Herman Miller

Supporting the Biomechanics of Movement

The science and research behind the Mirra™ chair

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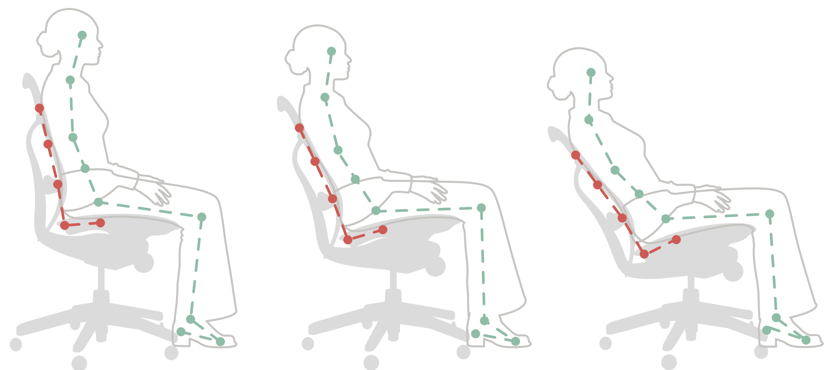
A work chair's movement should mirror the user's movement.
Tilt is to a chair what suspension is to a car. A work chair can offer a great seat and back design, but without a great tilt, the work chair will not move with and respond to the user's movements and postures.

Figure 1

Simultaneously measuring the movement of the chair (red dots) and the sitter (blue dots) while reclining helped us to determine the body's natural pivot locations and, thereby, design the chair's physical pivot points to mimic those of the body.



What We Know: The seated body has natural pivot points at the hip, knee, and ankle. The ideal work chair will mimic as closely as possible those pivot points, thus allowing the sitter to move naturally and with ease around the chair's engineered pivot points. The pivot points within the user's body and the movement of the chair should work together to create a tilt movement that doesn't stress or lift the body.

The type and engineering of a work chair's tilt will make the difference between dynamic and static seating.

A chair with a center tilt pivots around a physical pivot point under the center of the chair's seat. In this simple design, the chair's back and seat usually move together in a 1:1 ratio. This means the sitter's feet will come off the floor when leaning back, and it will be difficult to hold a reclined position in any relaxed fashion. Because the sitter's feet come off the floor, the chair with center tilt will give the seated user a feeling of instability.

A chair with a knee tilt pivots the chair's seat around a physical pivot point under the seat and behind the user's knees. A chair with a knee tilt pivots the seat and back, though not necessarily at the same rate. Because the seat-to-back ratio is still fairly even, the user's body angles will not comfortably open and relax when reclining.

A chair with an ankle tilt pivots the seat around a virtual pivot point located near the user's ankle. The virtual ankle pivot provides user control over the recline action of the chair. The user's feet will stay on the floor, which lends greater stability and provides user control over the recline action of the chair.

A synchronous tilt establishes a prearranged relationship between the movement of the chair's seat and back. This relationship allows the body to open up as the user reclines—important to prevent muscle fatigue and improve circulation.

A chair with a hip pivot rotates around a virtual hip pivot point located near the user's hips. The virtual hip pivot between the seat and back helps the user to maintain full contact with the chair's seat and back through the full range of recline. The virtual hip pivot closely mimics the body's hip (pelvis) when the sitter tilts back in a chair.

A work chair that has a synchronous tilt and can closely approximate the ankle and hip pivots of the body will provide the most comfortable and relaxed experience for the sitter.

Therefore: The more closely a work chair moves like the body, the more likely it is that the seated user will move his or her body.

The ideal work chair will mimic the body's natural pivot points and allow the sitter to move naturally around the chair's engineered pivot points. A work chair needs a synchronous tilt to allow the seated body to open up as it reclines.

And because gross torso postures change approximately 53 times an hour, or about once every minute, the ideal work chair must allow the user's body to remain relaxed as postures are changed and maintained (Dowell *et al.* 2001).

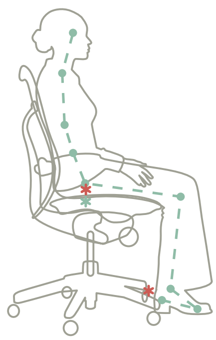
Design Problem: Tilt is to a chair what suspension is to a car. A work chair can offer a great seat and back design, but without a great tilt, the work chair will not support the user's movements and postures.

When sitters move through the tilt range of a typical work chair, they might be supported at the beginning and at the end, but not equally through the entire "ride" of the chair. Sitters need to have the same level of support throughout the travel range. They need to feel balanced and supported while moving anywhere within the recline range.

Design Solution: The tilt motion of the chair builds upon kinematic research that helped to develop the Aeron® chair. The Mirra chair is designed to echo, or mirror, the natural pivot points (hip, knee, ankle) of the human body, and to transfer weight from the seat to the back without changing the relationship between the chair's back and the sitter's back. Its synchronous tilt allows the user, in a sense, to forget the chair is there. Mirra's back-to-seat ratio during recline is a comfortable 2:1.

