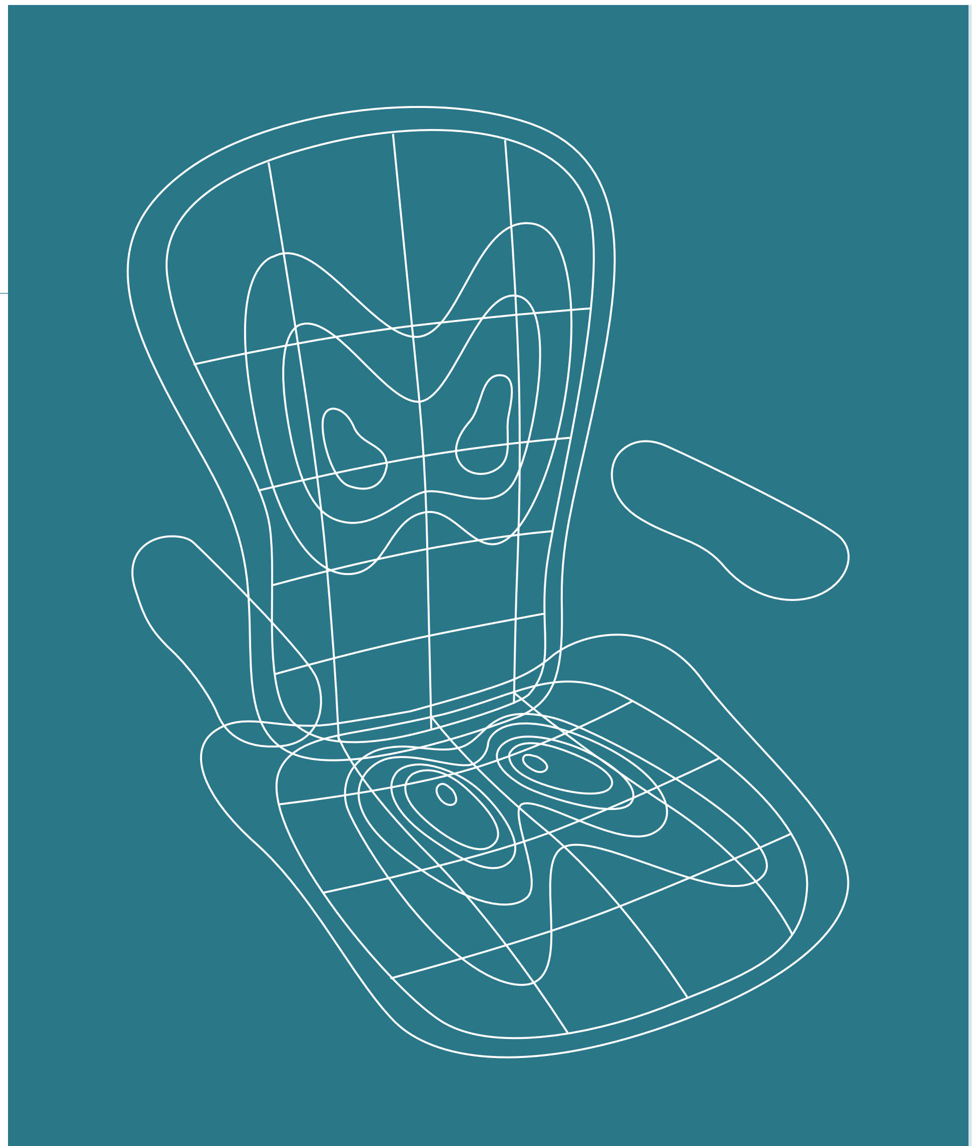
Herman Miller

The Art of Pressure Distribution

Ergonomic criteria for the design of the Aeron® chair

by Bill Stumpf, Don Chadwick, and Bill Dowell



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.

Figure 1

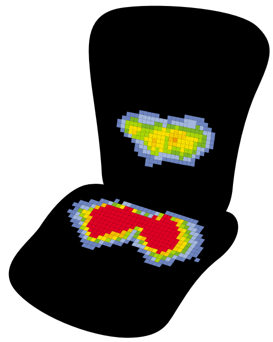
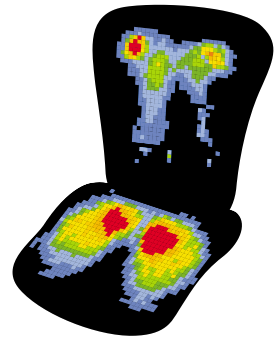


Figure 2



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

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 area 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.

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 straight-forward 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 cushion 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 lower back 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 users from a wide anthropometric range 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 assumes a reclining posture (Figure 2).

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.

Office work chair seats and backrests are typically 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, 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 1) (Zacharkow 1988, Hertzberg 1958).

