assumes will be supported by the backrest.

Recline Support Force

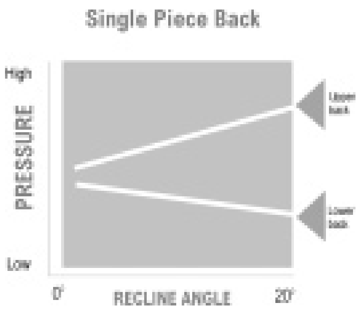
A common feature in current office chairs is the ability to recline on the backrest. However, many people who are smaller in stature cannot take advantage of this feature because the design of the support system does not allow them to recline easily. Researching the interaction between different size people and the mechanism that generates backrest support force has exposed a new perspective.

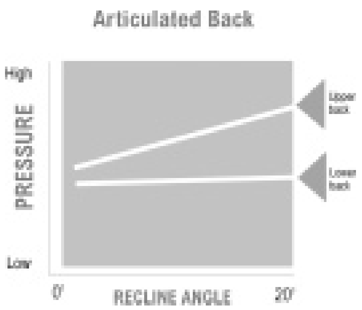


As a person reclines on the backrest of a chair, the amount of force necessary to support a safe and comfortable recline also increases. Carefully measuring recline forces has revealed that in most chair designs smaller people need a smaller increase in support force than larger people. Although most of today s chairs have a recline force adjustment, they only adjust the gross amount of force. So, when a small person adjusts the recline support force to a setting that holds them upright, as they try to recline the force quickly increases to a level that pushes them back into an upright posture. An improved mechanism has been designed that lowers the rate of force increase as the recline support is adjusted downward.

The result is that all users can maintain an upright, supported task position yet comfortably change to a stable and supported reclined posture, regardless of their physiological uniqueness.

Proving Performance





To validate the effectiveness of this new concept, a pressure monitoring system was used. It measures the forces of the torso, pressing against the backrest, and evaluated the fit and motion of back and seat with a variety of users. In chairs with a rigid contour backrest, there is reduced pressure at the lumbar curve of the lower back and increased pressure at the thoracic curve of the upper back when the user reclines[4]. This pressure shift occurs because the lumbar curve of the spine increases as the user reclines and the upper rib cage rotates back. The lumbar area of the spine naturally pulls away from the backrest causing the pressure reading to drop. At the same time the upper back pushes into the backrest causing the pressure reading to increase.

But, in chairs with a new dynamic backrest, pressure readings of the lumbar and thoracic regions change much less when the user reclines or changes posture. This demonstrates that backrests that are designed to have independently adjustable recline (or thoracic) force and lumbar force do in fact change form to closely match the shape of the individuals back. Posture changes induced by the user are supported by like changes in the shape of the backrest.

Sitting in Uncompromised Comfort

Most of us spend at least half the day sitting (Kelsey[2]). We sit in cars, trains and buses on the way to work. During work, we sit most of the day performing computer-intense work or participating in meetings. At the end of the day we sit at home eating meals, engaged in conversation, reading a book, or watching TV. Currently, in our information-based society, half of all workers are sitting in offices and this number continues to grow.

As we ve become a society that sits for a greater percentage of the day has made the office chair a critical component in determining our overall comfort and health. The chair must not only support the body but also must support it as it changes position. The concept of a dynamic back support presented in this paper offers new thinking about the biomechanics of chair design. This will herald a shift in expectations as chairs begin to move the same way our bodies move.

