GE-II Evidence Report

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Contents

GE-II Research

The GE-II is the next evolution in the Kirton range of specialist seating. This document explains the philosophy behind its design. It is one based on design heritage, design quality, and in-depth knowledge of biomechanics, contemporary ergonomic theory, and new data from laboratory research carried out in partnership between Kirton and scientists from the UK and the US.

Background

Before getting to the science, it is important to understand where the GE-II came from. The GE-II has the same DNA as the Delta, and the Ultima before that (Appendix A1 – A3). The Ultima came into existence at a time when tilt-in-space was viewed by some as a form of restraint. There were two reasons for this. Firstly, there was no scientific evidence to support clinical experience on the benefits of tilt-in-space, and secondly, the first tilt-in-space chairs by other manufacturers were very poorly designed. One such chair was the Buxton chair (Appendix A4). Although this was used extensively throughout the NHS it was perceived as a form of restraint, being referred to as 'inhuman' (Appendix A5). In response to this, the R&D team at Kirton developed the Ultima to change people's perceptions of tilt-in-space by good design (Appendix A2). It introduced a seat length adjustment to ensure the pelvis contacted the backrest, thereby improving posture. It introduced an elevating legrest which the Delta evolved into a more sophisticated arcing legrest (Appendix A2). It had a much improved tilt movement that reduced the feeling of falling back, and the armrests did not move. The crude design of tilt-in-space chairs prior to the Ultima simulated someone being tipped back, where all patient contact surfaces rocked back together. This resulted in total physical detachment between the patient and their environment. Keeping the armrests fixed minimised this by providing stable surfaces and important somatosensory information. The Ultima was an important product in the development of the specialist seating sector in changing hearts and minds on tilt-in-space chairs in long term care settings. However, despite anecdotal evidence of the medical benefits of the Ultima, there remained little scientific corroboration. Two reviews on the tilt-in-space literature are provided by Sprigle and Sposato (1997) and Michael *et al.* (2007).

The typical model for the design of specialist seating is collaboration between manufacturers and clinicians such as occupational therapists and physiotherapists. This is and will continue to be fundamental to new product development at Kirton. In 2003, however, Kirton expanded its research capability beyond clinicians by collaborating with scientists to investigate the biomechanical principles of seating. For this, laboratory research was carried out with scientists from Anglia Ruskin University, Cambridge, and the Hospital for Special Surgery, New York. One early success from this partnership was the range of Intelli-Gel® cushions now manufactured by Kirton. For Kirton's specialist seating, research was carried out on people's spines in terms of posture and loading, and muscle activity, for a variety of sitting postures considered important in long term care. This resulted in new knowledge in biomechanics on which the GE-II is built.

Intelli-Gel® is protected by US Patents 5749111, 6026527,6413458, 6797765, 7076822 and other US and International patents pending

GE-II Design Philosophy and Supporting Scientific Evidence

Where the GE-II differs from the Ultima and Delta is in the philosophy of how to support the upper body. In fact, the difference is such that the ergonomics of the backrests between chairs are polarised. This is not obvious when looking at the chair but it becomes apparent when sitting in it. The Delta follows traditional ergonomic theory and aims to extend the spine whereas the GE-II, based on a more critical analysis of the science, facilitates moderate flexion.

Flexion vs Extension

Extension was originally recommended because of research carried out in Sweden in the 1960s and 1970s. Nachemson (1964) developed a means by which the pressure in the nucleus pulposus of the intervertebral discs could be measured in vivo. Nachemson used a specially constructed needle with a pressure-sensitive membrane at its tip for this purpose. He demonstrated that the hydrostatic pressure of the nucleus pulposus was higher in sitting than in standing. Andersson and colleagues (1974) extended Nachemson's research to measure lower lumbar disc pressure for a variety of sitting postures. These scientists measured reduced pressure when the lumbar spine was extended compared to when it was flexed. The researchers therefore concluded that seating should encourage an extended spine. They explained that this could be achieved with a lumbar support or by fixing the pelvis and reclining the backrest. They advocated a lumbar support believing that support to the pelvis is likely to result in shearing stresses in the lowest discs. These recommendations became widely accepted by researchers, clinicians and chair designers.

