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ERGONOMICS REVIEW

Balans seating

for VARIÉRUSA

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Ergonomics review: VARIÉRUSA

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Please note:

The following paper reviews research findings relevant to the Balans design concept.

The research literature that examined so-called "kneeling chairs" consistently identified their use of these Balans chairs in testing.

Other seats that may be referred to as "kneeling chairs" despite quite different design dimensions and may or may not reflect the same scientific research principles.

About this paper

The following is a general review of the scientific literature relevant to the design and use of the Balans® seat concept - and its comparison with conventional and alternative seating. It was written by Rani Lueder, CPE of Humanics ErgoSystems, Inc. for VARIÉRUSA.

The Balans® seating concept was developed in the 1970's by Hans Christian Mengshoel and designer Peter Opsvik[1] in response to a growing recognition of the limitations of conventional seating from Mandal (1976).

This Balans design is characterized by an open thigh-torso angle and lower leg support that flex (bend) the knees and support balanced movement. Although often referred to as a “kneeling chair" or a "knee-supported chair", the actual locus of lower leg support on the Balans seat is below the knees and at the shin to reduce potential loading at the knees.

Figure 1. The Balans design concept is characterized by an open angle between the thighs and torso utilizing lower leg support to counter the effects of gravity.

Balans chairs are designed with the aim of encouraging neutral postures and facilitating postural changes. Although early versions of the chair provided limited adjustability, subsequent generations incorporated a range of features to include seat depth and height depth adjustability, swivel, back and frontal (chest) support and rocking.

[1] The early versions of the Balans chairs that were based on Mengshoel’s design concept were designed by Norwegian designers Svein Gusrud and Oddvin Rykken as well as Peter Opsvik.

Overview (what we have learned)

Long-term sitting in conventional postures increases the risk of developing chronic musculoskeletal disorders, particularly involving the neck, back and shoulders. The rates of spinal disorders in particular have continued to increase in the general population (Harkness et al, 2005) and have become more severe and expensive, affecting our discomfort, health, quality of life and effectiveness at work (Ferguson et al, 2000). Most people will develop severe back injuries and illnesses in their life and once sustained, these tend to recur and worsen.

Movement is important, but it is not enough

Movement matters

We have long known that constrained sitting is bad for our health (*s.f.,* Adams and Hutton, 1983, Duncan and Ferguson, 1974, Eklund, 1967, Graf et. al, 1995, Hunting, et. al, 1980, 1981, Hult, 1954, Langdon, 1965, NIOSH, 1997).

As far back as 1777, Ramazzini described hazards of constrained sitting by writers:

> *“Now 'tis certain that constant sitting produces Obstructions of the Viscera, especially of the Liver and Spleen, Crudities of the Stomach, a Torper of the Leggs, a languid Motion of the refluent Blood and Cacbexies. In a word, Writers are depriv'd of all the Advantages arising from moderate and salutary Exercise.”*

Although a range of factors may contribute to back injuries and musculoskeletal disorders, there is clear evidence that long term sitting in awkward and constrained postures greatly increases the associated risk. As today’s workers age, they become more susceptible to developing health disorders[2]. At the same time, the work process continues to intensify.

Workers who maintain fixed sitting postures report greater discomfort and chronic disorders (*s.f.* Graf et al., 1993, 1995). Movement has the potential to reduce these risks (Aaras et al, 2000, Kilbom, 1987).

Yet, as we continue to learn about the causes of musculoskeletal disorders, our focus has also shifted from identifying the best single sitting posture towards a more dynamic view of sitting and movement.

Yet movement is not enough

Postures are also critical. The research clearly establishes that long-term sitting in awkward postures reduce comfort and work effectiveness and introduce health-related risk factor (*s.f.* review by Pynt and Higgs, 2010). Maintaining conventional slouching postures for only 10 minutes leads to the relaxation of back muscles (Solomonow et al., 2003a; see also review

[2] Of note, however, the research on back pain and aging is less clear; many young workers experience high rates of back injuries (*s.f.* review by Dionne et al, 2006)

by Pynt and Higgs, 2010) that transfers associated loads to ligaments and discs (Solomonow et al., 2003c),

Prolonged loading destabilizes the spine (Dolan and Green, 2006; Le et al, 2009; review by Pynt, 2010) and reduces muscle action, increasing laxity of viscoelastic tissues and risk of injury[3].

Even when workloads are low, these increase risk of injury following work (Le et al, 2009). Le et al (2009) notes

> *"Spinal stability refers to the functional and mechanical integrity of its various structures (intervertebral joint, discs, ligaments, facet joint and its capsule, nerve roots, spinal cord, etc.) within their respective physiological ranges.*
>
> *Poor stability or a deficit in maintaining the various structures within their correct alignment during movement may result in excessive movement and lead to injury (prolapsed disc, facet impingement, nerve root compression, stenosis, etc.) and associated neurological implications of pain, impairment of movement, and substantial loss of work days."*

While attempts to promote movement may mitigate exposure to ergonomic risk factors, it also fostered a misconception that movement is always beneficial and sufficient in itself to prevent harm. The widespread pronouncement that "*the best posture is the next one*" oversimplifies the ergonomics research and is often *flat out wrong* (*s.f.* review by Lueder, 2005).

All movements are not equivalent; for example, we should strive to avoid postural movements that overload ligaments (Solomonow, 2009), particularly in forward leaning (anterior) and twisted positions (Adams, 1994, 1996a, 1996b; Kumar, 2004; Lueder, 2005) which are commonly evident among today's office workers.

