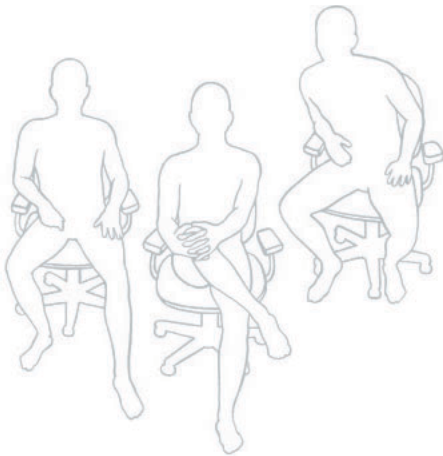


Body Support in the Office: Sitting, Seating, and Low Back Pain



Introduction

Clerical workers stood on the job until around the middle of the nineteenth century. When employers concluded that their workers might be more productive in a seated position, people began to sit at the office.^{1,2}

Today professional-level office workers spend about 70 percent of their time sitting in their offices, usually for 45 minutes at a stretch. Desk-bound workers such as telephone operators, telemarketers, and data entry workers spend nearly 100 percent of their working time sitting.³

The percentage of time spent in a seated position continues to rise as computer advances permit office workers to file, retrieve files, pick up their mail, and sometimes even attend meetings without leaving their seats.

In a recent study, the Herman Miller Research Group observed and cataloged movements of 40 office workers for a combined total of 160 hours. As a group, these workers spent 93 percent of their time sitting in an office chair.⁴ (see chart on page 1)

How Office Workers Spend Their Time and Position Themselves

This increasingly sedentary work style, coupled with the budget-breaking occupational health costs associated with back pain, has focused attention on sitting and on that important sitting tool, the office chair.

Consider the following United States statistics:

- Back problems are the most frequent cause of activity limitations in working-age adults.^{5,6}
- Back pain is the single most expensive health problem for working age adults.^{7,8,9} Twenty-two percent of all workers' compensation claims and 31 percent of all workers' compensation dollars are for lower back pain.¹⁰
- Among chronic disorders, lower back pain is the second-greatest cause of visits to physicians, the fifth most frequent reason for hospitalization, and the third most frequent reason for surgery.¹¹
- About 85 percent of Americans experience back trouble by the time they are 50 years old.^{12,13,14,15,16} Of those, 85 percent have it recurrently.¹⁷



| Behavior Variables | Percent of Time | |
|---------------------------------|------------------------|--------|
| Tasks | Mouse | 18.74% |
| | Key | 19.70% |
| | Read VDT | 7.73% |
| | Converse | 12.82% |
| | Phone | 12.35% |
| | Read Paper | 17.32% |
| | Rest | 3.86% |
| | Write | 7.60% |
| Torso Postures | Forward | 45.25% |
| | Upright | 26.96% |
| | Recline | 14.50% |
| | Turn | 5.75% |
| | Lean | 4.25% |
| Upper Extremity Postures | Neutral | 28.94% |
| | Neutral Extended Reach | 51.76% |
| | Far Extended Reach | 15.62% |

- About 17 percent of workers experience back pain every year, although only two to five percent file claims.^{18,19,20,21,22,23}
- Almost all back pain cases cost under \$500 in medical and disability payments, but a few extremely expensive cases bring the average cost up to between \$7,000 and \$10,000 (some sources say \$24,000)²⁴ per case. Disability payments account for two-thirds of these costs.^{25,26}
- Nationally, the cost of medical and disability outlays related to back pain was estimated at \$11 billion in 1986²⁷ and over \$20 billion in 1991.²⁸ This is three times as much as the cost of AIDS and lung cancer combined.²⁹
- Back pain seems only slightly less common for office workers than for industrial workers, although industrial workers experience much more disability.³⁰
- Discouragingly, the incidence of back problems has remained intractably high over time³¹ despite better medical care, more educational efforts, increased exercise awareness and exercise programs,³² and safer and better work environments.
- The vast majority of back pain problems are not caused by an identifiable event such as a fall.³³ Researchers believe that many back problems that seem to happen suddenly are actually culminations of long-term damage. Thus, back problems can be considered, in one sense, musculoskeletal disorders.
- Back pain is so poorly understood that only about 50 percent of chronic low back pain cases have identified causes, even after considerable investigation.^{34,35,36}
- Nor has it proven possible to guess which individuals will experience back pain. It is not clearly predicted by back inflexibility,^{37,38} cardiovascular fitness,³⁹ lifting strength,⁴⁰ or even evidence from back x-rays or physical exams.^{41,42,43,44,45} These conditions are associated with back pain, but back pain is typically the cause rather than the result of fitness loss.⁴⁶
- The strongest predictors of back pain discovered so far are surprising: smoking, lack of work enjoyment, low overall happiness levels, and workers' perceptions of lack of company concern.^{47,48,49,50,51,52,53,54} But even for these predictors, causal relationships are muddy; these social/psychological issues may affect whether people report back problems rather than whether they experience them.

Many people believe that back discomfort for office workers is a seating issue. However, back discomfort and the behavior of coping with back pain are complex, little-understood, and persistent phenomena that have social as well as physiological roots.

Although this paper will focus on the physical aspects of sitting and seating and their possible relationship to comfort, discomfort, and low back pain, it is important to remember that seating appears to be only one of many factors affecting back pain.

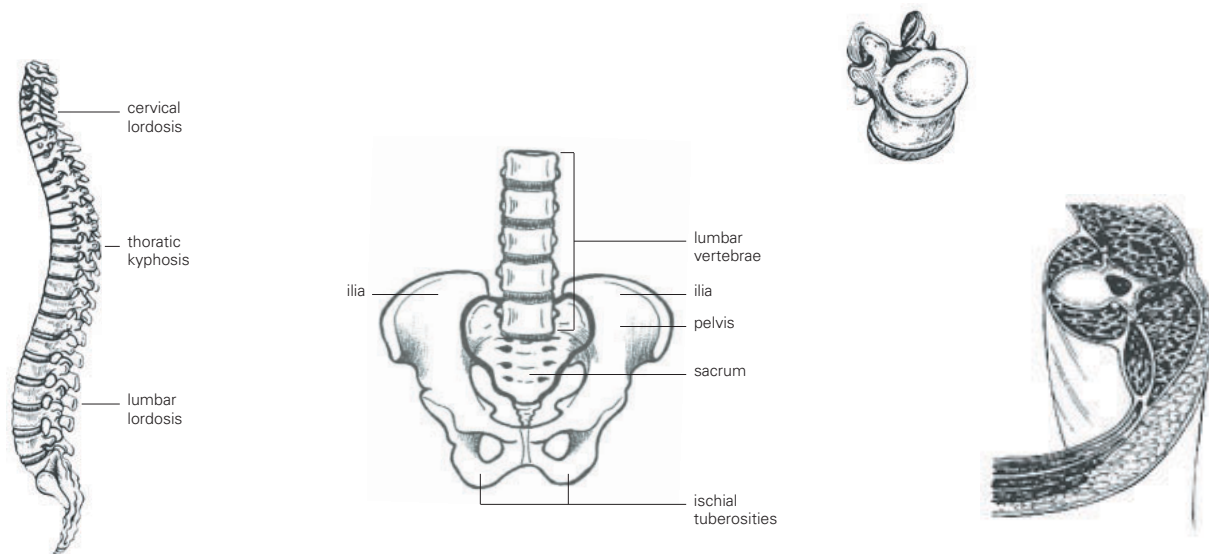
It is also important to understand that back comfort, discomfort, and low back pain are not necessarily parts of the same continuum. Back discomfort does not inevitably lead to the more chronic condition we call lower back pain; a person can be uncomfortable in a chair with very little known risk of developing low back pain.

