Supporting Natural Human Motion While Seated

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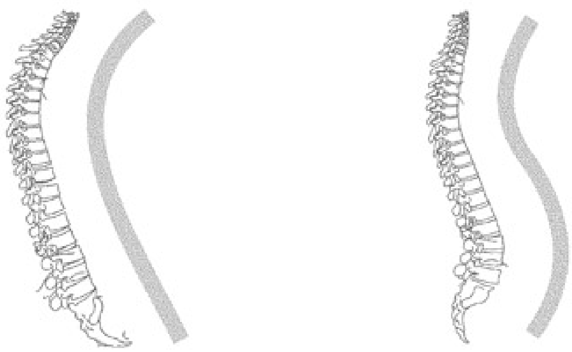
The changing shapes of the human spine
When you are seated, your spine changes shape with every movement. When leaning forward, the spine's shape becomes rounded. When sitting in a relaxed posture or when you sit upright the curve of your lower spine can flatten. And, as you recline against the chair's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

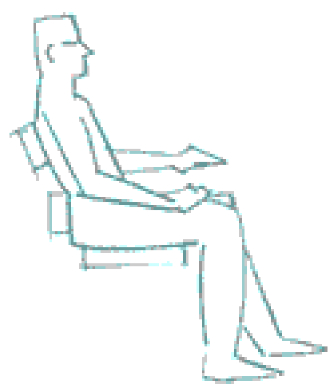


The spine's shape can range from a rounded "c" shape known as Kyphosis to a more stess-free "s" shape when lumbar lordosis is maintained.

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.

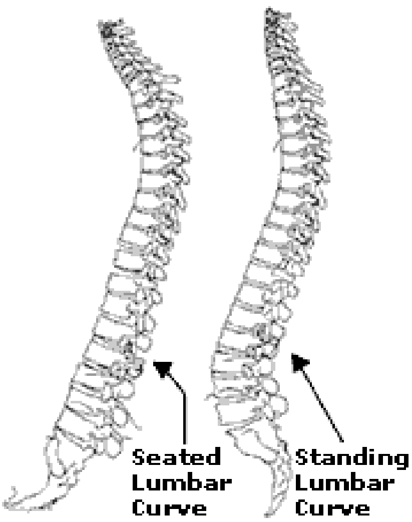
When you sit down, most chairs force you to adjust your body to the chair. Each model of office chair demands a slightly different posture. In order to develop a chair that can provide support to encourage the natural movements and changing shapes of the spine, we need to under-stand how a chair can 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.

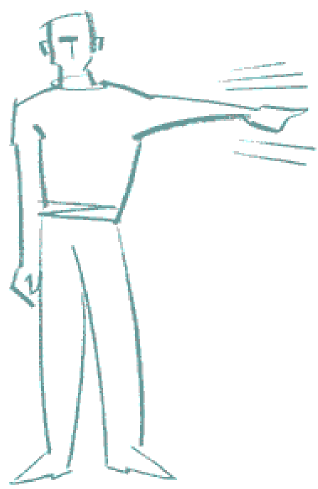
Why is Movement Important? Sharing the Load

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."

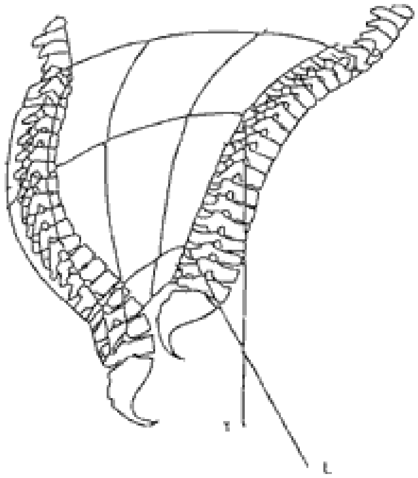
The second reason motion is important involves nutrient distribution in the spine. Between the vertebrae are fluid-filled disks. Spinal disks acquire nutrients through a process of continuously loading and unloading. Similar to a sponge transferring liquid in and out through compression and release, 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 geome-try 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.