The findings of Solomonow (2009) caused Chaitow (2009) to note:

> *"Ligaments it seems are far from simply being restraining structures that are strategically placed to support and stabilize joints... They are sensory organs that provide proprioceptive input to the CNS, as well as having reflexive influences on associated muscles, which therefore become major elements in the stabilization of joints".*

In conclusion, movement is critical for our well-being, but it is not the only consideration; the postures that we assume as we move are also paramount. Taken to extremes, a strict emphasis on promoting movement for its own sake may even introduce new risk factors.

[3] Le et al (2009)'s findings involved static work of up to 3 hours is associated with an increased laxity.

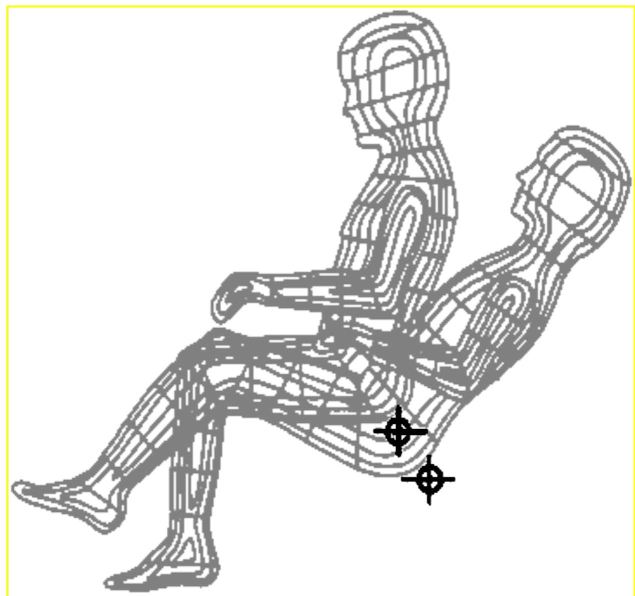
Rethinking "good postures"

Neutral postures

We are also rethinking the concept of *neutral postures* (Ankrum and Nemeth, 2000; Claus et al, 2009; Reinecke et al, 1994b). Of course, researchers recognize the benefits of *neutral postures*, which equalize the loads over the body and reduce the physical demands associated with range of motions. However, we continue to debate what *neutral postures* represent and how these might vary between individuals and changes in position.

Some research approaches, particularly muscle activity (EMGs) often lead to confounded conclusions (Smoliga et al, 2010; Ankrum 2000a; Ankrum 2000b). Much of what we know from the existing research is based on flawed or limited research approaches that leave some key findings in question.

For example, most findings are based on short-term studies, despite overwhelming evidence to the consequences of constrained sitting[4] (Beach et al, 2005). Research often measured a limited set of variables in unrealistic short-term laboratory environments.



Measurements of contours of the spine are often been influenced by external tissues of the users. Further, research has failed to adequately consider the implications of the dramatic increase in obesity in the American population[5]; research findings are largely based on people who are young and fit and free of musculoskeletal disorders, age-related degeneration of the spine (including stenosis), nervous system (Bazzucchi et al, 2005; Mariconda et al, 2007) and circulatory disorders that cause edema.

Further, the implications individual differences are poorly understood. For example, females have been found to have greater lumbar lordosis among adolescents (Straker et al, 2008) and adults (Dunk and Callaghan[6], 2005; de Carvalho et al, 2007).

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[4] Particularly on viscoelastic creep of ligaments and tendons and discs.

[5] The Centers for Disease Control estimates that in 2006 that 67% of the non-institutionalized US adult population is overweight or obese; 34% are obese. www.cdc.gov/nchs/fastats/overwt.htm

[6] Dunk and Callaghan (2005) found that females had greater lumbar lordosis and a slightly forward leaning spine compared to males when sitting. Females also positioned themselves closer to the front of a seat pan.

Centered postures

One important benefit of neutral postures is that it enables users to maintain position while sitting close to their center of gravity. Indeed, postures that shift away from these neutral positions are tolerated poorly and for less time (Reinecke et al, 1994b)

It is often difficult to sit upright and unsupported for very long in conventional seating. Most people would rather slump than perform the muscle work needed to sit upright. Leaning against a backrest reduces both intradiscal pressures in the spine and loads at the back portion of the spine (fixator loads involving the facet joints) relative to conventional upright postures (Rohlmann et al, 2001)

Several things happen when we maintain conventional unsupported postures – even with movement. Of particular importance, we tend to slump forward, reversing the lumbar curve (lumbar kyphosis) (Bridger et al, 1989)

If users are fit, their strong abdominal muscles might help stabilize their postures (Corlett and Eklund, 1984) although this is not fully agreed on (Kumar, 2004). Fit or not, postural support shifts from the muscles to the ligaments that support the spine. Ligaments deform, increasing risk of spine and joint injury.

Sitting in conventional chairs generally shifts the user forward from their center of gravity. Users benefit when the center of rotation of the chair is close to that of the user. Centered positions facilitate changes of posture (Andersson, 1986, Fleischer et al, 1987). Andersson (1986) concluded that the relationship between the pivot point of the chair and its user is more important than the dimensions of the backrest[7],[8].

Conventional chairs that recline by tilting back at the knees are particularly problematic in this respect. During recline, standard knee-pivoting chairs take the user back, down and away from their worksurface. Chairs that recline in this way will correspondingly expose users to additional risk as they become obliged to elevate their arms and extend their reach and their neck to see their visual target (typically, the document or computer screen).