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Steelcase, 1999

SUPPORTING THE LUMBAR AND THORACIC REGIONS OF THE BACK DURING SITTING

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INTRODUCTION

As sedentary, static work postures have become increasingly prevalent in our workplaces, musculoskeletal problems -- in particular, low back pain and discomfort -- have also increased. Recent scientific evidence has shown that prolonged, static sitting may compromise spinal structures by reducing disc nutrition, restricting capillary blood flow, and increasing muscle fatigue. Holm and Nachemson (1983), suggest that the flow of nutrient-rich fluids to and from the intervertebral discs increases with lumbar movement. Adams (1983) also found that postural changes reduced muscle fatigue. Most researchers agree on the desirability of changing one's posture while providing adequate backrest support. The backrest function is to stabilize the torso's posture, support spinal curvature and reduce the vertical loading of the upper trunk to the backrest thereby reducing the loading on the spine. Supporting the back in a reclined position can result in reducing the load transferred through the spine and pelvis by as much as 31 percent. This transfer of load to the backrest can significantly reduce intradiscal pressure and back muscle activity contributing to overall seating comfort. However as Chaffin and Andersson (1984) reported, adequate back support should also allow for movement and postural changes. In summary proper back support should allow a worker to maintain a relaxed, but supported, posture and should allow for freedom of active motion over the course of the day.

REVIEW AND THEORY

To understand how the back changes it's posture while in a seated position, the authors previously studied (Faiks F, Reinecke S, 1998) the kinematic motion of the back during unrestricted movement. It was found that motion of the trunk represents a combination of spinal movement and pelvic rotation. As a seated individual moves from an upright to a reclined position, both thoracic *kyphosis* and lumbar *lordosis* increases. The path and rate of motion of the lumbar spine (L3) are independent of the path and rate of motion of the thoracic spine (T6), additionally, both parameters vary with the complex, combined motion of pelvic rotation, as well as changes in spinal curvature. To provide maximal support, a chair=s backrest should follow the motion of the back while the seated individual changes position. The backrest must, therefore, be flexible enough to provide continuous support while moving from an upright to reclined position.

This two-part investigation was designed to understand the magnitude of independent support of the upper (thoracic) and lower (lumbar) back. It was hypothesized that the force magnitude of the thoracic and lumbar region would be unique, yet inter-dependent.

PROCEDURES

STATIC SUPPORT: A prototype chair that consisted of two independent back elements was used to provide independent support to the lower and upper back.

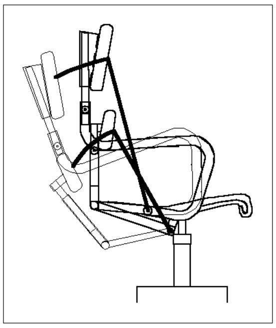

Figure 1: Test chair with independent thoracic and lumbar supports

Twenty-one (21) subjects (10 females, 11 males) where selected to represent the 5th, 50th and 95th percentile in physical stature. Subjects were instructed to sit in a fully reclined (110E), relaxed position. During this relaxed position, only the thoracic region was supported; no lumbar support was present. A researcher (from behind the chair) applied a measurable perpendicular force to the thoracic support and pushed the subject to the upright (90E) position. As the subject was lifted to an upright position the amount of force was recorded at 5E intervals. Lumbar support forces were recorded while the thoracic support was locked at both 90E and 110E. A force was applied to the lumbar support until the subject felt comfortable. This sequence was repeated three times for each subject. This static evaluation provided baseline force levels to study dynamic motion.

DYNAMIC SUPPORT: Twelve subjects (6 females, 6 males) were tested in a second test fixture. The thoracic support consisted of a support arm, which was adjustable for center of rotation and moment arm length. The thoracic support was positioned at T6 for each subject. The amount of thoracic force was produced by an external servomotor which "lifted" the subject from a reclined, to an upright position. The lumbar support was provided by a 20 cm. contoured foam surface. The amount of lumbar force consisted of a range as determined by the static study and provided dynamic movement. The subject, while continuously moving, adjusted the magnitude of lumbar support to meet their individual requirements. The selected lumbar force was recorded for each subject. Once the lumbar support level was set, subjects were asked to recline and relax. The thoracic support was then activated to "lift" the subject to the upright posture while continuously recording forces and degree of inclination of the thoracic region. Two additional tests were recorded, one with the lumbar support force increased by 1.7 kg above the subject's subjective comfort level, and one with the force decreased by 1.7 kg below the subject's comfort level. These recorded levels for both the thoracic and lumbar regions are the forces needed to dynamically support the back from a reclined to upright posture.

