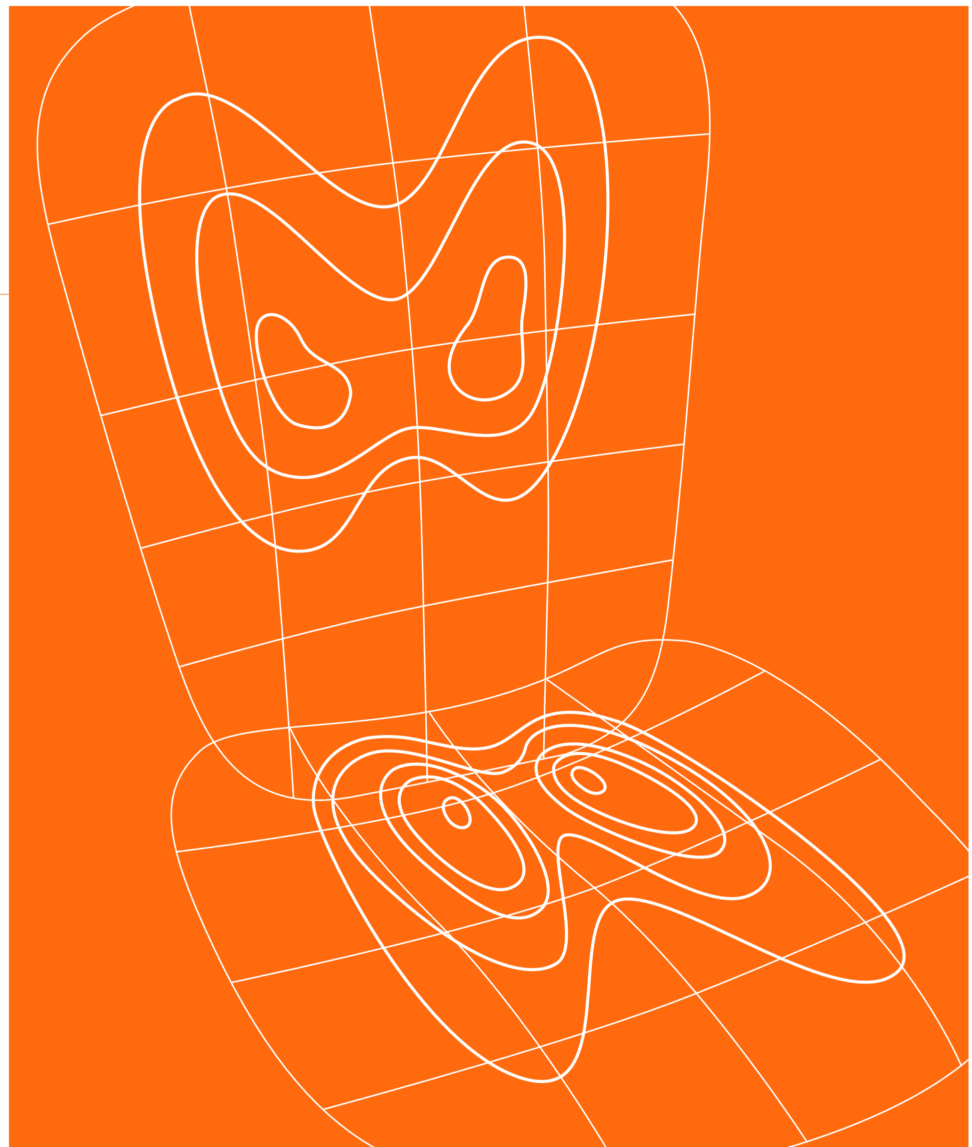
Herman Miller

The Art of Pressure Distribution

Ergonomic criteria for the design of adaptive suspension work chairs



A chair should be topographically neutral.
The perfect work chair would conform equally well to all body shapes, sizes, and contours without applying circulation-restricting pressure anywhere.

Pressure mapping shows how seated body pressure is distributed. Red indicates peak pressure areas; orange, yellow, green, blue, and purple indicate decreasing pressure areas.