Sitting and Back Discomfort

The Ergonomics of Back Discomfort

The physical causes of back discomfort or cumulative back pain are believed to stem from the same kinds of ergonomic stresses, or risk factors, that cause musculoskeletal disorders (MSDs) of the upper limbs.

- Sustained or prolonged postures. Holding a position for a long time reduces blood flow, depletes nutrients, and leads to a buildup of metabolic wastes.
- Awkward or non-neutral postures of the spine. Twisting, bending, or flattening the lower back can cause back pain by contributing to stretched, overworked muscles and ligaments. These postures can also squeeze or even rupture the cartilaginous discs between vertebrae.
- Compression forces. Too much load on the discs through extra weight can also affect the discs.
- Localized contact stresses. Pressure on the back or lower legs can affect blood flow both at the site of pressure and in the legs and feet.
- Repetition without rest breaks. Repeated bending, twisting, or lifting can outpace the body's ability to repair itself after exertions.⁵⁵



Back Physiology

Understanding how sitting and chairs interact with these risk factors requires a basic familiarity with the complex body parts and processes involved in the simple act of sitting down. Sitting is a mechanical interaction between five important body elements: vertebrae, pelvis, discs between the vertebrae, muscles, and skin.

The mechanical act of sitting is controlled by a complex interaction between the skeletal system and the soft-tissue structures. The primary skeletal structures influencing the mechanics of posture are the spinal column and the pelvis. The soft-tissue structures are the intravertebral discs, muscles, ligaments, and tendons.

Vertebrae The intricate stack of 24 vertebral bones called the spine or spinal column is one of the most important structures in the body when it comes to seating. Each vertebra supports the next one at three points: the broad center plate and two lateral buttresses, called joints or facets. The joint surfaces are coated with a slick cartilage to promote repetitive ease of motion and durability.

The sequence of 24 vertebrae subtly forms three natural curvatures. Beginning at the top of the spinal column, the cervical region (neck) consists of seven vertebrae that produce a forward spinal curvature known as a lordosis. Next, the thoracic region (mid back) consists of 12 vertebrae that provide a rearward spinal curvature or khyphosis. At the bottom of the spinal column, the lumbar region (low back) consisting of five vertebrae promotes another forward spinal curvature or lordosis.

Pelvis, Sacrum, and Ischial Tuberosities The base of the spine is called the sacrum. It is a large, triangular fusion of five vertebrae wedged between two pelvic bones called the ilia. Together, these three bones are known as the pelvic girdle. The two primary bones of the pelvis that we sit on are called ischial tuberosities. The pelvis can tip forward or backward, changing the curvature of the lumbar region (lower back).

Intervertebral Discs The intervertebral discs are tough lozenges of fibrous cartilage with a thick fluid in the center. They separate the broad center plates of the vertebrae from each other and give the spine flexibility and cushioning.

In addition to the main discs between the vertebral plates, thinner layers of cartilage cushion the smaller weight-bearing lateral joints (facets) between vertebrae.

The disc cores are living; in adult humans they obtain nutrients by filtration through the disc walls. Lack of nutrition, age, pressure, and other factors we don't fully understand can cause them to lose their strength, develop microfractures, and flatten.⁵⁶ Flattened discs allow the vertebrae to press close together, potentially causing wear and tear on the vertebral facets or pressure on major nerves emerging from the spinal cord.

Discs and cartilage do not contain nerves, so excess pressure on the discs is not painful unless and until the disc presses on nearby nerves. This is one reason back pain can sometimes begin without warning, and why it is possible to be comfortable while experiencing ongoing cumulative trauma to the discs.

Muscles Muscles of all shapes and sizes surround the spine. The strong, thick layers of muscles along the outside of the spine keep the torso upright by contracting, the way a tight guy rope keeps a tent pole upright. If the upper body develops a lopsided load toward the front of the body (as when bending forward or carrying a load), the outside lower back muscles have to contract even harder to keep the whole structure from slumping forward.

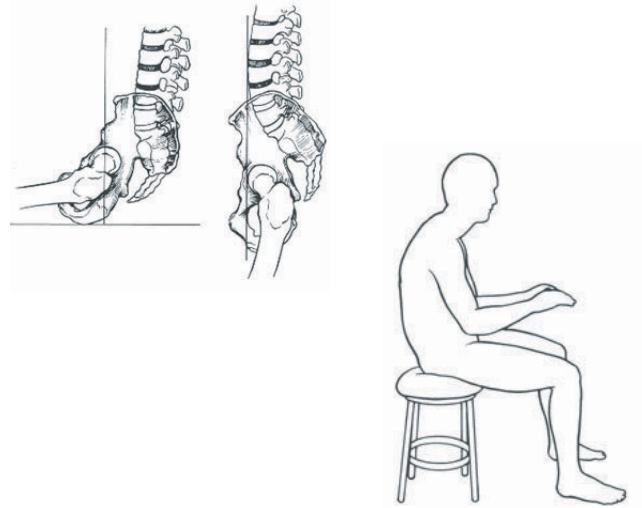
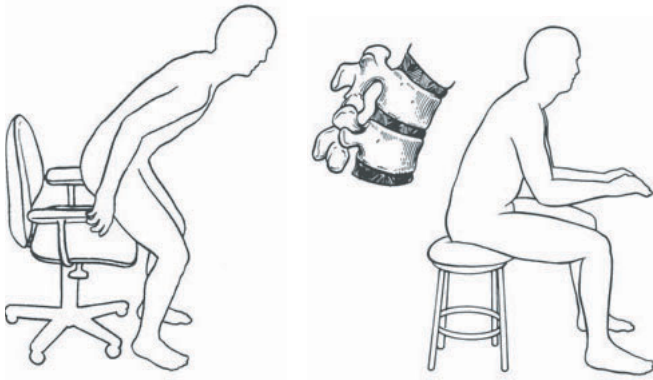
Muscles enhance blood flow by means of the pumping action that occurs when they alternately contract and relax. They can also inhibit blood flow by compressing blood vessels during prolonged, unmoving contractions.

Ligaments Ligaments are tough, inelastic connective tissue binding bone to bone (as opposed to tendons, which connect muscle to bone). A web of ligaments holds the spinal column together and attaches the spine to the pelvis.

Ligaments, like other tissues, are subject to fatigue—a loss of strength induced by repeated stresses over time. Because ligaments behave mechanically like certain plastics and tend to soften after a number of cycles, they are susceptible to failure if not permitted to heal—especially if the stresses in those cycles exceed certain limits.⁵⁷

Ligaments, rather than muscles, are probably the factor that limits how much we can bend or twist our backs.⁵⁸

Skin and Tissues The skin and other tissues (muscle, fat, blood vessels, and nerves) of the buttocks, thighs, and back need a constant flow of blood to stay healthy. Too much external pressure for long periods can reduce the blood flow and cause other kinds of damage, ranging from wringing fluids out of cells to impeding the transmission of nerve signals.



Biodynamics of Sitting

When a person sits, all these body parts interact in a chain of mechanical events with many short-term and long-term stresses.