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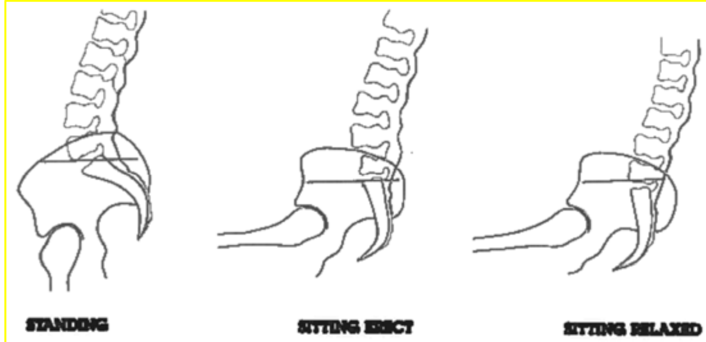
[7] Corlett (2002) and Rebiffe (1980) suggested the optimum height of the lumbar support depends on the users' activities. For example, the driver of a car benefits from a lumbar support that is higher than that of the passenger, as driver's arms are higher (on steering wheel), and must reach the controls.

[8] A close fit between users and their chairs' center of rotations also helps prevent the "shirttail effect", where the backrest displaces upward, pulling up users' shirttails.

Sitting versus standing

Until recent years, it was assumed that standing is better for our spine than sitting.

Upon sitting, our hamstrings flex, rotating the pelvis back and excessively flattening the lumbar curve. On the other hand, standing causes the pelvis to rotate forward, thereby increasing the extent of lumbar lordosis.



Research that is more recent suggests that both standing and sitting are problematic. Standing postures are associated with greater pelvic tilt and lumbar lordosis (De Carvalho et al, 2010, Keegan, 1953).

Early findings (Andersson et al 1974, 1975, 1986) that loads on the spine are greater when sitting than when standing have since been contradicted by studies using more sophisticated technology (Wilke, 1999, Solomonow and others), suggesting that some of these early conclusions were limited by the technology at the time. However, Leivseth and Drerup (1997) found less spinal shrinkage when sitting (particularly relaxed sitting) than with standing work. They attributed this to several factors, but particularly to the greater bending and twisting while standing.

Rethinking postural support

Forward tilting seats

Much of this shift in focus regarding the adverse health effects of long-term constrained sitting resulted from the writings of Mandal (1976, 1981, 1982), a Danish plastic surgeon. He associated conventional sitting with a flattening of the lumbar spine.

While Mandal generated considerable interest in the notion of promoting a more natural and healthful sitting posture by tilting the seat pan forward, many noted that users found it difficult to maintain this posture without supporting the lower legs because of the greater effort required to prevent sliding forward / resisting the forward gravitational slide. For this reason, the conventional forward tilting seat is generally considered a failed concept – particularly with the substantial forward tilts Mandal recommended 15 or 20 degrees. Those have been shown not to work because it takes so much more muscle work to sit in that position[9].

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[9] Even so, this writer has sometimes found forward sloping seat designs that are fairly effective. The basis for these differences are not obvious but seem to relate to the interaction between the center of gravity of the seat versus that of the user, and the ability to establish an open posture that does not

Forward tilting seats that lack leg support did not significantly affect the negative impact of forward reaching (Bendix et al 1988b[10]).

Bridger (1988) provides an excellent explanation for why forward-sloping seats might prove less effective than anticipated.

> *Bendix and Biering-Sorensen (1983) evaluated subjects' postural adaptations to a conventional seat that could be adjusted to slope forward at angles of 0, 5, 10 and 15°. They found that with increasing forward slope, the spine moved forward toward lumbar lordosis.*
>
> *However, in comparing the 0 and 15° seats, an increase in lumbar curvature of only 4° was observed. This occurred because subjects adapted their sitting posture to the sloping seats by extending the hip joints. The increased trunk-thigh angle brought about by the forward-sloping seat did not lead to a straightforward decrease in lumbar flexion...*
>
> *As these authors point out, postural adaptation to a forward sloping seat may take place in a number of ways. The whole body may tilt forward, in which case no increase in the trunk-thigh angle need occur. Alternatively, the hip joints may extend, thereby increasing the trunk-thigh angle but without necessarily altering the posture of the spine and pelvis. Finally, as suggested by Mandal, the increased trunk-thigh angle may be accompanied by anteriorpelvic rotation, which would result in a reduction in lumbar flexion, given that the upper trunk did not move. These possibilities represent extremes and might arguably occur in combination.*

Backrest recline

Leaning back provides important benefits.

Backrests perform several important functions. These supports may

a) open the thigh-torso angle;

b) transfer physical loads from gravity onto the backrest;

c) sometimes promote lumbar lordosis (Andersson et al, 1986); and

d) help stabilize the spine (Bendix et al, 1996),

require them to exert a great amount of effort . Often, those seats that work stabilize postural support (such as with the Balans) or provide some sort of a rocking motion.

[10] It should be noted that this short term study examined forward tilting seats but NOT Balans-type chairs. Of note, the study found that users still preferred higher seats that tilt forward.

Backrests may both reduce loads on the spine (intradiscal pressure) and muscle work (Andersson et al, 1974, Yamaguchi and Umezawa, 1970 with reclined seat pans).