Figure 2

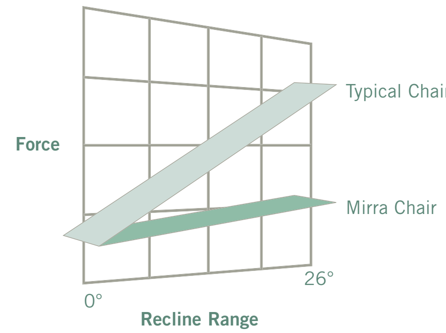
Pivot points on the Mirra chair are located in physical proximity to the natural pivot points of the human body.



* Mirra chair hip and ankle virtual pivots
* Mirra chair physical pivot point

Figure 3

The result of a constant application of resistance to the user's movement means that the user doesn't have to work hard to recline. This is achieved through Harmonic™ tilt.



Mirra's designers were able to refine the chair's motion by locating its pivot points extremely closely to the natural pivot points of the human body (Figure 2).

When the sitter tilts back in the chair, the body revolves around the pelvis, or the hip pivot. In Mirra's design, the chair's virtual hip pivot closely approximates that of the sitter's natural hip pivot. This mirroring reduces the possibility of shearing, in which the backrest and/or seat moves away from the user's body during recline. Mirra's virtual ankle pivot is located just 4 1/3 inches off the floor, approximating the height of the ankle joint, so that there is no lifting of the heels when the sitter is in a reclined position (Figure 1).

During development, Mirra's designers took advantage of a new measurement tool to evaluate and refine the motion or "ride" of the new chair. Mechanical prototypes of the design were analyzed using a system that records the position of reflective markers located at strategic points on the chair and on the test subject sitting in the chair. The system tracked the motion of these markers as the subject moved from an upright to a reclining posture and back again (Danek *et al.* 1999).

The Mirra chair's tilt design changes the center of gravity as the user moves and reclines. Once the sitter tunes the tilt tension to his or her weight, Mirra takes over. Its tilt responds to the sitter's size and provides balanced support as the sitter moves from an upright posture to a completely reclined one and as it stops anywhere within that recline range (Figure 1).

This is accomplished through the Harmonic™ tilt mechanism, which we also refer to as a virtual variable rate spring. It introduces the notion of a moving fulcrum in the recline mechanism, which truly balances the spring tension and ride to the weight of the user. Typically, any tilt energy source has a single "ride-curve," which moves through the same spring rate regardless of the changing force on the spring (adjusting tilt tension merely rearranges the pre-load to the same spring constant). Hence, large people slip from full upright positions into reclined positions to balance, and smaller people struggle to get a chair to fully recline.

A tilt should produce a characteristic that we call dwell. Dwell provides the user the ability to maintain balance at any position within the recline range of a chair. A chair has to have an energy source to counteract shifting weight when the sitter moves the body's center of gravity. This is especially true if the movement is to mimic the body's natural pivot points. If a chair merely balances shifting weight, its motion is foreign to the natural motions of the body. Mirra's tilt design significantly affects the dwell, and here the chair offers a far more controlled and relaxed movement than most work chairs do.

When a chair reclines, the rate of the tilt's spring provides resistance to the user's force. Typically, this force-to-resistance ratio is linear, meaning the amount of force it takes for the user to recline the first five degrees in the range is less than the force it takes for the same user to recline the last five degrees. In other words, the resistance to the user's movement is not even. But Mirra's tilt is designed to react in a nonlinear way, which means that the sitter will feel the same amount of resistance anywhere with the range of recline. In other words, the sitter experiences the same balanced ride (Figure 3).

The balanced ride of the Harmonic tilt was developed using the concepts of fully automatic tilt balancing and applying them to a simpler tilt. It is like an automatic focus camera, where the user slightly depresses a button and the camera adjusts to the image. Mirra's tilt mechanism utilizes a unique composite leaf spring as the energy source, and by moving its fulcrum in a synchronized fashion through the recline range, the spring rate begins to shift. The result: an XXL-sized user can enjoy a balanced ride through the full cycle of the recline as much as an XS-sized user. The ability of Mirra to adjust will indeed provide a new feeling for larger users, who have come to expect a chair that reclines too quickly and without control and for smaller users, who have come to expect a work chair that can’t recline without exerting an uncomfortable and often impossible amount of energy.

The primary goal throughout the development of the Mirra chair was to design a chair with natural performance—natural meaning intuitive, mirroring the movements of the body—a “friendly companion,” supporting the body without demanding much effort or thought from the sitter. The goal is realized through the Harmonic tilt, which provides a natural motion for the body, both as it reclines and as it stops anywhere within the recline range.

References

Danek, Thelen, and Veldman (1999), “Chair Tilt Analysis: Comparison Study,” Hope College Department of Physics and Engineering.

Dowell, Green, and Yuan (2001), “Office Seating Behaviors: An Investigation of Posture, Task, and Job Type,” *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting.*

Credits

Studio 7.5, located in Berlin, Germany, is composed of Nicolai Neubert, Claudia Plikat, Burkhard Schmitz, Carola Zwick, 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 late 1990s.

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.