The act of sitting begins with a slightly forward lean (to keep the body balanced) and a bending of hips and knees. The sitter may grasp armrests to help hold the torso up while it's off-balance. The long thigh bones (femurs) rotate in their pelvic sockets, while the strong ligaments attaching the femurs to the pelvis pull on the rear of the pelvis, tipping it back. About 65 percent of the total change of angle takes place in the hip joint; the rest happens mainly through pelvis rotation.^{59,60,61}

The backward tilting of the pelvis pulls the lower back into a straighter shape. Most of the shape change happens in the first three or four vertebrae above the pelvis, although six or seven vertebrae in all are involved.⁶² In the process, the front edges of the vertebrae squeeze closer together while the back edges spread apart, putting great pressure on the front portions of the intervertebral discs.

The straightening of the lower back moves the spine a few centimeters away from the upper body's balance center, or center of gravity. Where the torso was once nearly balanced over this inward curve of the spine, it is now markedly front-heavy in relationship to the straightened curve of the spine.^{63,64} To keep the torso from slumping forward, the lower back muscles on the outside of the spine contract strongly and steadily.^{65,66}

The discs, already stressed by being pinched at their front edges, are further compressed by the muscle contractions. Fluid seeps out slowly from the discs, flattening them slightly over the course of the day. Flattened discs make the cartilage-cushioned vertebral facets bear more weight and may also put some pressure on the nerves emerging from between the vertebrae.

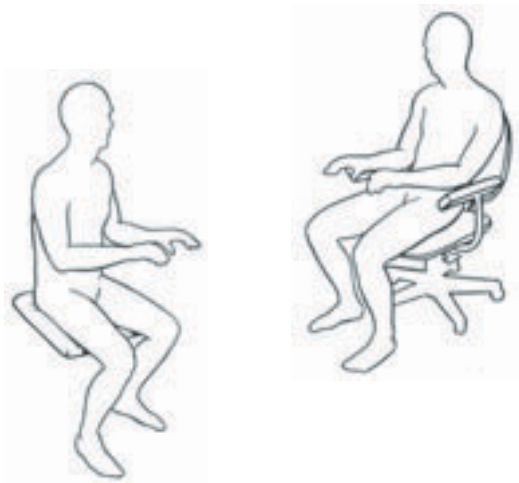
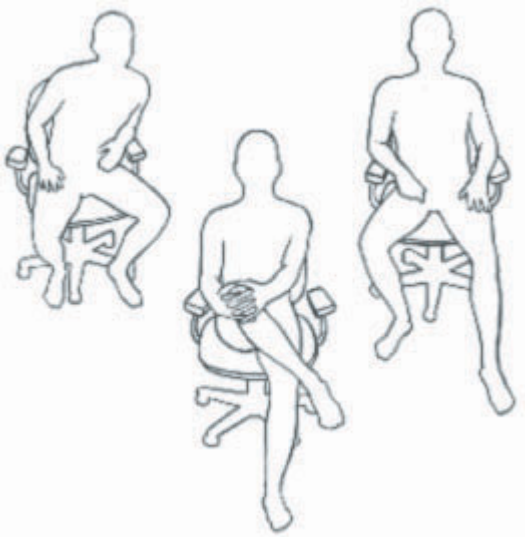
The lower back muscles are not the only ones at work. Because unsupported sitting is unstable, even a body that seems to be sitting still moves continually and imperceptibly, making tiny rocking movements over the ischial tuberosities.^{67,68}

At the same time, the skin and muscles under the ischial tuberosities are compressed. The large buttock muscles, the gluteus maximus, slide aside, leaving the ischial tuberosities resting on a cushion of fat and skin. Blood flow and the filtering of nutrients and waste products to and from the disc cores are inhibited. Even well cushioned chairs create localized pressures capable of stopping blood flow.

After a period of time in one position, the muscles in the lower back become fatigued^{69,70} and the sitter tends to relax them in favor of letting the ligaments help hold the torso upright.⁷¹ If there is no postural support to keep the lower back and torso upright, the person tends to slump down and forward, causing an outward-curving shape in the lower back, stretching ligaments and further increasing compression of the discs. Simultaneously, the head comes forward, forcing the muscles at the back of the neck to work to keep the head in its original position.⁷² Muscle tension at the back of the neck may increase as much as 50 percent when a person changes from an upright to a slumped sitting posture.

If lumbar or pelvic support is available, the lower back muscles relax with less downward and forward slumping of the torso. The backrest can keep the lower back in a lordotic shape. Further, pelvic support can fill the space that exists between the lower back and the seat back. If the backrest is reclined, the discs also get some relief, sharing with the backrest the job of holding up the torso. A more balanced alignment shifts the primary weight-bearing role of the upper torso to the skeletal structure, and as a result, muscles are far less stressed.

Overall, the act of sitting can place many stresses on the body. The most obvious ergonomic risk factors are the compressive forces experienced by the discs and the sustained static exertions maintained by the back muscles. This may explain why people who sit all day have about as much lower back pain as people who spend most of their time in a standing position.⁷³ In fact, the more we sit, the higher our risk of herniated discs and other back troubles.⁷⁴



Postural Variation

Why People Fidget

Over time, sitting people tend to fidget.

Posture changes are generally believed to be signs of discomfort.^{75,76,77,78,79} and have been observed to be more frequent in uncomfortable or poorly adjusted chairs.⁸⁰ Some researchers attribute this to weight and hard surfaces creating uncomfortable high-pressure spots on the skin. Others believe it has to do with trying to achieve stable (low-energy) postures when muscle groups become tired,⁸¹ or simply shifting work from one set of muscles to another. Still other explanations have to do with boredom, temperature and humidity buildup, or even daily cycles of restlessness.^{82,83} (People who are concentrating hard or working fast tend to move less.)

But it's misleading to use these findings to conclude that the absence of posture change means complete and long-term comfort. Prolonged, immobile sitting has many drawbacks.^{84,85,86,87}

Experts in the rehabilitation field emphasize the importance of frequent weight shifts (every 15 minutes or so) for the prevention of tissue breakdown due to impaired circulation.^{88,89,90}

Posture change stimulates the sponge-like compression and decompression that deliver nutrients to the disc cores^{91,92,93,94} and prevents some of the temporary disc shrinkage that normally occurs over the course of a day.⁹⁵ Disc shrinkage may cause discomfort^{96,97} and affect how hard it is to lift things.⁹⁸ It also increases the possibility of pressure on major nerves or of overloading the facet joints between adjacent vertebrae.^{99,100}

Uninterrupted sitting gradually stretches ligaments in the back, which stay stretched for about a half hour after getting up. Although we usually think of limber ligaments as healthy, during this recovery period the spine is slightly less stable and presumably more vulnerable to overextension.¹⁰¹

Finally, prolonged sitting can increase the risk of varicose veins, thrombosis, and pulmonary embolism in some people.¹⁰²

So, unless it's driven by discomfort, fidgeting is good. Sitters should feel free to move around.^{103,104}

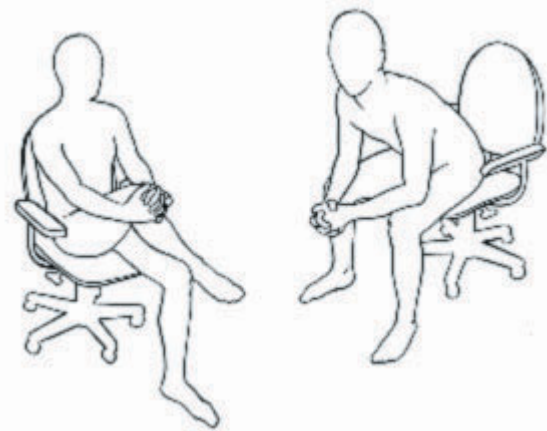
Types of Work Postures

The repertoire of the accomplished fidgeter includes several common sitting postures in addition to sitting upright: forward-tilted sitting, reclined sitting, cross-legged sitting, standing, and stable but unsupported postures. None of these postures is “correct”—each has its own advantages and disadvantages—but, in moderation, none is particularly harmful. The best way to sit is to change position frequently.