These supports stabilize posture by reducing the effort required to fight gravity.

a) as the weight of the torso shifts back against the backrest, and

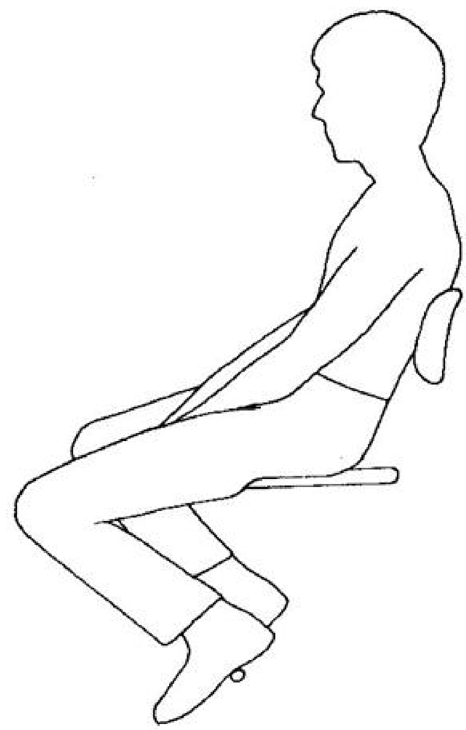
b) as the angle between torso and the legs increases.

Yet reclining also has disadvantages.

Many (perhaps even most) intensive computer users slump against their backrest, locking in their pelvis and causing them to lose (or reverse) their lumbar curve (Dolan and Adams, 2001).

Corlett and Eklund (1984) note, “this will lead to increased pressure on and within the discs, both from forces arising from the stretched muscles and ligaments and the increased wedging at the anterior [forward] edges of the disks”. Bendix (1996) suggested, “The traditional conception that a backrest facilitates lordosis is apparently not true”.

There are also functional limitations associated with reclining. Loads on the shoulders and arms may increase when reclining causes the users to move back against their work items. It is difficult to lean back when our visual target is a document and our hands need to reach the mouse. Reclined postures increase loads on the neck as employees attempt to meet the visual field requirements of the task (Grandjean et al, 1983, Corlett, 1999).



One example of a reclined posture with backrest support (Corlett and Eklund, 1984, with permission)

Lumbar supports

Research indicates that lumbar supports can reduce load on the spine (Andersson et al, 1974b, 1975). By tilting individual vertebra, it also increases pressures at the front of the discs (Adams et al, 1996a, Bendix et al, 1996, Corlett, 1999).

Although Andersson’s research findings suggest that lumbar supports can reduce intradiscal loads on the lumbar spine, the benefits of backrest lumbar supports are not consistent (Corlett, 1999). Bendix et al (1996) reported that lumbar supports on backrests helped to reinstate lumbar curves compared to straight backrests while performing tasks, but not during passive sitting and reading. Using pig cadavers, Brodeur and Reynolds (1990) concluded that lumbar supports have little effect on the contours of the lumbar spine. Rather, they found that the lumbar curvature is primarily affected by the pelvic angle.

Characteristics of the lumbar support vary between users[11] and may vary over time for the same individual. Corlett (2002), Rebiffe (1980) and others suggested that the optimum height of the lumbar support depends on the users' activities. For example, the driver of a car would benefit from a higher lumbar than the passenger where the driver's arms are higher (on the steering wheel), and they need to reach the controls.

Additionally, lumbar supports only benefit users if they are properly designed, correctly adjusted for the user, and the user sits in the chair in a manner that takes advantage of the feature.

How do workers sit in conventional seats?

Users rarely take advantage of their chair adjustment features

In her review of the research, Lueder (1994, 2005) summarized a broad range of studies indicating that most users do not adjust their chair or take advantage of key seat features. Vink et al (2007) reported that many or most workers never adjust their chair; adjustments performed are frequently limited to the seat height.

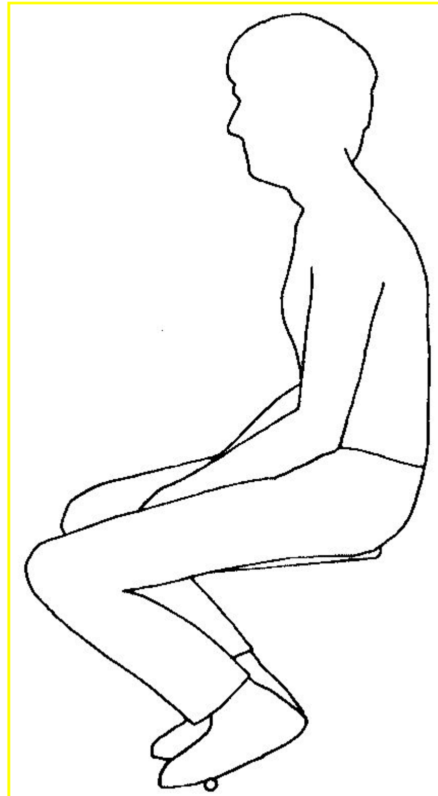
[11] Pregnant women and heavy users, for example, have more forward center of gravities. Tichauer (1978) notes that while men have centers of gravity above their hip socket, for women these are forward. Perhaps this is why various researchers (s.f. Bridger et al, 1989) have reported that women have deeper lumbar contours than men.

They tend to sit with their back unsupported

People generally prefer sitting to standing. Unfortunately, when doing so for extended durations in constrained positions, their postures become increasingly hazardous.

In today's offices many or most of office employees work with their backs unsupported by their backrest (e.g., Dowell et al, 2001). In his presentation, Dowell (2001) reported that the large majority of workers work with their back unsupported at any given time, although the rates vary with the task.

Please take a walk around your office to verify this for yourself. This writer once surveyed a large telecom center with over 1,000 intensive computer users. There was not a single person leaning back against their backrest in the entire center.



Unsupported sitting posture (Corlett &Eklund, 1984, with permission)

They tend towards forward-leaning positions

Sitting in static positions leads to small movements in our chair that we often refer to as "fidgeting" (Bhatnager et al, 1985, Fenety et al, 2000). That is, as people become uncomfortable they tend to move more, perhaps to compensate for reduced effectiveness at work. This tendency to fidget with time is associated with a tendency towards forward oriented (anterior) movements and postures that increase loads on the spine and soft tissues[12] (Andersson, 1980, Andersson et al, 1974a, 1975, 1986, Bhatnager et al, 1985, Rohlmann et al, 2001, Wilke et al, 1999).