RESULTS

STATIC SUPPORT: At the upright posture, the magnitude of support at the lumbar and thoracic were similar, average thoracic force was 6.22 kg (STD 2.36 kg), average lumbar force was 7.037 kg (STD 4.13 kg). The amount of force in the reclined posture was much higher for the thoracic 11.08 kg (STD 2.86 kg) as compared to the lumbar 8.22 kg (STD 2.04 kg). The rate of force change for the thoracic was 0.252 (an increase of .252 kg of force for every degree of back inclination). While the lumbar only increased at 0.058.

DYNAMIC SUPPORT: Force applied at the lumbar region was inversely proportional to the force at the thoracic region. As the amount of lumbar support is increased, the amount of support needed in the thoracic region decreased. As the amount of lumbar support is decreased, the amount of support in the thoracic region increased. A difference was observed for males and females. Male support levels for thoracic and lumbar were near equal at the upright posture. As the subject reclined the thoracic force increased. Lumbar force levels were maintained as determined from the static test. Female's thoracic support levels were lower than lumbar supports at the upright posture. As the subject reclined, the thoracic force increased but remained below the lumbar support level.

DISCUSSION

The amount of back support required at the lumbar region differs from the thoracic region ($p<.05$). The amount of support to the thoracic region increases at a greater rate as a person reclines relative to the support of the lumbar region. The amount of support to the lumbar region inversely affects the amount of support to the thoracic region. Supporting natural human motion requires the proper magnitude, distribution and dynamic response of the support system. This is central to ensuring that the natural motion of the spine is encouraged while being supported at all times. These differential force levels must be accommodated to ensure that the backrest continues to support posture while promoting the natural motion of the spine. The backrest should incorporate upper and lower support mechanisms that are independently adjustable. Magnitude and rate of change for the thoracic and lumbar regions vary and work in unison as a distributed support system.

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Ergonomic Review: Armrests

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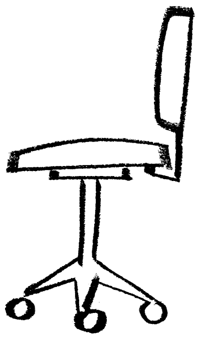
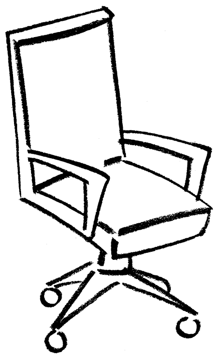
The nature of job tasks in the office work environment has changed significantly since armrests were added to office chairs. This literature review examines applicable research in an effort to understand the importance of adjustable armrests and to distinguish some of the issues surrounding proper design features. Evidence suggests that adjustable armrests can relieve muscle activity and promote better seated posture in workers who use computer input devices as a regular part of their job.

Overview

It is difficult to grasp how dramatically seating has changed in recent decades. The standard secretarial chair in the 1950 s provided a low backrest that might adjust a few inches…but little else in the way of adjustability. Typically, these chairs afforded no relief for the upper back and arms.





Armrests were largely considered status symbols for executives. But even they could not adjust these supports.

In the last decade, we have learned that not only computer users experience high rates of physical discomfort; many office workers are more uncomfortable than once presumed[1].

Musculo-Skeletal Disorders (MSD's) are not new - but they are prevalent in today s computer workplaces. From 1982 to 1997, recorded rates in the US increased more than twelve-fold.

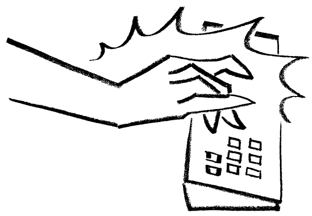
Some generally recognized risk factors for MSD's include:

- Static and constrained postures
- Awkward and unnatural positions
- Excessive force
- Repetition

… or a combination of these factors. The design of the armrest may affect all of these risk factors.

Why use armrests?

Designing good armrests is not easy. Not only do people come in a broad range of sizes; they often develop their own sitting styles. Women tend to sit upright, while men tend to lounge.



