HermanMiller

The Kinematics of Sitting

Ergonomic criteria for the design of the Aeron® chair

by Bill Stumpf, Don Chadwick, and Bill Dowell

A chair should move the way the body moves.

In the best of all possible worlds, the body is free to position itself spontaneously, constrained only by gravity. A person seated at work should be able to move freely and unselfconsciously from computer-related tasks to more relaxed or interactive postures. The work chair should follow along, providing optimal support whether the body is in motion or at rest.

Figure 1

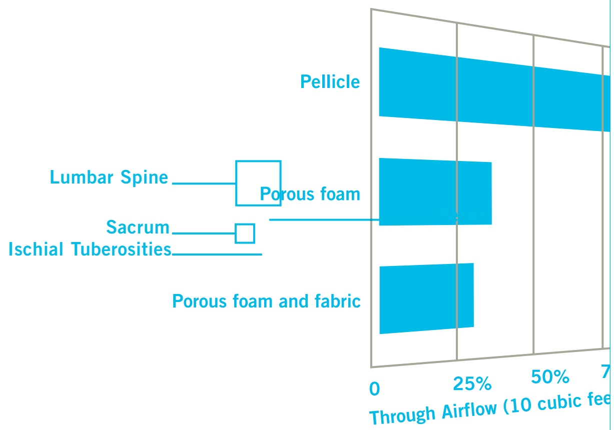
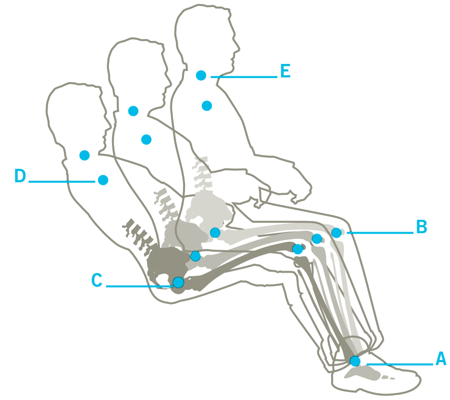


Figure 2



What We Know: People assume many different positions when they sit at work. Movement while seated is healthy. People rarely adjust their chairs.

People who sit at their work rarely sit still. Field studies of people working at VDTs (Grandjean *et al.* 1983, Grieco *et al.* 1986) found them assuming a wide variety of postures even while performing a single task. Our own research and observations of seated behavior in the office identified three distinct modes of sitting at work:

- Forward sitting: used for performing work on the plane of a desk or for interacting with office equipment (Mandal 1985). (People of small stature working at a fixed-height work surface are virtually forced to assume this posture.)
- Slightly reclined sitting: used for conversation, telephoning, keyboarding, and mousing. Research shows that it is a preferred work posture (Grandjean 1980, Laubli 1986).
- Deeply reclined sitting: used for resting, reading, and, in some cases, keyboarding.

Experts agree that changing positions at work has important benefits for the sitter: Muscle movement serves as a pump to improve blood circulation (Schoberth 1978), movement of the spine nourishes the intervertebral discs (Holm and Nachemson 1983), reclining while seated pumps nutrients to the discs (Andersson 1981), and continuous movement of joints is therapeutic for joints and ligaments (Reinecke 1994). But if a chair requires its user to adjust it in order to shift into another position, it may have the effect of keeping the sitter undesirably still. Studies of people sitting at work indicate that they tend not to use manual adjustments on their chairs (Kleeman and Prunier 1980, Stewart 1980).

Therefore: A good work chair allows a person to sit comfortably and properly supported in each of the three basic work postures and to move spontaneously between them while maintaining that comfort and support.

Design Problem: Support the lower back's natural curve in all the sitting postures assumed at work without requiring the sitter to make conscious, active adjustments to the chair.

In the seated position, the body does not automatically adjust to achieve optimal spinal and pelvic alignment. The unsupported lower back tends either to straighten or to slump in an outward, kyphotic curve rather than the more healthful inward, lordotic curve it naturally assumes in a standing position (Andersson *et al.* 1979).

Studies of the seated body have shown that the position of the pelvis determines the shape of the spine (Schoberth 1970), due to the relatively rigid connection between the sacrum (the base of the spine) and the pelvis. In a seated position, the pelvis tends to rotate backward, causing the lumbar spine to flatten or curve outward (Andersson *et al.* 1979). Providing support that stabilizes the pelvis to prevent backward rotation ensures a natural curve, whereas applying pressure to the lumbar spine does not (Kroemer 1971, Grandjean 1980, Zacharkow 1988). A chair that provides support that nests the sacral-pelvic area as well as a deliberately placed target to engage the ischial tuberosities (sitting bones) creates a pocket that holds the pelvis in its natural position (Figure 1).