In fact, loads on the spine (intradiscal pressures) are almost twice as high when flexing forward during unsupported sitting – and almost three times higher than relaxed sitting (Wilke et al, 1999). Others have found that leaning forwards (flexion) led to a dramatic increase in intradiscal pressures as well (Andersson et al, 1974a, 1975, Rohlmann et al., 2001).

[12] Rohlmann et al (2001) suggests that different conclusions might be attributed to the complex geometry of the spine and how much we do not know. For example, high intradiscal pressures in the spine reflect greater loads on the forward portion of the spinal column, but tell us little about loads transferred by the bony protrusions (facet joints) of the spine.

Forward-leaning postures also increase risk of disc rupture because the posterior segment of the disc lacks the strength to bear the associated forces – even when intradiscal pressures are low[13] (Adams et al, 1994).

The posterior longitudinal ligaments are considerably thinner than the anterior (front) ligaments. Further, the fibrous tissues that surrounds the intervertebral discs[14] are not equivalent – anterior postures are much likely to cause tearing.

Fleischer (1987) emphasized the importance of designing chairs to enable users to promote movements that are known to be beneficial, particularly in the fore-aft / upright-reclined directions (as opposed to forward-leaning / anterior postures).

Twisting / rotation / bending movements

Twisting is common; in fact, it is difficult to function without it. Twisting is also unique to human beings (Kumar, 2004). Twisting (i.e., axial rotation of the spine) increases compressive loads on the spine (Au et al, 2001) and risk of injury (Au et al, 2001, Kumar et al., 1998, Kumar, 2001).

Figure 2. Research indicates that today's adolescents are experiencing high rates of back and neck / shoulder symptoms (e.g., Straker et al, 2008) that often continue into adulthood. Risk is particularly pronounced during growth spurts (Lueder & Rice, 2008).

A key concern is how we can teach these young people to avoid risk and learn proper sitting habits that they can take with them into adulthood.

Kumar (2001) described spinal rotation as "*a destabilizating motion for an inherently unstable structure".* He explained how prolonged and extreme twisting could damage joints. First, heightened loads increase the forces acting on the joints, deform connective tissues and ultimately destabilize the joints. With time, as muscles fatigue and joints weaken, the resulting imbalance can lead to unnatural and uncoordinated movements at the joints that can result in injury.

Research suggests that extremely small (less than 2° per vertebral segment) rotations are not harmful and may even benefit users[15] (Van Deursen et al, 2001). Such micro-movements correspond to the natural / free range of motion of the individual motion segments that make

[13] These researchers noted that serious disc failure is closely associated with the "moment arm" forces associated with forward bending – even when the compressive loads on the spine itself are not particularly high. They add, "Conversely, if the bending moment is small or absent, no amount of compression can damage the soft tissues before the vertebrae".

[14] This fibro-cartilaginous tissue of the intervertebral discs is called the annulus fibrosus.

up the spine[16]. Minute rotary movements[17] in one's chair may reduce forces acting on the lumbar spine from improved disc' nutrition and lessened back pain (Lengsfeld et al, 2000b).

Yet our spine enables us to twist considerably farther than the 2° mentioned above – actually (when including motion of each of the segments), up to about 70° to each side across the spine (Kumar, 1996, 2004).

Kumar (2004) described the massive body of research demonstrating a very strong relationship between twisting and back injury[18]. Some suggest that as little as 20° of twist involving across the mid-back may greatly increase the risk of disc herniation. Kumar described a number of possible mechanisms for this increased risk of injuries, including compression of spine.

Yet biomechanical forces on the spine (moment arm) alone cannot explain the increase in risk with twisting. Au et al (2001) found that even when biomechanical loads are equivalent in different postures, twisting resulted in considerably greater compression of the spine than leaning forwards or controlled sideways bending. The authors note, "it is interesting to consider that the torso is very limited in the production of dynamic twisting torque", even when relatively small levels of force are involved.

Kumar (2004) describes the effect of twisting as jamming the facet joints (bony protrusions of the vertebra), twisting intervertebral discs, tightening some ligaments while slackening others.

Even so, the associated risks vary across the spine and are greater at the lumbar spine. The different vertebrae that make up the spine are very flexible, and designed to rotate to different degrees. Part of this greater flexibility of the lumbar spine is related to the facet joints, which are differently designed to prevent rotation and lateral bending (flexion) displacement (Evjenth and Hamberg, 1985)

Seated twisting also reduces muscle strength. In his previous research, Kumar (2004) found that sitting forward in a neutral posture requires the least amount of strength, but the loads increase as the user moves to 20° of combined vertebral rotation. He concluded, "Thus, when it comes to forceful exertions involving axial rotations, human capability is considerably limited". He continues that "with increasing reach distances, the strengths significantly declined…"

Such studies point to twisting – even rotation while seated at the low (lumbar) and mid-back (thoracolumbar junction) may sometimes increase risk substantially.

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[15] This laboratory study by Van Deursen et al (2001) used pig cadavers. These findings may well have been confounded because they removed the facet joints (bony extensions at the back of vertebra) and related spinal components. Even so, these researchers maintained that this did not affect results as the range of rotation was within the joint's free inter-space range of movement.

[16] Panjabi and White (2001) suggest the natural range may be closer to 3°.

[17] These researchers used one patient diagnosed with degenerative instability of the lumbar spine. The rotational movements of the chair were 1.2° to the right and left, at a frequency of .22 Hz.