Our work also influences what we need in an armrest. Many computer users type considerably harder than is needed; this is particularly so among those experiencing discomfort[2]. Armrests may help these users type more lightly[3].

Armrests must accommodate users different workstation configurations – including devices such as keyboards that tilt back.

Finally, the overall design of the chair affects how we sit – and support our arms. It should support a variety of postures to promote comfort, work effectiveness, and long-term well being. Chair design affects how armrests are used – and the extent to which the adjustments benefit users.

With this in mind, the following is a review of ergonomic considerations for armrest design and use.

1. Armrests affect more than the arms.
   The hand-arm-shoulder-neck system is complex. For example, neck/shoulder discomfort resulting from inadequate support may cause people to sit in ways that eventually cause discomfort at another site, such as forearms and wrists.

   Users may also experience discomfort at a different area than the actual site of injury. This can lead to confusion; for example, users might take steps to alleviate wrist pain – though their discomfort may sometimes result from stress on the neck and shoulders from inadequate arm support.

   Damage to a nerve may also lead to a secondary injury to another part of the nerve. The nervous system communicates through nerves that radiate out from the spine. Damage to one area of the nerve (such as at the cervical spine) may contribute to secondary injuries at another site of the nerve (such as at the wrist)[4].

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2. Armrests relieve loads on the neck, shoulders and arms.
Many of today s computer users experience neck/shoulder symptoms. When raising the arms to type, the shoulder girdle tightens and suspends arms. Static work with elevated and unsupported arms increases the load on the neck, shoulder, and back, contributing to neck and shoulder MSD s[5]. Forces magnify when holding one s arms to the side. Working with unsupported arms may impair circulation, restrict the natural range of shoulder motion, degenerate shoulder tendons, and dramatically shorten time to fatigue.

Supporting one s arms can alleviate these static muscle loads - and helps prevent neck, shoulder and arm pain and discomfort.

… And may help promote good postures.

Armrests help support people within their personal vision and reach zone. In fact, achieving a comfortable armrest position to maintain the vision and reach zone is so important that it usually dictates how high users adjust their seat. People will ignore leg length in adjusting seat height if their vision and reach zone is satisfied. Consequently, at a standard height desk smaller people sit *higher* than tall users.

When foot support is lost, sitting forward on the seat with feet propped on the chair base is a common posture among people using keyboards.

Armrests are particularly critical when the worksurface is much higher than the chair because the higher the keyboards, the more people struggle to find a way to support their arms.

When armrests are not available, users often sit in awkward positions, such as by hunching forward and leaning forearms on the desk. This lack of arm support not only affects posture – but may also exacerbate injury by leaning against sharp worksurface edges.

3. Armrests alleviate stress on the back.
Armrests reduce loads on the spine by about 10% of the user s body weight. This reduced load is approximately equivalent to that associated with using a forward sloping seat.

If designed properly, armrests can help keep users from slumping and facilitate leaning back.

4. And help prevent excessive pressures on the seat…
Armrests help alleviate loads on the soft tissues and the back by supporting some of the weight otherwise supported by the torso.

Armrests that adjust in height, width and pivot provide more surface area to support more of the arms weight than designs that only adjust in height and pivot, or provide only height and width controls.

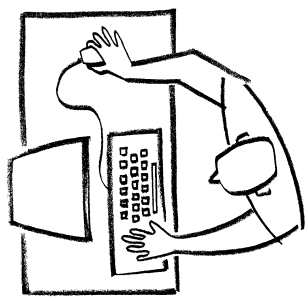
5. Armrests alleviate stress on the lower limbs.
When rising from a chair, loads are transferred to the knees and hips, similar to those going up stairs. These loads can be particularly stressful for users with temporary or chronic health concerns[a].

Armrests facilitate rising from a chair… while cutting the force (hip moment) in half.

6. Armrests stabilize posture, and help us do our work.
Many computer tasks require working with arms in awkward, fixed positions. Users may experience specific symptoms of discomfort or pain – or there may be a generalized discomfort or muscle fatigue.