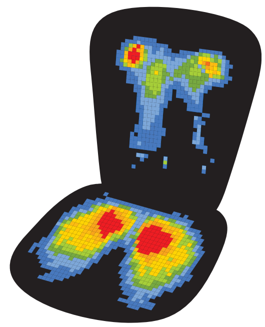


Figure 1

Sitting in a reclined position in a chair with topographically neutral support distributes pressure across the thoracic area and away from the spine.

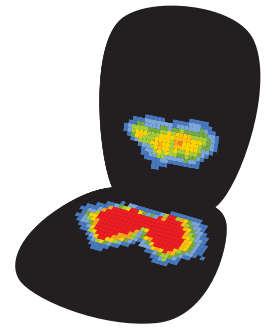


Figure 2

Sitting in a sling-type chair puts pressure on the gluteus maximus muscles at the sides of the buttocks as well as on the heads of the femur bones and sciatic nerves.

What We Know: Surface pressure can cause discomfort while sitting. People of different body weights and builds distribute their weight on a chair in similar patterns, but pressure intensity and areas of distribution vary from person to person. Good pressure distribution in a chair focuses peak pressure under the sitting bones in upright postures and in the lumbar and thoracic areas in reclined postures.

Correct pressure distribution is critical to seated comfort (Grandjean *et al.* 1973). A high level of surface pressure can constrict blood vessels in underlying tissues, restricting blood flow, which the sitter experiences as discomfort.

What may seem like a small interference in pressure distribution can have a profound effect. For example, sitting on your wallet may seem harmless, but Gunnar Andersson MD, an orthopedic surgeon specializing in spinal and back injuries and chairman of orthopedics at Rush Presbyterian/St. Luke's Medical Center in Chicago, tells Herman Miller that there are severe consequences to sitting on your wallet. "The wallet is in a place where, when you sit, it's pushing right on the sciatic nerve, and because of the position of the wallet, you're sitting off center, with one side higher than the other, so to sit up straight, you have to curve your spine. This puts an uneven load on the sacroiliac joints and on the lower back. It's a terrible idea to sit with your wallet in your back pocket."

Researchers have experimented with a number of technologies to measure surface pressure distribution and its relationship to chair comfort. Most recently, thin, flexible, pressure-sensitive mats connected to computers have been used to "map" the pressure-distribution properties of seating elements in office, automotive, and medical applications. These sensor-lined mats are draped over the chair's seat pan and backrest; when a test subject sits in the chair, pressure gradients show up as different colors on the computer screen, mapping the peak pressure zones experienced by the sitter (Reed and Grant 1993).

Using pressure maps to evaluate chair design is not a straightforward process; different people sitting in the same chair may exhibit very different pressure maps, depending on their weight and build. For instance, while heavier people generally show higher pressure peaks than lighter people, a heavy, pear-shaped person may exhibit lower pressure peaks than a lighter person with less internal padding to sit on (Reed *et al.* 1994).

Because of the large variance in peak pressure patterns among people of different sizes and shapes, it is difficult to prescribe ideal seat and back contours or softness levels that would minimize uncomfortable pressure points for all sitters. We do know, however, that the skin and fat tissue under the ischial tuberosities, or "sitting bones," is less sensitive to pressure than the muscle tissue surrounding the tuberosities and better suited to carrying load than the other tissues of the buttocks and thighs (Reed *et al.* 1994).

In addition, chairs with backrests that exhibit pressure peaks in areas of the lumbar away from the spine have been judged more comfortable than chairs that show lower pressure gradients in these regions (Kamijo *et al.* 1982), although pressures resulting from a very firm lumbar support can cause discomfort (Reed *et al.* 1991a, 1991b). Our own research has found a strong correlation ($r=.638$; $n=978$) between overall seated comfort and the degree to which the sitter perceives the chair as providing good lower back support.

Therefore: A comfortable chair will produce pressure distributions for a wide anthropometric range of users that show peaks in the area of the ischial tuberosities when the sitter is in an upright posture and areas of the back away from the spine when the sitter is in a reclining posture (Figure 1).

Design Problem: Design a chair that is "topographically neutral," so that the sitter's body, and not the underlying structures of the seat pan and backrest, determines peak pressure areas.