[18] Risk increased even when lifting was not involved. For example, Kumar (2004) describes research by Marras (1993) that found "twisting without lifting is associated with disc prolapse with an odds ratio of 3.0. A combination of twisting and lifting increased the odds ratio to 6.1.

We need more research to understand the full impact of these issues. Even so, caution is warranted, we expect people to rotate sideways to some extent during seated work, but then it should not be encouraged either.

Balans

Balans and lumbar lordosis

Although the research findings varied, the majority demonstrated improvements in lumbar lordosis – that is, a shift towards more neutral postures - when sitting on the Balans chair.

Further, the flexed knee position may work in concert with the increased thigh-torso angle in promoting neutral postures. The Balans chairs tested in these studies lacked the backrests currently available in some models of the Balans chair.

Adams et al (1990)[19] compared the contours of the spine associated when sitting on the Balans and conventional chairs was well as standing and lying. These researchers reported that sitting on the Balans chair was associated with the most "neutral". They suggested that these benefits would be particularly beneficial for some users, given age-related changes in muscle, body fat composition, bone density, loss of elasticity of connective tissues.

The gradual age-related dehydration of vertebral discs will reduce these users' ability to withstand compression and misalignment of the spine.

Frey and Tecklin (1986) found that the lumbar lordosis of users sitting in a Balans Multi-Chair was more neutral than users sitting in a conventional chair, and bore a closer resemblance to the relaxed posture while standing at a workstation.

Bendix et al[20] (1988a) found that subjects adapted to a Balans chair exhibited more forward tilt of the pelvis and lumbar lordosis than did users sitting on a chair with a forward-tilting seat pan. Balans users also sustained a more upright head and trunk posture. Although these researchers noted that users generally tended to prefer the forward tilting chair over longer periods, one wonders whether this preference might have related to a greater ease of slumping in the forward tilted chair. The authors suggested that the Balans chair might be a good alternative for some situations.

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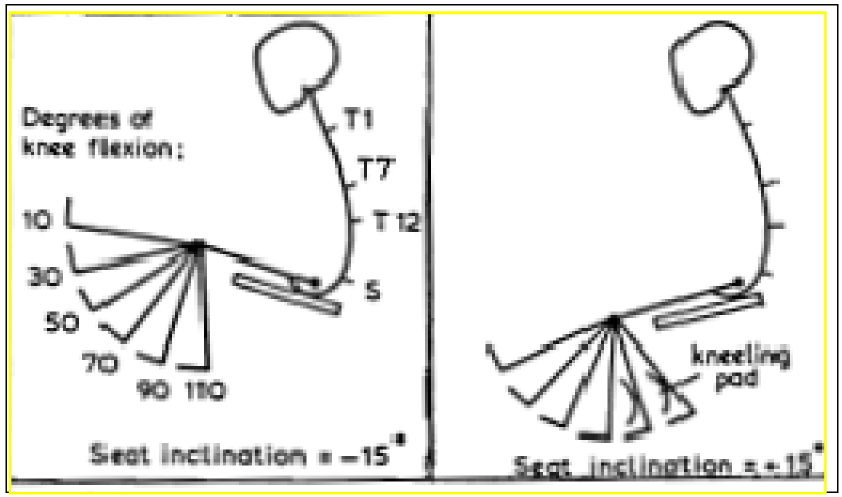
[19] Adams et al (1990) used a 3D digitizer in this pilot study to evaluate the cervical, thoracic, lumbar, and sacral angles relative to a vertically projected line. For one experimental group, these researches compared the spinal profile on the Balans and other conventional seats with limited adjustments; for the other experimental group, they compared the profiles associated with standing and lying supine (face up) and prone (face down).

[20] These researchers used a stadiometer to evaluate spinal shrinkage of 12 healthy subjects over 3 weeks while performing office and simulated assembly work. Spinal shrinkage was measured over each sitting period; this measure is considered an index of compressive loads acting on the spine.



Bennett et al (1989) measured muscle activity/ EMGs and lumbar lordosis[21] of 20 subjects sitting in static and dynamic postures in Balans Multi, straight-backed and conventional office chairs and while standing. These researchers found that sitting in the Balans chair increased lumbar lordosis relative to sitting in upright and conventional seating, though less so than when standing.

Bridger et al (1989) measured the spinal angles and hip and lumbar mobility of 25 female subjects standing and in four sitting postures. Lumbar lordosis decreased with reductions in the trunk-thigh angles, which also related to a reduction in hip mobility.

Ericson and Goldie (1989) compared the extent of spinal shrinkage associated with sitting on a conventional, forward-sloping[22] and Balans chairs. The subjects' spines shrank more when sitting on the Balans than on conventional chairs. The authors attributed this difference to the lack of a backrest, emphasizing the importance of providing back support with the Balans.

Bishu et al (1991) reported inconsistent results with their small pilot study involving short-term use of folding metal chair, the classroom chair, and the Balans. Findings from the small size and short-term 30 minute sitting trials were inconclusive. Although the Balans was not found most comfortable, the researchers conclude that chair designers need to focus more on the included angle between the seat pan and backrest as well as on the shape of the backrest.

[21] These researchers used a flexicurve "flexible ruler" to measure lumbar lordosis. Subjects aged between 22 and 37.

[22] The forward sloping chair was the "Ullman chair" with front half of seat sloping forward and back half horizontal. Eight healthy subjects worked on computers at their workplaces in 45 minute trials. Eight healthy subjects used to professional VDU work volunteered to participate in this field study, which was performed at their own workplaces.