This pelvic pocket is relatively easy to construct in a chair in which the back and seat remain fixed, but difficult to design into a work chair that tilts. Consider, for example, work chairs in which the backrest reclines a fixed number of degrees for every degree of seat movement. As the seat moves down and the backrest reclines, the two tend to move apart (as evidenced by the fact that the sitter's blouse or shirt tends to come untucked in the process). In this case, support for the sacral-pelvic region moves to a higher position on the back, which can have the effect of rotating the pelvis backwards to create more kyphotic lumbar curve.

Figure 3

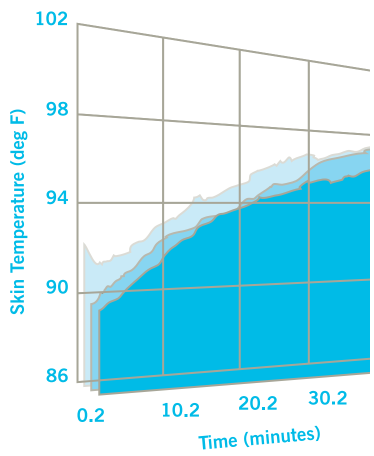


Figure 4

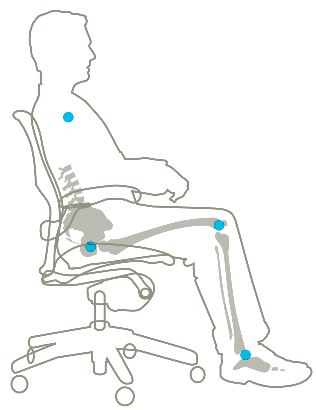
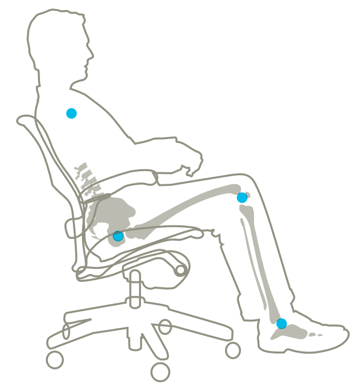


Figure 5



Design Solution: Provide support that nests the sacral-pelvic area and tilt action that echoes body mechanics.

The design of the Aeron chair bypasses current mechanical models in favor of a tilt geometry based on human body linkages. Bill Stumpf's research with Roger Kaufman at George Washington University identified the relationship of the body's major pivot points as it moves between the three basic seated postures. If it were possible for the body to move from an upright seated position to a reclined position without the support or constraints of a chair, this is what it would look like (Figure 2):

- With the feet flat on the floor and a slightly open angle between the lower and upper leg, all of the body's major joints pivot about the center of the ankle joint (A).
- The knee joint (B) actually doesn't pivot so much as travel in a gentle arc.
- The hip joint (C) follows an inclined arched path about a line connected to the ankle pivot (A) and pivots as the trunk-to-thigh angle opens.
- The arms pivot about the shoulder joint (D).
- Throughout the movement the head pivots about the cervical spine (E) to maintain a constant relationship between the face plane and a visual target.

The linkages of the Aeron chair were designed to echo these body linkages in a movement that corresponds (coheres) to the natural movement (kinematics) of the human body. We call it the *kinematic coherence* model and refer to the mechanism as the Kinemat® tilt.

- In an upright position, the self-shaping ischial target in the seat pan and the contours of the backrest create a pocket to hold the pelvis at a slight forward tilt to enhance lordosis (Figure 3).
- As the chair reclines, the feet remain flat on the floor as the lower leg pivots around a stationary ankle joint. The backrest drops about the hip pivot point, maintaining the same point of contact between the backrest and the pelvis throughout the range of movement (Figure 4).
- The seat pan drops about a pivot point in the ankle joint in a synchronous relationship to the backrest to maintain the pelvic pocket and preclude lumbar shear (in which the chair's lumbar support moves away from the sitter's lumbar region) in all tilt angle positions. Armrests move with the backrest to support the arms as they drop back in their natural rotation at the shoulder joint (Figure 5).

The Aeron chair supports the body's natural linkages at all points, in all positions. As the sitter moves from upright to reclined, the feet are not lifted from the floor, as in column-tilt chairs; the back support does not lose contact with the sitter's back, as it does in many synchronous tilt chairs; the arms do not slide back on the armrests, as they do in chairs that have armrests attached to the seat pan rather than the backrest. In the Aeron chair, the sitter pays no penalty—in terms of comfort, support, or effort expended—to achieve the benefits of seated movement.

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Credits

Bill Stumpf studied 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.

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, 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.

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