Forward-inclined Sitting Some people like to sit on the front edge of their chairs or in forward-sloping seats, with their knees dropped a few inches. This has the positive effect of rotating the pelvis toward a more upright position, restoring some lordosis to the lower back.

The tradeoff for this posture can be fatigue and pressure. If too much weight (more than about a third of body weight) is transferred to the feet, leg discomfort becomes pronounced.¹⁰⁵ Sitting on the front edge of a seat can cause strong pressures under the thighs because so much of the body's weight is concentrated on the front rim of the seat. Chairs with forward-inclined seats can eliminate some of these drawbacks. Seating with a lower pelvic support provides another alternative, allowing the sitter to comfortably sit back in the chair.

Reclined Sitting Reclining the back opens the angle between the trunk and thigh and aids circulation and the digestive process. By transferring upper body weight to a chair, the lower spine has less weight to support. This can be a significant effect, reducing forces on the lower back by as much as 20 percent.¹⁰⁶



Crossing the Legs Crossing the knees or legs is a frequently observed posture that at first appears dysfunctional since it dramatically and uncomfortably increases pressure under one of the buttocks. Indeed, crossed-legged postures usually aren't held for very long.¹⁰⁷

It's believed that crossing the legs occurs in part to relieve pressure on one side of the buttocks. However, shifting from one buttock to the other provides temporary relief but accelerates rather than delays buttock fatigue.¹⁰⁸

Crossing the legs may stabilize the body. Increased pressure under the buttocks increases friction and is advantageous when the sitter is sliding forward in a slippery seat or one with an inclined backrest (which also makes the buttocks tend to slide forward). Crossing the legs also keeps the knees together with minimal effort.

Standing Standing, in moderation, is a healthy posture. The lower back is in its optimal shape for many people, and the torso and neck are usually well balanced. But standing puts considerable weight on the hips, knees, and feet, and makes the heart and veins work hard to bring blood back "uphill" from the feet. As with all the postures described here, standing shouldn't be overdone.

An especially important posture change involves shifting between sitting and standing.¹⁰⁹ This seems to keep the discs healthy, probably through hydration caused by the sponge effect, and appears related to well conditioned muscles and limber ligaments.

However, moving from sitting to standing can be stressful. It is associated with many accidents among older people¹¹⁰ and briefly places a biomechanical force equivalent to about seven times one's body weight on the knees.¹¹¹ The most stable method of standing from a seated position involves placing the feet under the seat to help maintain balance while pushing off from the armrests.¹¹² The worst seats to rise from are low and armless with no under-seat room: the center spot on a typical sofa, for example.

Stabilized Unsupported Postures Unsupported sitters unconsciously try to stabilize themselves in positions that use little energy. The two postures seen most frequently among sitters who have no backrests or armrests are (1) leaning forward, resting arms on thighs, and (2) leaning back, hooking fingers around crossed knees.¹¹³ Although they use less muscle energy than other unsupported positions, both these postures can result in very high pressures on the discs in the lower back.

Matching Posture to Activity

Posture change usually isn't random. Sitting posture tends to change markedly when we shift from one activity to another. There are, in fact, typical and predictable postures for certain activities,^{114,115,116} although there may be differences between groups such as men and women.^{117,118,119} There are often good reasons for typical activity-related postures.

Reading There are two main reading postures, which vary according to the location and orientation of the reading material. The first is the forward, book-and-arms-on-the-table position. The second is the reclined, book-in-the-hands posture.

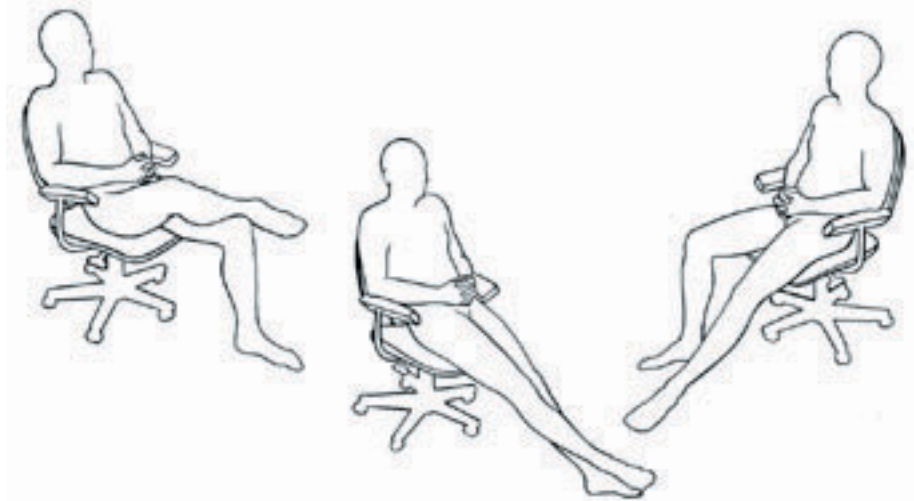
Both postures are driven by two factors: (1) good viewing of the reading material and (2) stabilizing the body for maximum relaxation while the mind does the work of reading.

The forward posture has many disadvantages. First, the forward position causes kyphosis in the lower back. Second, looking down at reading material causes a great deal of work in neck and upper back muscles and is often related to discomfort in this area.¹²⁰ Third, resting the arms on a hard work surface can potentially cause pressure on the ulnar nerve, either in the elbow or the forearm. These disadvantages have inspired numerous experiments with slanted and rounded-edge work surfaces^{121,122,123} and sitting with the knees lowered.

The reclined reading posture is generally preferable because the lower back is in a better shape than when sitting forward. The head, while still bent forward, is more balanced. The primary disadvantage here is arm fatigue, which can be reduced by armrests.

Writing Because it involves more precise hand-eye coordination, writing affects posture in more complex ways than reading.

The most common writing posture is a forward one, although some people write while reclined. The forward writing position is generally different from the forward reading position; when writing, people are more likely to sit upright, even to the point of being unsupported in the back—a posture associated with lower back fatigue.



People usually align the paper diagonally with the arm and write with the head tilted to one side. Higher work surfaces can cause the elbows to splay out, resulting in even more asymmetry.¹²⁴

Keying VDT jobs typically involve less posture change than non-VDT jobs, which have a greater variety of activities. Increasingly, VDT workers are sending and receiving mail, filing, getting phone messages, and even attending meetings via their computers. Voluntary posture change may be more important for VDT workers than for most other people because their work involves little involuntary or job-related posture change.

During keyboard work, forearm support is an important determinant of trunk posture. Apart from the musculoskeletal disorder implications of unsupported arms, a lack of arm support can result in a slumped posture as the arms' weight pulls the upper trunk forward and downward.¹²⁵

Chair Design and Back Discomfort

What Chair Design Can Do

Good seating design can improve anatomical performance by lessening ergonomic stresses on the body. Although many of these stresses can be reduced by changing sitting behaviors, seating designers attempt to alleviate them through the design of the chair. This is not a simple task; the interaction between body, posture, the work surface, personal preference, and the chair can be complex.