Bettany-Saltikov et al (2008) compared the lumbar curvatures of users[23] sitting on "kneeling" with conventional computer chairs. They concluded the use of "kneeling chairs" set with 20° of forward tilt did indeed promote neutral lumbar curvatures that more closely resembled standing postures.

Figure 3. Brunswic (1984a, 1984b) described the added benefit of sitting in the Balans chair, related to the integral relationship between the thigh-torso and knee angles.

She noted "*The effect of moving the hips and knees was additive in a 1:2 proportion such that an increase extension of the knees of 20°correspond roughly to a 10° flexion of the hips.*

[That is, when sitting in the Balans, bending the knees promotes lumbar lordosis, and the benefit represents half that of the increased thigh-torso angles.]

The simultaneous alteration of these two components could flex the spine in proportion to the addition of each phenomenon taken separately."

Brunswic (1984a, 1984b) found that users sitting on the Balans seat evidenced improved lumbar lordosis in the experimental setting, but the benefits disappeared in the real world setting. This writer presumes the loss of benefits related to the non-adjustable working height of the users. She emphasized the importance of ensuring the seating accommodated the task and the work environment.

Link et al (1990) compared the lumbar curves of subjects standing and in a conventional and Balans Multi-Chair[24]. Subjects had significantly more lumbar lordosis / extension when sitting in the Balans Multi-Chair compared with sitting in the conventional chair.

Balans and EMGs

A number of EMG studies have found that muscle loads increased when sitting on the Balans chair. None of these studies compared sitting on Balans chairs that provide back support with conventional seating. Further, these studies have been closely controlled and lack the real world settings that today's office workers operate in.

Yet EMG research is controversial and often lead to confounded conclusions (Smoliga et al, 2010; Ankrum 2000a; Ankrum 2000b). The goal is not to minimize EMGs – after all, exercise is beneficial to health - but rather to avoid excessive muscle loads that exceeds the users' ability to recover. Further, Ankrum points out that much of the research has confused statistical significance with meaningful differences.

Bennett et al (1989) measured muscle activity/ EMGs noted that, given that lumbar lordosis improved in the Balans chair, the findings that Balans sitting involved higher EMGs than sitting in conventional chairs "suggests that EMG activity is not a good indicator of changes in lumbar posture". That is, changes in EMG activity are unable to evaluate the benefits associated with improvements in lumbar lordosis.

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[23] These researchers used a portable 3D mechanical digitizer "MIDAS System" to assess lumbar curvature, while placing anatomical landmarks on the 20 subjects, aged 18-35.

[24] Sixty-one men between 20 and 30 years of age served as subjects. Lumbar curves were measured with a flexible ruler with subjects standing and then sitting in the two chairs.

Shenoy and Aruin (2007) compared the EMGs associated with sitting on a forward-tilted seat and the Balans Multi Chair without back support[25]. Sitting on both the Balans and standard forward-tilting seat pan resulted in anticipatory activation of trunk and upper leg muscles in some postures. These findings suggest that although the forward-tilting seat and semi-kneeling body position might help in preserving a normal lordosis, it is not associated with anticipatory activation of lower leg muscles, which might reduce the ability of an individual to counteract muscle forces associated with these postures.

Lander et al (1987) found that EMG levels were higher after sitting on a Balans chair without back support, which presumably related to the work configuration and lack of backrest[26]. Cram and Vinitzky (1995) emphasized the importance of providing pelvic and back support with alternative seating.

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[25] . Nine healthy subjects were seated on either the Balans or a conventional chair with arms extended. They were instructed to initiate body exertions in four directions.

[26] Twenty healthy subjects were randomly assigned to one of two groups. Group 1 subjects sat in the Balans chair for a 30-minute study period and then sat in a conventional office chair for an additional 30-minute period. Group 2 subjects were studied in the reverse seating order.

Balans and loads on the knees

Some studies point to a lack of any evidence of negative loading on the knees when sitting on the Balans. Two very early studies suggested that some users reported discomfort at the knees when sitting on Balans chairs. Both of these were poorly controlled informal studies that lacked commonly recognized approaches for controlling for confounding factors. These may also have reflected early versions of the chair, since this writer has not found any more recent reports of discomfort at the knees in the last two decades.

Stranden (2000) pointed to the absence of evidence linking sitting on the Balans seat with loads on the knees, and described a prior unpublished study (Stranden, 1981) that also found no such evidence.

> *Furthermore, the flexion of the knee joint during upward seat deflection does not represent a likely cause for venous compression. This is evident from earlier studies on `Balans' chairs, where venous pressure recordings at very much larger flexion did not indicate any venous obstruction at all (Stranden 1981). The most extreme sitting posture was applied at `Balans Skulptur', where flexion was about 160 ± 1708; still with no venous obstruction affecting venous pressure profiles.*

This writer has also reviewed partial reports from an in-house research study performed over nine months by physiotherapists at the Hospital of Robslend, Norway. They reported improvements in back pain but also acknowledged a potential for knee discomfort – which they said could be avoided through simple design changes.