MSD symptoms are typically stronger on users right side. These lateral differences in discomfort have become more pronounced with the introduction of the mouse and other input devices.

Mousing often requires considerable muscle work. Many users work with arms reaching out, wrists bent more than 15° to the side, and shoulders hunched forward. Data entry on numeric keypads is another example of a task that can be fatiguing. Adjustable armrests can allow users to intermittently support postures and facilitate changes in position.



[a] Of note, infirmities are not only a function of age. Most of us develop a disability at some time in our lives, resulting from sprained ankles, arthritis, pregnancy, or other health considerations. For such users, ease of rising from a chair takes on particular relevance.

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And how should they be designed?

1. Armrests should support asymmetrical work.
   Armrests should be individually adjustable to accommodate uncentered postures such as from mousing, writing, and using calculators.

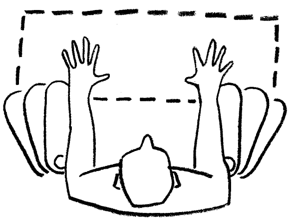
2. Pivoting armrests.
   Benefits of pivoting armrests include:
   a) Independent pivoting action helps accommodate sideways arm postures commonly found among computer users. Mouse users often work with the right arm more bent to the side (abducted).

   b) Specific workstations may interfere with armrests, contributing to poor working postures. For example, narrow diameter corner worksurfaces may obstruct armrests, and force users to work with excessively elevated arms. Adjustments that enable armrests to angle inward can help prevent such problems.

   c) Pivoting armrests allow users to support their arms while working in a wider range of postures.

   d) Computer users arms hang more naturally near their sides when arm caps adjust for both width and angle. Abduction is reduced if the arm cap can be placed directly under the elbow.

   However, it is not enough to provide pivot adjustments.[7] Armrests that pivot without adjusting in width may not support natural work postures. Because the distance between pivot points is fixed, people that are short (or have narrow shoulders) are forced to hunch and reach to the side (outward rotation and abduction of the shoulders) while using a mouse or working with equipment.[8]

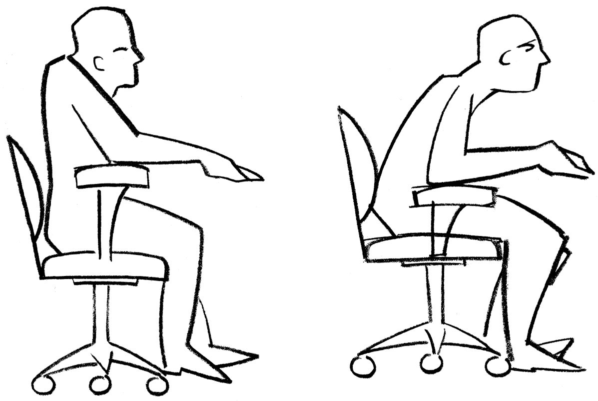


The shape and size of the armrest also affects how they are used. For example, short users may find that pivoting armrests that are too long interfere with work[9].

3. Armrests should accommodate a broad range of users.
   There has been an increasing recognition of the importance of adjustable height armrests for accommodating intensive computer users.

   Postures that are symmetrical and supported are generally preferred. Armrests should allow users to sit centered and supported.

   Research indicates that armrests that support the elbows are more effective at relieving stress on the back[10]. Armrests that adjust horizontally help alleviate muscle loads on the neck/shoulder and back[11].



On the other hand, armrests that are inflexible, poorly designed, or that obstruct positioning in front of the worksurface may force the user to hunch or twist. When armrests are too high, users are more likely to hunch shoulders. Armrests that are too low cause slouching and twisting.

Armrest controls ranges must fit different size users:
- Armrest heights should adjust from 7 to 10.75 inches above the seat, in order to fit 5th to 95th percentile females and males.[12]
- Armrest widths should adjust about 4 inches to fit 5th to 95th percentile males and females.