Can chair design, or chair comfort, increase productivity? A survey of office workers found that employees believe that increased comfort would result in increased productivity,¹²⁶ and experts often agree.^{127,128} More than one study has documented significant performance improvements (as much as 24 percent) among clerical workers moved to appropriately sized and comfortable furniture, including chairs.^{129,130,131,132,133,134}

Chairs can have an impact on back comfort and health to the extent that they affect the major ergonomic risk factors of sitting:

- sustained static postures
- direct loads on the spine
- loads on the spine that are magnified by flattened lower backs and other postures

- pressure on the skin and underlying tissues
- increased musculoskeletal stress

The risk factors can be translated into design objectives for office seating.

1. Allow or encourage varied posture and posture change.
2. Reduce muscle activity required while sitting.
3. Reduce the weight carried by the lower spine.
4. Encourage natural lower back shape (lordosis).
5. Reduce contact pressure on the skin and other tissues.
6. Fit different body sizes.

1. Allow Posture Change Long-term sitting has been associated with increased likelihood of lower back pain.¹³⁵ Moving around improves circulation, changes pressure hot spots, transfers workload from one muscle group to another, and maintains healthy discs by facilitating fluid exchange to the disc cores.^{136,137,138,139}

The benefits extend all the way to the feet. Inactive sitting with immobile legs has been associated with foot swelling and lowered leg skin temperatures in several studies.^{140,141,142}

Chairs can allow posture change if they:

- recline
- are large enough to permit occasional off-center postures
- keep the individual at a height that allows the legs to assist in posture changes and allows different postures for the legs and feet
- don't have too-soft cushions that constrain the person in one position
- have easy-to-use mechanisms for height adjustment, tilt-lock release, lower back/pelvic support, and other adjustments
- and, perhaps most important, are comfortable in a variety of postures and chair positions

2. Reduce Muscle Activity Required While Sitting The back muscles work about the same amount in a standing posture as in a seated posture with no back support.¹⁴³ However, back muscle activity drops when the sitter:^{144,145,146,147}

- uses a slightly reclining (10–20 degrees) backrest
- uses chair armrests
- straightens or extends the legs¹⁴⁸

Muscle activity is not significantly further reduced when thoracic support is used, or when the backrest is reclined more than about 20 degrees.^{149,150,151,152} Using an extra-deep lumbar support or tucking the legs under the seat actually increases back muscle activity.¹⁵³

3. Reduce the Weight Carried by the Spine The upper body weight of a person sitting without back support accounts for about one-half of total body weight. Chair backrests and armrests can help reduce the burden the discs have to carry by taking on some of that upper body weight. A person's arms and shoulders typically account for about 15 percent of body weight. Studies show that the use of arm supports reduces the force on the lower back by as much as 26 percent¹⁵⁴ to 40 percent.¹⁵⁵

Even more of the upper body can be supported by the chair's backrest. Studies have shown that if the user reclines as little as 20 degrees, the backrest can carry up to 47 percent of the upper body's weight.^{156,157,158} Of course, as the chair reclines, the weight transfer to the armrests becomes less significant.

4. Restore Lordosis Chair designers use four methods to help preserve lordosis during sitting: (1) providing supportive curves in the lumbar area of the backrest, (2) changing the relationship between the seat and backrest to widen the angle between the trunk and the thighs, (3) contouring the seat pan to change the angle of the pelvis, and (4) stabilizing the pelvis with support at the base of the spine.

Contours in the lower backrest can prevent the lower back from slumping or flattening.¹⁵⁹ While ergonomists say that technically the best location for lumbar support is approximately at the level of the fourth and fifth lumbar vertebrae,¹⁶⁰ they also say that precise location isn't important as long as it is in the lumbar region—about 6 to 10 inches above the seat pan.^{161,162}

Research suggests that about two inches of lumbar contour produces optimal spinal curves in terms of minimizing disc pressure.^{163,164,165,166} More is not necessarily better; another study showed that contours thicker than this can cause the muscles in the lower back to tense up.¹⁶⁷ Personal preference plays an important role; two people with the same fourth vertebra height may prefer different lumbar support heights or depths. Given the sensitivity of the lower back, chairs with pronounced lumbar contours should probably offer height-adjustable lumbar support.

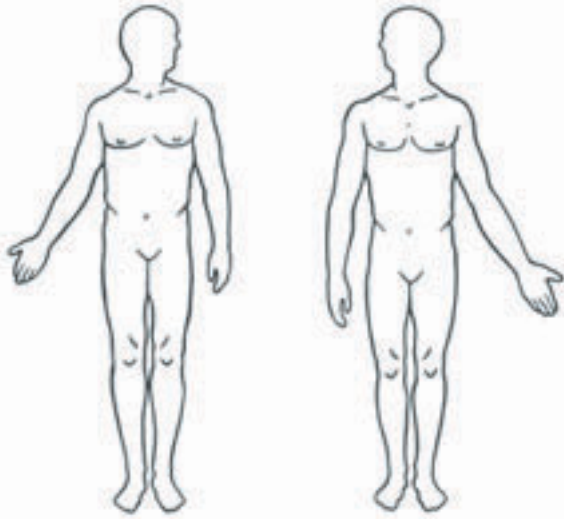
Chairs can also preserve lordosis by manipulating the backrest angle in relation to the seat angle. Since the optimal lordotic curve for most people occurs when they are standing, some chair designs attempt to hold the sitter in what amounts to a semi-standing position, either by keeping the torso upright while dropping the knees ("forward-tilt" chairs) or by keeping the thighs horizontal while inclining the back (chairs with reclining backrests).

It is also important to recognize that posture is directly affected by the position of the pelvis because it is rigidly connected to the spine. Consequently, chairs with lower back/pelvic support help maintain proper pelvis/spinal column balance and more effectively promote lumbar lordosis.

Which approach is better? Studies of users of steeply forward-tilted chairs have not shown any improvements in daily spinal shrinkage (an estimator of disc pressure),¹⁶⁸ but do show an improvement in lordosis, especially in chairs with steep forward inclines of about 15 degrees.¹⁶⁹ However, users of these chairs can experience uncomfortable feelings of sliding forward. They may compensate by pushing back with the feet, but this can tire the legs¹⁷⁰ and requires a chair that is a few inches higher than a level chair.^{171,172} Chairs with moderate forward inclines are more comfortable than those with extreme inclines, but still may not be preferred by all people.¹⁷³

Chairs with reclining backrests have none of these disadvantages and offer the advantage of transferring a significant amount of body weight to the backrest.¹⁷⁴ This may be why users of reclining backrests have less daily spinal shrinkage than people whose chairs have upright backrests.

The trunk-thigh angle doesn't have to be extreme. The curvature of the lumbar spine closely approximates the curvature of the standing position when the backrest is reclined to only 110 degrees, if the



lumbar support is about 1.5 inches deep.¹⁷⁵ However, reclining chairs move the upper body away from the work surface, which can make it more difficult to see one's work.

Another method of preserving lordosis involves the use of a seat cushion that rotates the pelvis forward through a pronounced cupping shape at the rear of the seat.¹⁷⁶ This method has the disadvantage of limiting posture variety.