Figure 3

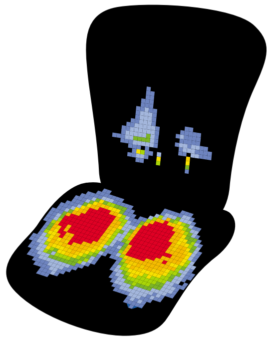


Figure 4

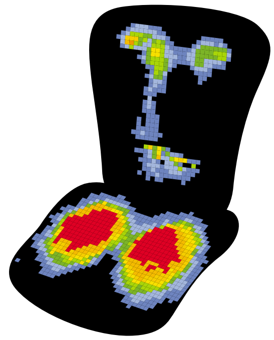
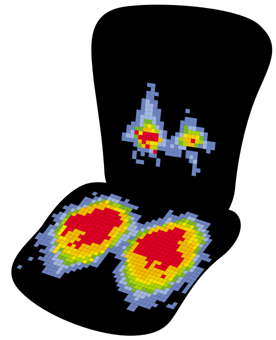


Figure 5



Design Solution: Minimize chair structure and eliminate the need for foam padding by tensioning a material with two-way stretch inside a contoured frame. Dimension the chair in three sizes so the frame fits differently proportioned persons.

Instead of foam cushions that may impose improper contours, the Aeron chair uses the Pellicle® suspension, an elastic material that conforms to the shape of the person who sits in it. Using pressure-mapping technology, we experimented with different tensions across the backrest and seat pan, fine-tuning the Pellicle suspension 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. Because the chair's kinematics encourage deeply reclined postures, the Aeron backrest may be called on to support an unusually high percentage of the sitter's body weight. During development, we tested subjects of varying heights, weights, and critical body dimensions in different prototypes of the Aeron chair, controlling seat height and back-angle reclinations. Experimenting with different methods of tensioning the Pellicle on the frame, 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.

Stretching the Pellicle material across seat and backrest frames proportioned in three sizes—for the three models of the Aeron chair—ensured that people representing a wide range of weights and proportions would get the benefits of the chair's carefully tuned pressure distribution. Sitting in an appropriately sized Aeron chair, a person has virtually no contact with the frame. Positioned comfortably on the elastic Pellicle, the sitter's body, rather than the chair's structure, dictates pressure distribution.

What We Know Now

Pressure mapping techniques and our understanding of how pressure should be distributed in upright postures have evolved since the Aeron chair was designed in 1994. 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 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 than in reclined postures (Dowell *et al.* 2001).

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 5), 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 2).

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 Aeron chairs equipped with PostureFit™ technology, Designed to stabilize the pelvis through a custom-contoured fit of the sacral-pelvic region, the PostureFit device helps to maintain natural spinal curvatures without applying pressure to the lumbar area.

These maps show that pressure is distributed over a greater area, including the sacral-pelvic and thoracic as well as lumbar regions of the back, in chairs utilizing the PostureFit device (Figure 4) than in chairs not equipped PostureFit (Figure 3) or those with lumbar support. The results indicate that the PostureFit technology improves support for upright postures.

References

Aissaoui *et al.* (2001), "Analysis of sliding and pressure distribution during a repositioning of persons in a simulator chair," *IEEE Transactions on Neural Systems & Rehabilitation Engineering* 9(2): June.

Dowell *et al.* (2001), "Office Seating Behaviors: and investigation of posture, task, and job type," *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting.*

Grandjean *et al.* (1973), "An ergonomic investigation of multipurpose chairs," *Human Factors.*

Hertzberg (1958), "Seat comfort," *Annotated Bibliography of Applied Physical Anthropology in Human Engineering.*

Kamijo *et al.* (1982), *"Evaluation of seating comfort," Society of Automotive Engineers Technical Paper 820761.*

Reed and Grant (1993), "Development of a measurement protocol and analysis techniques for assessment of body pressure distributions on office chairs," technical report, University of Michigan Center for Ergonomics.

Reed *et al.* (1991a), "An investigation of driver discomfort and related seat design factors in extended-duration driving," *Society of Automotive Engineers Technical Paper 910117.*

Reed *et al.* (1991b), "An investigation of automotive seating discomfort and seat design factors," final report, University of Michigan Transportation Research Institute.

Reed *et al.* (1994), "Survey of auto seat design recommendations for improved comfort," technical report, University of Michigan Transportation Research Institute.

Zacharkow (1988), *Posture: Sitting, Standing, Chair Design, and Exercise.*

Credits

A specialist in the ergonomics of seating design, *Bill Stumpf* has been studying behavioral and physiological aspects of sitting at work for more than 20 years. He designed the Ergon® chair introduced by Herman Miller in 1976 and, with Don Chadwick, the equally innovative Equa® and Aeron chairs.

Codesigner of two groundbreaking ergonomic work chairs for Herman Miller, *Don Chadwick* has been instrumental in exploring and introducing new materials and production methods to office seating manufacture.

Bill Dowell 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 antropometric 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.

For more information about our products and services or to see a list of dealers, please visit us at www.HermanMiller.com or call (800) 851 1196.