Drury and Francher (1985) performed a small pilot study of 12 subjects sitting in Balans and conventional chars for 2½ hours. Balans chair users chair reported higher rates of body part discomforts at the knees and (to a lesser extent). Even so, the authors noted, "*a minority of subjects preferred this [Balans] chair to their own".*

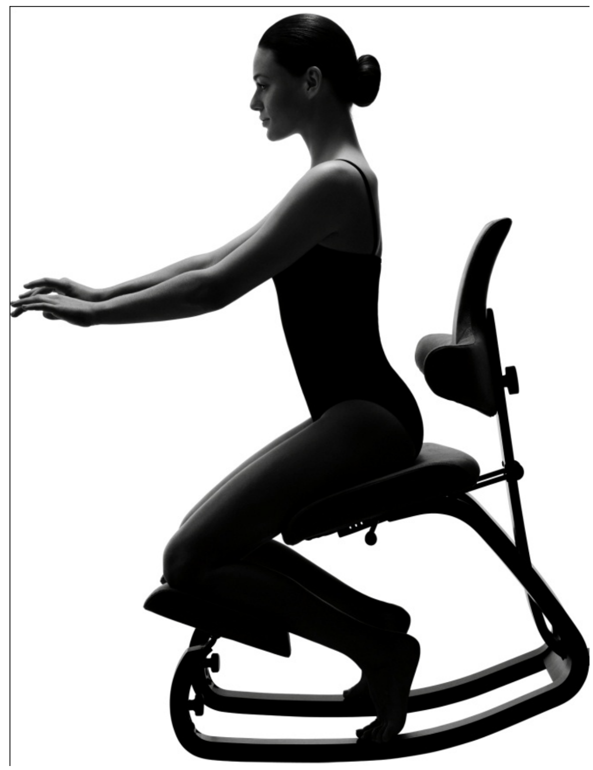

Figure 4. The Thatsit Balans design enables users to promote circulation and reduce leg swelling by activating the venous pumping action of the legs, such as by rocking with one leg on the floor and the other leg on the shin support.

Stranden (2000) describes how the use of the three venous pumping systems synchronizes to aid circulation to the heart and prevent edema.

Dr. Grandjean's writings on the topic:

Several of Grandjean's editions of "Fitting the task to the man" (e.g., 1988 – see also Kroemer and Grandjean (1997)) reference an unpublished in-house report from the Swiss Federal Institute that was reputedly written in German by Krueger (1984), noting in each case.

> *"Krueger (1984) tested four models and found that the load on knees and lower legs is too high and sitting becomes painful after a while. (Some subjects even refused to sit longer than 2 h)."*

Some others followed suit, describing this study – and one cannot help but wonder if it might have been taken as a secondary source from Grandjean without referencing it as such or reading the original material. Notably, Hermanau (1995, 1999) writes

> *"Studies by Krueger (1984), however, found that the load on the knees and lower legs is too great and sitting becomes painful."*

Yet *The Swiss Federal Institute* indicated that they had no record of having sponsored such an unpublished German report and that it apparently not available directly from their Institute, leaving one to wonder whether recent articles that cite this report might be making inferences from secondary references to text that they have not actually read.

Through extensive follow through, Mr. Ed Miano of VarierUSA was able to locate Dr. Kruger (the correct spelling of his name), who had long since retired, but who graciously digitized and provided a copy of his original paper as a pdf. Dr. Kruger expressed surprise that his in-house review had attained so much notoriety, given the rather informal intent of the small review, which used 4 subjects on a short-term basis and was based on cursory reviews of subject's comments in the absence of objective data.

Both the translated paper provided by Mr. Miano and a Google-translation of the German version of the original paper each suggest that the findings misrepresented some important issues and content relevant to the paper.

The author noted that the higher seat height of the Balans was also rated positively for all users. He also wrote that all four of the subjects experienced some degree of discomfort the different versions of Balans chairs, but went on to describe the considerable variability in ratings between models. The chair that received the most positive ratings was the Balans Variable, which received positive scores by all users and "was found pleasant by all users".[27]Dr. Kruger noted that users continued to sit on this chair, without knee supports after the seating trials.

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[27] One question that was left unanswered was whether the order of the chairs were counter balanced and otherwise controlled to avoid an order effect in testing. The Variable was listed last.

Conclusion

The research indicates that standing, sitting and semi-standing positions each have their benefits but also the limitations.

While many consider the spinal contours associated with the standing posture desirable, in research also tells us that in the real world many or most people do not want to stand all day – and when they work standing, often they assume less than ideal ergonomic positions.

We know that most users are accustomed and seem to prefer conventional seats with backrests and arm supports. These can provide important benefits by enabling some users to assume more neutral postures while transferring the loads from gravity to the backrests.

Yet many workers sitting in conventional chairs also spend much of the day with their back unsupported and their chair improperly adjusted – or not adjusted at all. As the day progresses, working postures often tend toward forward leaning anterior postures that put them at particular risk of discomfort and injuries to their spine and musculoskeletal system.

Balans chairs enable users to assume semi-standing postures. Users can slump in these chairs as well as conventional seating. Even so, research demonstrates the Balans seat can in some circumstances more effectively promote lumbar lordosis and though the debate rages on may eventually be found to be even "more neutral" than standing positions.

Almost all of the studies that assessed the Balans chair used versions of this chair that lacked back support. Yet such back supports provide important benefits, even if only to intermittently stretch and stabilize the spine. It seems reasonable to presume that the findings associated with the Balans would have been even stronger had these studies included back supports on the Balans chairs.

Further, while these studies compared the effects of sitting on conventional and Balans seats, there has been a lack of attention to the potential benefits for some users when alternating between both kinds of chairs. Yet for some users – particularly those who spend much of the time in forward oriented postures, the opportunity to alternate between these postures may provide important benefits.

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Rani Lueder, MSIE, CPE is President of Humanics ErgoSystems, Inc. an ergonomics consulting firm in Encino, California. She has consulted in workplace ergonomics, product design research and accommodating special populations since 1982.

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Since 1988, she continues to serve on retainer to several organizations in Japan, including the Waseda University's Seating Research Lab, ErgoSeating Japan and the Japan Institute of Human Posture Research. She served as US organizing chair for the Second International Conference on Seated Posture, held in Tokyo.

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