**Aeron: The Kinematics of Sitting**

Ergonomic criteria for the design of a new work 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.

**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 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).

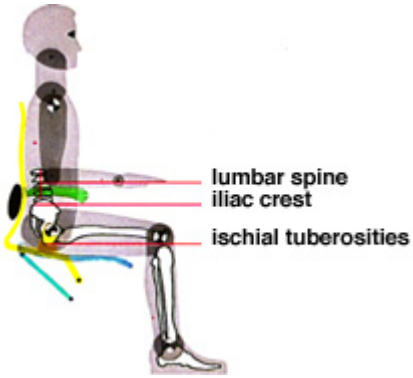
But if a chair requires its user to adjust it in order to shift into another position, it may have the effect of keeping the sitter undesirably still. Studies of people sitting at work indicate that they tend not to use manual adjustments on their chairs (Kleeman and Prunier 1980, Stewart 1980). Our own observations in the field lead us to believe that people are not likely to make conscious postural or mechanical adjustments that might be required to provide the best lower back support when moving from one position to another.

***Therefore:***
*Therefore 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).*

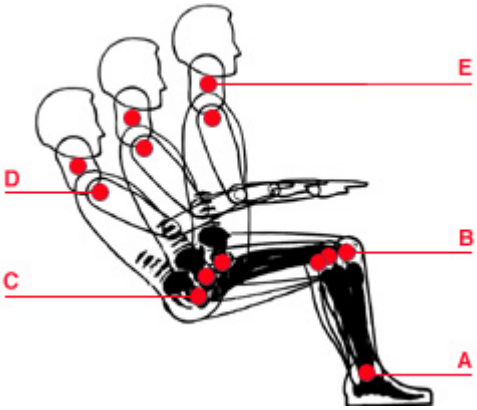
*Studies of the seated body have shown that the position of the pelvis determines the shape of the spine (Schoberth 1970), due to the relatively rigid connection between the base of the spine and the pelvis. A slightly forward pelvic tilt automatically produces the optimal lumbar curve. In a seated position, pressure applied to the iliac crest at the top of the pelvis creates the appropriate tilt and ensures a natural curve, whereas applying pressure to the lumbar spine does not (Kroemer 1971, Grandjean 1980, Zacharkow 1988). A chair that provides support for the iliac crest and a deliberately placed target to engage the ischial tuberosities (sitting bones) helps to tilt the pelvis forward and creates a pocket that holds it in this optimal position.*




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 iliac crest moves to a higher position on the back, which can have the effect of rotating the pelvis backwards to create a more kyphotic lumbar curve.

***Design solution:***
*Provide support for the iliac crest 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.*

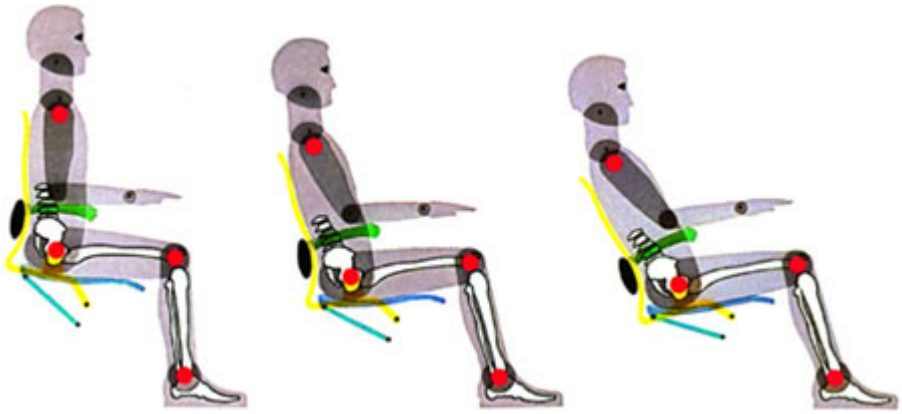



With the feet flat on the floor and a slightly open angle between the lower and upper leg, all of the body's major joints pivot about the center of the ankle joint (A).

- *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. As it moves from forward to reclined positions, the chair automatically adjusts to maintain the pelvic positioning that optimizes lordosis. Because this movement 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 forward pressure on the iliac crest created by the contour of the backrest and the adjustable lumbar pad create a pocket to hold the pelvis at a slight forward tilt to enhance lordosis.*
- *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 iliac crest throughout the range of movement.*
- *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.*

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 lumbar support does not move away from its supportive position at the iliac crest, 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.

*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.*