A final method would be to provide contoured support to the pelvic region, just below the belt line.

5. Reduce Pressure on the Skin and Other Tissues Pressure distribution appears critical to long-term sitting comfort, as users of flat wooden seats know.^{177,178} Chairs that are too high to allow the feet to reach the floor can cause uncomfortable pressure on the backs of the thighs.¹⁷⁹ Adding only an inch of foam to flat, hard seats can triple the length of time before discomfort sets in.¹⁸⁰

But this is another instance where it's possible to have too much of a good thing. When we sit, the gluteus maximus muscles move out of the way so we sit on relatively insensitive bone and fat in the ischial area of the pelvis. Too much soft padding or seat contouring can put pressure on the gluteus maximi at the sides of the buttocks, causing muscle pain.^{181,182,183} It can also put pressure on the heads of the femur bones (the trochanters) and, possibly, on the sciatic nerves next to the trochanters.^{184,185} Anyone who has stayed too long in a sling-type playground swing has experienced this discomfort.

6. Adjust to Fit Adjustable chairs attempt to compensate for the remarkable variation in human size.

Designers typically try to accommodate the vast mid-range of body sizes, often targeting the range from 5th percentile female dimensions at the small end to 95th percentile male dimensions at the large end. However, even chairs that meet these dimensional ranges are likely to be poorly fitted to some aspect of the bodies of sitters.

There are two reasons for this. First, the anthropometric tables from which human dimensions are drawn are often based on military personnel, reflecting a membership that typically excludes very short or very tall people. There are more very short or tall people in the general population than in the military.

Second, many people have at least one body area that is short, long, wide, or thin relative to their overall standing height or torso length. So 5 percent of people will have legs too short for most seat adjustment ranges, 5 percent will have arms too short for most armrest-adjustment ranges, and so forth. Since these may not be the same people, much more than 5 percent of the population has at least one body dimension that doesn't fit a chair well.

Chair designers often have to compromise on adjustability to keep costs down or because some kinds of adjustability simply aren't currently attainable. Current height-adjustment mechanisms, for example, usually cannot be engineered to provide more than around five inches of total adjustment. (Stools and other high seats can have greater adjustment ranges.) Yet the variation in lower leg lengths of 95 percent of the adult American population spans more than eight inches.

Two dimensions are especially critical for large segments of the population: seat pan depth, which can limit the ability of short people to reach the chair's backrest, and seat height, which may produce pressure on the backs of short people's legs and reduce their mobility. Backrest cushions and foot supports are often used to adapt, but they are poor compromises if they change the user's posture or limit posture variety.

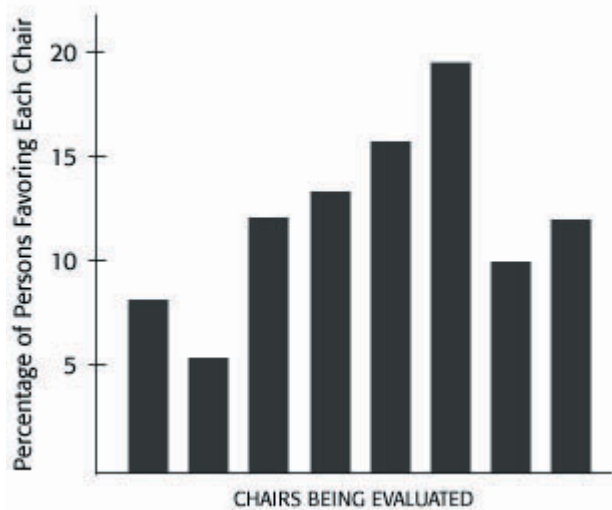
Evaluating and Choosing Chairs

Even with an understanding of sitting dynamics and chair features, it can be difficult to choose among the hundreds of office chairs on the market. Many organizations narrow the field based on features, price, and quality and then allow their employees to participate in the final choices.

Users usually evaluate chairs on the basis of "comfort" or "discomfort," but these terms are difficult to define. Some experts say comfort is simply the absence of discomfort,¹⁸⁶ while others have noted that the two may be different experiences; discomfort has been studied more because it can be more objectively measured.¹⁸⁷

Others have tried to distill predictors of perceived comfort from questionnaires or chair characteristics. One study, for example, found that objectively measured backrest curvature and thigh-trunk angle seemed to be associated with chair comfort ratings.¹⁸⁸ Others found correlations with evaluations of seat pan design, backrest curvature,

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armrests, seat slope, height of lumbar support, or ease of adjustability.^{189,190} Still others, looking for the most important body-related component of seating comfort, found that back and buttock comfort is most important, while thigh and leg comfort is least important.¹⁹¹ And a few have noted that chair appearance, distractions, and other extraneous factors tend to influence the perception of comfort.^{192,193}

To arrive at comfort ratings, different methods for user-comfort evaluations have been tried. Techniques include:

- general comfort ratings, in which participants rate their feelings about a chair on a numeric scale
- rank ordering of chairs for overall comfort
- body-part discomfort ratings, in which participants describe the comfort or discomfort of their legs, lower back, upper back, etc.
- chair-feature evaluation checklists, in which participants rate the adequacy of specific chair features such as armrests or backrests, often using scales such as “too soft . . . too hard” rather than degrees of comfort

Although all these methods have been used with success, the chair-feature evaluation checklist seems to discriminate best among chairs,^{194,195} at least for evaluation periods of a day or less.

Unless simple, general comfort ratings are used, analysis can be fairly involved. In more extensive questionnaires, it's usually desirable to weight different answers according to some value system. Features such as upper and lower back support, seat depth, and seat height can arguably be considered among the most important.

In user evaluations of collections of different chairs, results typically show little consensus among a group of people as to the “best” chair. The absence of a clear group favorite can be problematic for an employer since any single chair may be the favorite of only a minority of users. In these situations, some employers standardize on more than one chair.

For how long should chairs be evaluated? The concept of “showroom comfort” (i.e., immediate comfort) as different from long-term comfort probably applies to office chairs, although this has not been thoroughly researched. It has been shown, however, that comfort

ratings after five minutes don't correspond to ratings after half an hour.¹⁹⁶ Although one study suggested that opinions stabilize after about 20 minutes,¹⁹⁷ subtle discomfort may not be noticeable until about 3 hours have passed.¹⁹⁸ Ergonomists commonly suggest that chairs be evaluated for at least as long as users are expected to sit at one time¹⁹⁹ (typically, about two hours) and preferably a week or more.

Ergonomists also stress that a chair should be evaluated in the context for which it is intended, in terms of both task and physical environment.^{200,201} For this reason, it is helpful to have the people who will ultimately use the chairs do the evaluation. They will probably evaluate the chair appropriately and the act of participating in a choice is a proven morale booster. Some utilize specialized evaluators. “Trained sitters,” older individuals, and people with back pain can make fine discriminations among fairly comfortable chairs.^{202,203,204,205}

Finally, the results of a user evaluation should be communicated to the chairs' manufacturers if the information would help design better chairs. Companies that produce office chairs don't always have a thorough understanding of users' reactions and viewpoints and can use all the positive and negative information they can get.

What Chair Design Can't Do

Chairs are only a part of the puzzle of seated posture and its effects on the human body. Beyond furniture, the web of critical factors affecting both the experience and reporting of back pain includes the sitter's body condition and health habits, the task requirements of office work, the sitter's state of mind, and management attitudes about prevention and blame.