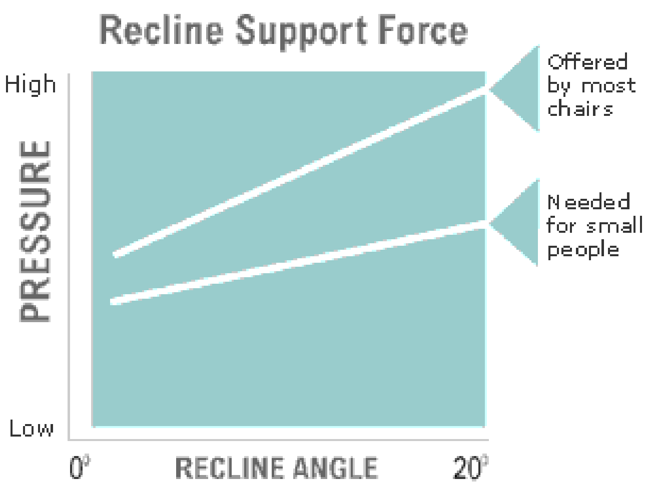
In short, to properly support the human back, the backrest should provide a motion that is more complex than simply reclining with a fixed ratio to the seat pan. The new model suggests that a chair's backrest should change its contour-ing relative to the user's back in order to provide optimal lower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

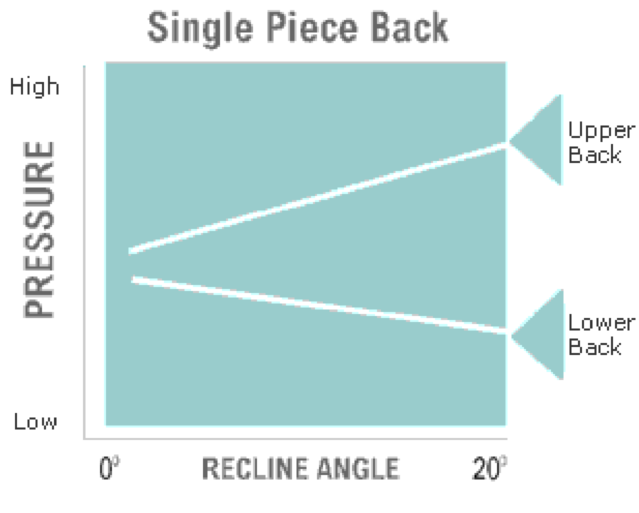
A common feature in current office chairs is the ability to recline on the backrest. However, many people who are smaller in stature cannot take advantage of this feature because the design of the support system does not allow them to recline easily. Researching the interaction between different size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

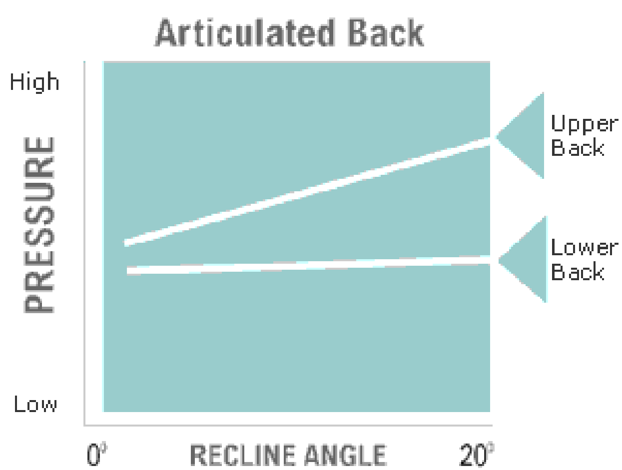


As a person reclines on the backrest of a chair, the amount of force necessary to support a safe and comfortable recline also increases. Carefully measuring recline forces has revealed that in most chair designs smaller people need a smaller increase in support force than larger people. Although most 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 pres-sure at the lumbar curve of the lower back and increased pressure at the thoracic curve of the upper back when the user reclines. 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). 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.

References:

Hubbard R: et al New Biomechanical Models for Automobile Seat Design. Proceedings of Society of Automotive Engineers International Congress and Exposition, 1993

Kelsey.JL. White AA III: Epidemiology and impact on low back pain. Spine. 1980;5(2):133-142

Faiks F, Reinecke S: Measuring the shape of the back while changing one's posture during sitting. Ergonomics Society. Taylor & Francis. UK, April 1998

Reinecke S, Weisman G, Wilder P, Pope M; Effect of seating posture on pressure distribution. Proc. RESNA 10th Annual Conference, San Jose, CA. 1987