The Art of Pressure Distribution

Ergonomic Criteria for the Design of a New Work 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 and sizes without applying circulation-restricting pressure anywhere.

What We Know

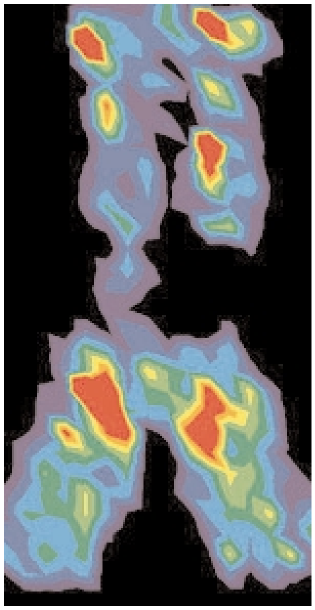
Surface pressure can cause discomfort while sitting. People of different body weights and builds distribute their weight on a chair in similar patterns, but pressure intensity and area of distribution vary from person to person. Good pressure distribution in a chair focuses peak pressure under the sitting bones and in the lumbar area.

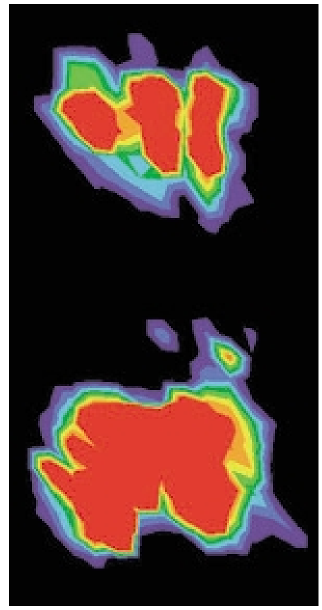
Correct pressure distribution is critical to seated comfort (Grandjean et al. 1973). Surface pressure has been found to constrict blood vessels in underlying tissues, restricting blood flow, which the sitter experiences as discomfort.

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 office and automotive seating. 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) (see illustration).

Using pressure maps to evaluate chair design is not a straightforward process, however, as 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 buttock and thigh (Reed et al. 1994).





In addition, chairs with backrests that exhibit pressure peaks in the lumbar area away from the spine have been judged more comfortable than chairs that show lower pressure gradients in the region of the lower back (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 and in the lumbar region, away from the spine (see illustration above).

Design Problem

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

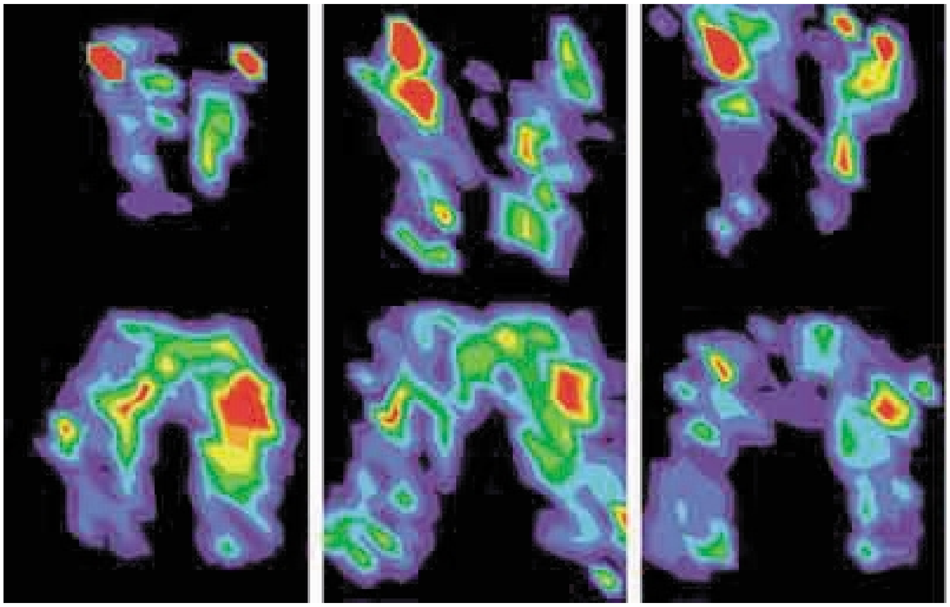
Office work-chair seats and backs are typically made of metal and plastic structural parts padded with foam and upholstered in fabric. Chair designers try to minimize circulation-restricting pressure with the right combination of contour and padding, curving the chair's structure away from pressure-sensitive 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 (Zacharkow 1988; Hertzberg 1958) (see illustration above).

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 and behind the lumbar curve, with wide distribution of lower values along the thighs and across the back and away from 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. Using a Jasco Force Management System, we tested subjects of varying heights, weights, and critical body dimensions in different prototypes of the Aeron chair. Seat height was relative to each person's popliteal height; back-angle reclination remained constant for all users. 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 (see illustration).

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 in the elastic Pellicle, the sitter's body, rather than the chair's structure, dictates pressure distribution.

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. Co-designer 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. His award-winning design for modular reception seating was introduced by Herman Miller in 1974. As research program manager for Herman Miller, *Bill Dowell* has studied anthropmetry and pressure distribution and conducted field research on the components of subjective comfort. He is a member of the Human Factors and Ergonomic Society committee revising the ANSI/HFES VDT Workstation Standard.