Employers try to lower their financial risk and workers' health risk through prevention programs that attempt to address all these factors. Prevention programs are usually divided into three categories:

- primary prevention, aimed at reducing the occurrence of low back pain
- secondary prevention, aimed at minimizing disability among workers who have low back pain but are not yet impaired or disabled
- tertiary prevention, aimed at reducing damage once low back pain has become disabling

In nonoffice jobs, these prevention programs can be very complex, involving measurement of worker strength and the physical requirements of jobs, matching worker capabilities to job requirements, installing assistive machinery, and other efforts. For office workers, training, return-to-work programs, job design, and environmental design are important methods.

Training Training is an important component of all three levels of prevention programs; it can help healthy workers avoid back pain and assist injured workers in their recovery.

However, experts note that “the cause-effect relationship is not clearly established between the precipitating factors and the anatomic structure of the spine . . . knowledge on how to decrease occurrence is therefore limited.”²⁰⁶ Many studies have been done on all aspects of training, but there has been no clear consensus that training is effective in reducing the incidence of back pain, its duration, or its severity. However, some studies do show positive results, and many people believe that training can be cost-effective and worthwhile.²⁰⁷

Many of the training topics used in industry—safe lifting methods, stretching exercises, and strength and fitness training—are only marginally useful to office workers. The issues of relevance to office workers include:

- an overview of the physiology and mechanics of the back
- the possible roles of smoking, age, and stress in back pain
- the importance of frequent posture change
- the value of reclined posture (as opposed to the stereotyped upright “correct” posture)
- a discussion of stressful postures and movements often seen in office work
- training in how and why to make chair and workstation adjustments
- stress management techniques
- the worker’s role in sharing responsibility for prevention and recovery

The last point is difficult to convey, yet the most successful preventive programs seem to be those that motivate workers to apply what is taught.²⁰⁸

Although most training has traditionally been aimed at workers, it is equally important to train managers and healthcare professionals. One company slashed their lower-back-related workers’ compensation claims by 90 percent in just three years by training managers and medical personnel to view lower back pain reports positively, paying attention to even minor back pain episodes and treating workers with back pain as “differently abled” rather than disabled.^{209,210}

Training for medical personnel includes emphasis on early intervention, initial conservative treatment, follow-up, and an understanding of workers’ job conditions.²¹¹

Return-to-Work Programs Employers and insurers have found that getting employees to work soon after the most severe pain has passed, or having them “employed” in full-day therapy sessions, keeps the employee in a working frame of mind. Resumption of work is considered a part of therapy.^{212,213,214}

Generally, the longer workers are off the job, the less likely they are to ever return to work and the more likely they are to go on lifetime disability payments. After about six months’ absence, for example, the likelihood of ever returning to work is only 50 percent; after two years it is virtually nil. The reasons are widely believed to be psychological rather than medical, since nearly all employees eventually come back to work if their return is initiated early.^{215,216} Modifying work to allow workers with back pain to stay at work is key.

Job Design Redesigning jobs can be a valuable preventive measure.

The purpose of job redesign is to remove, reduce, or dilute risk factors. One possibility that has shown promise in reducing fatigue for keyboard workers is allowing frequent rest breaks, as often as 30 seconds every 10 minutes.^{217,218,219} Employees can be encouraged to change posture during these breaks.

Ergonomists often stress job variety as a way to dilute risk factors. One of the first considerations is “enlarging” routine or physically stressful jobs to include more kinds of activities, especially nonstressful ones and ones that use different muscle-tendon groups and postures.

Environmental Design In addition to using good chairs, other parts of the office environment can be changed to reduce back-pain risk factors. The general principles are similar to those for seating design and design to reduce musculoskeletal disorders of the upper extremities: encourage varied posture, reduce or support muscle activity, reduce repetitive or sustained exertions, reduce the weight carried by the spine, and avoid nonneutral back postures.

For example:

- Office tasks that stress the back, such as lifting, carrying or bending, can often be mitigated by using carts, changing the height of shelves, rearranging storage, and so forth.
- In individual workspaces, repetitious reaches can often be eliminated entirely by moving frequently handled objects, such as telephones, closer to the body.
- Sit-stand work surfaces or separate standing-height work surfaces offer opportunities for changing between sitting and standing.
- Twisting the torso is often caused by a lack of leg space that prevents the legs from swiveling when the upper body does. Clearing out floor storage or moving pedestals can help.
- Adding armrests or adjusting armrests to the right height can help take weight off the back. Since different chairs have different armrest heights, changing chairs is another possibility.
- Discussions with forward-sitters can provide insight into whether the environment is discouraging reclining positions. For example, unlocking tilt locks and softening the tilt tension can encourage some users to recline more and transfer weight to the chair backrest. In other cases, adjusting or adding cushions to the backrest can help smaller users reach the backrest in a deep chair. Still other workers avoid reclining when their feet can't reach the floor; adjusting chair height or adding a footrest (a last resort) can help. Reclining can also be encouraged by providing more room to stretch out the legs (with a deeper work surface or a keyboard tray) or by changing the height of a work surface.
- Chairs can be adjusted to reduce prolonged postures. Adjusting the tilt tension for easy transitions from upright to reclined postures is especially critical.

Conclusion

Although we would prefer simple answers to the occurrence of low back pain among office workers, there are none. In many cases, the origins and even the diagnosis of back pain are uncertain, as are the remedies and preventive measures. The multifactorial nature of the problem requires complex responses that involve management as well as design.

The role of seating and sitting in this multifactorial situation is by no means clear. We can describe physiological events during sitting that increase ergonomic risk factors and that can be mitigated by certain chair-design features. But no one has systematically proven that chair design absolutely prevents or causes low back pain or low back disability. Nevertheless, in the absence of absolute proof it is wise to apply the ergonomic principles of “good” seating and sitting in the sensible expectation that it will do something positive.

We can also draw connections between chair design and comfort and, indirectly, individual performance. The relationship is plausible and is moderately supported by research, although the exact interactions are not understood. We do, however, have good ways to measure comfort as experienced by users of chairs.

The best program for preventing back discomfort in the office workplace involves management commitment, employee awareness and training, medical management, job design, workstation design, and the selection of office seating that fits the user, is comfortable, and supports the body in a variety of postures appropriate to the task. No single chair is guaranteed to fill the bill in every situation. Those who select chairs have the responsibility of assessing the characteristics, needs, and preferences of their work force.

Ergonomic Chair Features

The variety of “ergonomic features” offered by office chairs can be bewildering. This list of common chair features explains the potential usefulness of each, based on the material presented in this paper.

Although establishing dimensional criteria for chair adjustments must depend on the specific situation, recommended ranges are given in documents such as the “ANSI/HFS 100 Standard for VDT Workstations” (available from the Human Factors and Ergonomics Society, PO Box 1369, Santa Monica, CA, 90406).

Many of the features described here allow a chair to adjust to a given posture, body size, or task. It is important to keep in mind that posture change is essential to healthful sitting. Adjustability features should allow, rather than inhibit, free movement in the chair.

Seat-height adjustability allows users to adjust the chair so that their feet are on the floor or the work surface or keyboard is at an appropriate height or, preferably, both. Pneumatic adjustment mechanisms are easier to use than mechanical ones.

Seat-depth adjustability, achieved through an adjustment that moves the backrest in or out or through a sliding seat pan, changes the front-to-back depth of the seat. A shorter seat pan allows small people to use the chair's backrest; a deeper one feels more stable to taller individuals.