Many office work chair seats and backrests are made of metal and plastic structural parts padded with foam and upholstered in fabric. Chair designers try to minimize circulation-restricting pressure with the right combination of contour and padding,

Figure 3

Sitting in an upright position in a chair with lumbar support shows bands of pressure where the lower back comes in contact with the lumbar support.

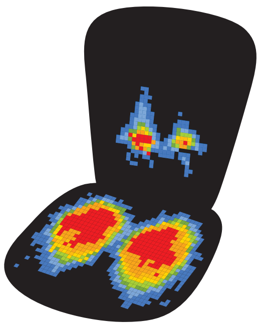


Figure 4

Sitting in an upright position in a chair with postural support distributes pressure across the sacral-pelvic, lumbar, and thoracic areas.

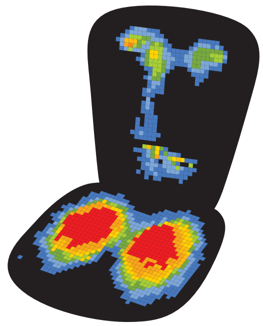
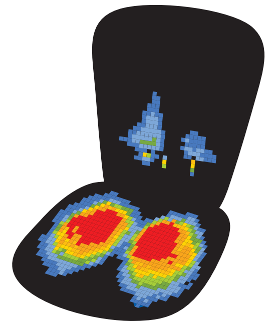


Figure 5

Sitting in an upright position in a chair without postural support limits the distribution of pressure across the sacral-pelvic, lumbar, and thoracic areas.



curving the chair's structure away from pressure-sensitive areas of the body and cushioning it with foam.

This is difficult to achieve in a design that must serve a diverse user population. Seat shapes that work well for the bone structure and leg length of a tall male are likely to hit a short female in all the wrong places. Foam density that provides optimal comfort for a small, plump woman may "bottom-out" under a heavier but leaner man. Extra padding does not necessarily solve the problem, because a too-soft seat can put pressure on the gluteus maximus muscles at the sides of the buttocks as well as on the heads of the femur bones and the sciatic nerves, resulting in the kind of discomfort experienced when sitting in a sling-type playground swing or a director's chair (Figure 2) (Zacharkow 1988, Hertzberg 1958).

Design Solution: Minimize chair structure and eliminate the need for foam padding by tensioning a material that provides dynamic support. Engineer the chair so the structure fits differently proportioned persons.

Instead of foam cushions that may impose improper contours, a work chair with a topographically neutral suspension will conform to the shape of the person who sits in it. Using pressure-mapping technology, we experimented with different tensions across the backrests and seats, fine-tuning our suspension designs to produce the desirable distribution patterns: peak pressure zones under the ischia, with wide distribution of lower values along the thighs and across the back, avoiding the spine and the area behind the knees.

We were particularly interested in achieving a wide distribution of pressure across the backrest. While the seat of a chair typically carries most of the body's weight, the more one reclines, the more weight is transferred to the backrest. We also know that a chair's tilt range and kinematics—and the extent to which it mimics the body's natural pivot points and more naturally transfers weight from the seat to the backrest—will encourage or discourage reclining. So the backrest may be called on to support a higher percentage of the sitter's body weight.

During development of our adaptive suspension work chairs, we tested subjects of varying heights, weights, and critical body dimensions in different chair prototypes, controlling seat height and back-angle reclinations. Experimenting also with varying levels of perforation and tension of the suspension material, we worked to achieve a pressure-distribution pattern for a variety of body types that was high and wide across the sitter's back, distributing weight away from the spine.

A topographically neutral seat and backrest, when designed to support a wide range of weights and proportions, ensured that people would get the benefits of the chair's carefully tuned pressure distribution. Positioned comfortably on an adaptive suspension material, the sitter's body, rather than the chair's structure, dictates pressure distribution.

What We Know Now

Pressure mapping technologies that measure the distribution of pressure across a chair's backrest and seat pan have been refined since they were first used in the development of the Aeron® chair. They now provide more detailed and accurate readings of the levels of pressure experienced by the sitter. Although early pressure distribution maps were made with subjects always sitting in reclined postures, we now know that small changes in the tilt of the backrest can result in large differences in the way pressure is distributed across the sitter's back (Aissaoui *et al.* 2001). Using more advanced technology, we are now able to map and compare pressure distribution patterns in upright as well as reclined positions.