People make fewer errors when their keyboard is at about the right height[13]. It is reasonable that properly designed armrests may increase employee effectiveness and productivity.

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4. Armrests should stabilize position, yet promote shifts in posture.
   Today s computer users often perform work requiring high precision while using mice and other input devices – for hours at a time. Such precise motions may increase the risk of developing symptoms. Users may benefit from supports that provide postural stability while allowing them to work in a variety of postures.

   Many users prefer soft chair armrests to palmrests in order to promote free arm motion; to avoid unnatural hand positions, a palmrest should only be used as a rest, not as a support while keying.

   Armrests that are independent of other seat components often provide users with greater control over their working position – because they do not need to reposition their hands when leaning back. This stabilization of arm position may encourage some users to take greater advantage of backrest features.

5. Armrests should allow for (but not encourage) continuous use.
   Many ergonomists believe that armrests should be used intermittently. Although there is a vast amount of literature supporting the benefits from using armrests, constant use of these supports may also affect users posture in unintended ways. For example, continuous arm support may cause users to deviate their wrists while typing.

   Ergonomists currently do not fully understand the long-term implications of intermittent versus constant use. Perhaps some people will benefit from working with continuous use – while doing so makes others uncomfortable.

   Employees with symptoms may find that continuous use of armrests facilitates recovery – while others may become uncomfortable. It is also possible that some users find that continuous support alleviates neck and shoulder pain – while their wrists become less comfortable.

   Certainly, the tradeoffs associated with continuous use are, to some extent, a function of the specific design of the armrest. A well-designed armrest will be more beneficial to more users – and offer less potential for adverse effects.

   Regardless of what ergonomists ultimately decide, many users will support their arms continuously while working at the keyboard. And if they can t do so on an armrest, they will find a more hazardous and less acceptable means. Therefore, it is important that the armrest allows users to work with arms constantly supported without introducing unnecessary risk factors.

6. Armrests should not interfere with getting close to the worksurface.
   The optimum length of the armrest depends on the specific configuration and placement of the arms on the chair.

   However, under all circumstances, the design of the armrest should not interfere with proper seated postures at the work surface. Poorly designed armrests may constrain postures, causing users to hunch forward and work with elevated arms.

7. Armrests should not have sharp edges.
   Armrests should be broad and padded, and support the "fleshy" portion of the forearm. These supports should be designed so that they do not impact the highly sensitive ulnar nerve near the elbow (Pheasant, 1997).

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8. Armrests should be easy to adjust.
It is now widely recognized that many users do not adjust their chairs[14]. We have also learned that adjustability alone is not enough. People must be aware that their chair adjusts. They must also know why it is important to perform the adjustments.

Finally, adjustments must be easy to use. Lueder[15] provided these guidelines for evaluating ease of adjustment:

- Adjustments can be performed from the normal sitting work position.
- Controls are easy to recognize and understand.
- Adjustments offer immediate feedback about the settings.
- Adjustments are logical, consistent, and work as expected.
- Controls require a minimum of motions and effort.

Helander[16] found that the second and third of these principles were particularly important. Helander also reported that a large number of adjustments did not discourage their use.

Training

Training in proper seat adjustment is a central component for ensuring that users are accommodated. Helander[17] noted that training was particularly crucial with poorly designed chairs.

Conclusion

Current research demonstrates that armrests serve an important function in promoting comfort, well being – and in supporting the work process.

Armrests improve posture and promote freedom of movement while stabilizing the way we sit. They also reduce the muscle loads on the neck, shoulders and arms; reduce pressures on the spine; distribute pressures on the seat, support rising and sitting in the chair, and help us do our work.

Evidence suggests adjustable armrests that support task-related arm postures can provide an important means of alleviating stress. Pursuing the evolution of these important adjuncts to working health is a worthwhile endeavor. We have come a long way since the 1950 s.

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Note: This is an abbreviated set of references. For a document with a complete list of citations, contact your Steelcase representative or on the Internet at www.humanics-es.com/armrest.htm

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