Backrest-angle adjustability allows the sitter to change the angle of the backrest relative to the angle of the seat. Although this may be accomplished with an adjustment mechanism, it can also be achieved through the use of flexing materials or springs in the chair shell. With backrest angle adjustability, the chair can support different degrees of recline. Reclining transfers some upper-body weight to the chair backrest and lightens the load on the lower back's intervertebral discs. Backrest-angle adjustability also allows the sitter to increase the angle between torso and thighs, reducing pressure on discs by restoring the natural inward curve of the lower back, called lordosis.

Chair recline, or tilt, achieves the benefits of recline by changing the angle of the entire seat relative to the floor. There are two types of tilt geometries: column tilt, in which the chair pivots at the top of the base post and lifts the knees slightly while the back descends, and knee tilt, in which the pivot point is forward of the post, nearer the knees. In a knee-tilt chair, the knee lift is negligible, but the back (and head) descend more than in a column tilt chair.

Seat pan-angle adjustability generally refers to the ability to change the angle of the seat forward or back. It allows the user to choose a fixed angle instead of a free-floating recline. Often this feature provides forward tilt, in which the thighs slope downward. The main purpose of forward tilt is to open the angle between the trunk and thighs, inducing lordosis and reducing disc pressure.

Armrests support the arms, reducing the work of the shoulders and possibly the upper arms. Used inappropriately, armrests can inhibit free motion of the arms during activities such as typing.

Height-adjustable armrests help avoid the problems of too-high armrests, which result in elevated shoulders and pressure on the undersides of the elbows and forearms, and too-low armrests, which require the worker to slump or lean to one side to use them. Height-adjustable armrests also can keep armrests out of the way during typing or other activities requiring free motion.

Width-adjustable armrests let the sitter change the distance between armrests. Armrests close to the body help avoid the splayed elbows that cause wrists to bend to the side during activities such as keying. A mechanism that allows the user to adjust armrests while seated permits closer positions than one that requires out-of-the-chair adjustment, since the latter must leave hip room for entering and leaving the chair.

Padded armrests potentially avoid uncomfortable pressure on the undersides of the forearms and elbows.

Lumbar support is intended to promote lordosis and is usually accomplished through gentle curves in the backrest shape. Backrest-height adjustability refers to the ability to change the height of the lumbar support area of the chair backrest, although it is often interpreted to mean the ability to change the height of the entire backrest. This feature accommodates preferences by different workers regarding where and how the lumbar support curve contacts the back.

Lumbar-depth adjustability affects the size and sometimes the firmness of the lumbar support curve in a chair's backrest. Like backrest-height adjustability, it accommodates different preferences and body shapes.

Pelvic stabilization also promotes lower back support at the sacrum, the base of the spine, by enhancing upright posture.

Adjusting Chairs and Workstations for VDT Work

If a VDT workstation has many adjustments, the following steps should be considered basic. These instructions assume independently adjustable work surface and keyboard height and an adjustable chair. The steps are simplified for a typical case and should be modified based on job and personal factors.

1. Start with feet flat on the floor.
2. Adjust chair height to a comfortable position that keeps the feet on the floor and thighs approximately parallel to floor. Several studies

have indicated that many people prefer to adjust their chairs up to two inches higher than parallel thigh height,^{220,221,222} even when work surfaces are not influencing height settings. Forward sitters also may prefer to sit high, but recliners may prefer to sit lower in order to get a good grip on the floor when they recline. People in knee-tilt chairs tend to prefer higher positions than people with column-tilt chairs that lift the feet when reclining.

3. Adjust chair tilt tension so the user can recline primarily through shifting weight rather than by pushing off with the feet. If the heels rise significantly off the floor when reclining, the user is pushing with the feet too much and the tension should be lightened. If the user prefers not to recline, the tension can be kept tight.
4. Adjust the angle of the backrest to allow as much recline as feels comfortable.
5. Adjust the keyboard height to elbow height or lower. Adjust the angle so the wrists are in a neutral (straight) position and the elbows are angled 90 degrees or more.
6. Place the mouse where it can be used without reaching.
7. Adjust the monitor height so the entire viewing area is somewhere below eye level.
8. Adjust the monitor angle to face users' eyes. Users should be able to see their eyes in a small mirror placed at the center of the screen.
9. Check for monitor glare and correct it by changing or shielding the light source or rearranging the workstation. Do not reduce glare by compromising the monitor height, angle, or location.
10. Adjust the work surface height so the arms and shoulders are not raised significantly when writing or reading. Work surface height is more important than keyboard height for people who spend little time keying.
11. Place the documents used during VDT work at about the same distance from the eyes as the monitor and perpendicular to the line of sight.
12. Adjust document and monitor positions to minimize eye and head movement between them. People who look equally at the monitor and document may prefer to place them either side of a center line rather than have one or the other in the center.

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Glossary

Anterior: before or toward the front.

Compression forces: forces resulting from squeezing or pressing (rather than pulling).

Contact stresses: stresses caused by localized, external pressure.

Femur: the long bone in the thigh.

Intervertebral disc: a flat, circular mass of fibrous cartilage between vertebrae in the spine.

Ischial tuberosities: two protrusions of bone at the base of the pelvis; the sitting bones.

Gluteus maximus: the most external of the large muscles of the buttocks.

Kyphosis: a convex curvature of the spine, normally found in the thoracic area.

Lordosis: a concave curvature of the spine, normally found in the lower back area and also in the neck.

Low back compensation: financial payments for medical expenses and lost wages due to low back impairment or disability.

Low back disability: the inability to perform one's usual job because of low back pain or impairment. Disability depends on the nature of the job.

Low back impairment: the loss of some function of the spine, affecting approximately 6 to 10 percent of the U.S. population each year.

Low back pain: the subjective experience of pain in the lumbar area. In this report, low back pain, back pain, and back discomfort are used interchangeably.

Lumbar: having to do with the lower back, specifically with the five lumbar vertebrae just above the pelvis.

Musculoskeletal disorders (MSDs): injuries and illnesses that affect muscles, tendons, nerves, tendons, ligaments, joints or spinal discs. Workers suffering from MSDs may experience less strength for

gripping, less range of motion, loss of muscle function and inability to do everyday tasks. Symptoms may include pain, swelling or inflammation, stiffness and tingling among others. Reduction of work-related musculoskeletal disorders may be attributed to reduction of hazards in the work environment, along with training and awareness programs.

Pelvis: the lower portion of the trunk of the body, forming a basin-shaped structure of the vertebrate skeleton, bounded anteriorly and laterally by the hip bones and posteriorly by the sacrum and coccyx.

Pelvic stabilization (or support): The process and application of controlling pelvic tilt. When a human moves into a seated posture, the pelvis involuntarily rotates rearward (posterior). Controlling or stabilizing the pelvis in a forward angle improves posture by restoring natural spinal curvature.

Posterior: situated behind.

Sacrum: the triangular bone at the base of the spine formed by five fused vertebrae. The sacrum is part of the pelvis.

Sciatic nerve: the largest nerve in the body, running from the spine in the lower back and pelvis down the back of the thigh.

Thoracic: having to do with the upper part of the trunk, including the chest.

Trochanter: a large, knobby projection of the femur near the pelvis.

Tilt lock: a chair feature in which the recline action of the chair is frozen at a particular point.

VDT: Visual Display Terminal; often used to refer to a computer or terminal.

Vertebrae: the bones that form the spine.