Understanding comfort and pressure distribution for sitters in upright postures has become more critical as a growing percentage of office tasks are accomplished using computer technology. Sitting behaviors research conducted by Herman Miller indicates that people performing computer-related tasks spend a greater percentage of their time in upright rather than in reclined postures (Dowell *et al.* 2001). Our understanding of optimal distribution patterns for people sitting in an upright posture has evolved. In addition to looking for chair seat pressure map results that show peaks in the area of the ischial tuberosities or “sitting bones” and no significant pressure under the backs of the thighs near the knees, we look for backrest patterns that display particular patterns of pressure distribution depending on the sitter’s posture.

Pressure map studies of sitters in upright positions show bands of localized pressure where the lower back comes into contact with the chair’s lumbar support, but little pressure distribution across the rest of the back (Figure 3). This stands in sharp contrast to pressure maps of sitters in reclined postures, which show distributed pressures in the thoracic area near the scapula and away from the spine (Figure 1).

Hypothesizing that improved back support for upright postures would produce pressure distribution that more closely resembles that of reclining postures, we did pressure map studies of people sitting in adaptive suspension chairs with postural support. Chairs with sacral-pelvic support, designed to stabilize the pelvis, help to maintain natural spinal curvatures without applying pressure to the lumbar area.

Maps of chairs with postural support show that pressure is distributed over a greater area, including the sacral-pelvic and thoracic as well as lumbar regions of the back (Figure 4) than in chairs without posture support (Figure 5) or those with lumbar support only. From these pressure-mapping results, we know that work chairs designed with postural support will improve overall support for upright postures.

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Credits

Jerome Caruso is the designer of Celle™ chair. Caruso's designs extend beyond seating and the workplace. As Sub-Zero's designer for over 20 years, Caruso has been influential in shaping the look and function of kitchen products and appliances. The innovative mind and design expertise of Caruso is evident in the more than 75 design patents he holds. Jerome and his son, Steven, designed Herman Miller's Reaction® chair in 1998.

Don Chadwick co-designed, along with Bill Stumpf, the groundbreaking ergonomic Equa® and Aeron® chairs for Herman Miller. He has been instrumental in exploring and introducing new materials and production methods to office seating manufacturers.

Bill Dowell, C.P.E., leads a team of researchers at Herman Miller. His recent work includes published studies of seating behaviors, seated anthropometry, the effect of computing on seated posture, the components of subjective comfort, and methods for pressure mapping. Bill is a member of the Human Factors and Ergonomic Society, the CAESAR 3-D surface anthropometric survey, the work group that published the BIFMA Ergonomic Guideline for VDT Furniture, and the committee that revised the BSR/HFES 100 Standard for Human Factors Engineering of Computer Workstations. He is a board-certified ergonomist.

Gretchen Gscheidle is a product researcher at Herman Miller. Educated as an industrial designer, Gretchen now applies her creativity and problem-solving skills in her role as researcher on cross-functional product development teams. She has been the research link in the company's seating introductions beginning with the Aeron chair in 1994. Her research focuses on laboratory studies of pressure distribution, thermal comfort, kinematics, and usability, as well as field ethnography and user trials. Gretchen is a member of the Environmental Design Research Association and the Human Factors and Ergonomics Society and represents Herman Miller on the Office Ergonomics Research Committee.

Studio 7.5, located in Berlin, Germany, designed the Mirra® chair. Studio 7.5 is composed of Burkhard Schmitz, Claudia Plikat, Carola Zwick, Nicolai Neubert, and Roland Zwick. With the exception of engineer Roland Zwick, the designers are cofounders and partners of the firm, which opened in 1992, and also teachers of industrial design and product design at universities in Germany. An interest in the tools that define how people work has led Studio 7.5 to design software interfaces, office seating, and medical equipment. Studio 7.5 has been collaborating with Herman Miller since the mid 1990s.

Bill Stumpf has been studying behavioral and physiological aspects of sitting at work for more than 30 years. A specialist in the design of ergonomic seating, his designs include the Ergon® chair, introduced by Herman Miller in 1976 and, with Don Chadwick, the equally innovative Equa and Aeron chairs.