The R&D team at Kirton Healthcare reviewed the scientific literature on seating and found several studies that did not support Andersson. One such important study was carried out in Germany in the 1960s by an orthopaedic surgeon (Schoberth, 1969). This study was published in German which may have limited its impact internationally. Schoberth described the architecture of the human spine based on a study of 1035 school children. From his functional perspective, the human spine consists of one immobile middle part: the upper thoracic spine, and two mobile end pieces: the cervical spine on one side and the lumbar spine on the other side. The lumbar spine is connected to the sacrum which is rigidly connected to the pelvis. He goes on to say that the basis for the entire spinal architecture is the vertebral endplate of the sacrum.

Schoberth carried out research into the interaction between the position of the pelvis and the form of the spine in sitting. He found that, if the endplate of the sacrum is greater than 16° anteriorly tilted with respect to the horizontal in the sagittal plane, the lumbar spine will always be extended. If the endplate is more than 10° posteriorly tilted with respect to the horizontal in the sagittal plane, the lumbar spine will always be flexed. He explains that these rules apply providing that the spine is free to move. Schoberth concludes to say that the position of the pelvis determines the shape of the spine. Lumbar extension is of little importance in the sitting posture. In order to avoid fatigue, it is necessary to support the iliac crest of the pelvis and the sacrum. Support higher up on the backrest for resting positions should begin at the thorax.

In the subsequent 30 years, research has shown that extended sitting postures are not as beneficial as moderately flexed postures. Adams *et al.*, (2006) argued that recommendations concerning 'good' or 'bad' posture should not be based on experimental data concerning only one or two structures, and that the whole spine must be considered, including the muscles and fascia. Adams *et al.* highlighted a limitation in the Swedish work in that it drew general conclusions on spine biomechanics when concerning only the hydrostatic pressure in the nucleus pulposus of the intervertebral disc. Adams *et al.,* (1994) demonstrated that the nucleus pressure reduces only because load is shifted to the posterior margins of the disc, the anulus fibrosis. It is this part of the disc that generally degenerates and it is here where there are nerves of the type that is associated with pain (Adams *et al.*, 1996). Flexed postures, on the other hand, transfer the compressive load to the nucleus which is the part of the disc designed to take load, and the anterior anulus fibrosis which does not generally degrade.

Flexed postures have also been shown to reduce the compressive loading acting on the zygapophysial joints (or facet joints), and orientate the articular surfaces so they are parallel to each other resulting in low and evenly distributed contact stresses (Adams & Hutton, 1980). Lordotic postures, on the other hand, increase compressive loading on the zygapophysial joints (Adams & Hutton, 1980), and concentrate stresses in the inferior margins of the articular surfaces and on the tips of the inferior processes (Dunlop *et al*., 1984; Shirazi-Adl, 1991). The zygapophysial joints are a source of back pain (Adams *et al*., 2006).

Another advantage of flexed postures is improved intervertebral disc nutrition. It is known that the supply of metabolites to cells within the intervertebral disc is barely adequate for normal requirements (Maroudas *et al*., 1975; Urban *et al.*, 1977; Stairmand *et al.*, 1991) and impaired metabolite transport is associated with disc degeneration (Nachemson *et al.*, 1970; Holm & Nachemson, 1982). One of the transport mechanisms for nutrients into the disc is diffusion. The amount of metabolites that can diffuse into the disc is dependent on the distance to the nearest blood vessel on the disc's surface or in the vertebral body. Compared to erect standing, flexed postures stretch the posterior anulus by 60%, and compress the anterior anulus by 35% (Adams & Hutton, 1982; Pearcy & Tibrewal, 1984). There is a corresponding thinning of the posterior anulus and a thickening of the anterior anulus. Flexion therefore reduces the diffusion path length into the posterior anulus. This has been shown in cadaveric experiments (Adams & Hutton, 1986), and in measurements of diffusion into living discs (Urban *et al.*, 1977). In addition to enhancing diffusion, the stretched posterior anulus has an increased surface area resulting in a greater flux of metabolites being 'funnelled' into the inner posterior anulus (Adams & Hutton, 1986). Flexion will cause the opposite effect in the anterior anulus (Adams & Hutton, 1986) but, again, this is the last region of the disc to show degenerative changes (Adams *et al.*, 2006).

Pynt *et al.*, (2008) refer to these studies arguing against flexed postures because they exhibit more creep loading and shrinkage, due to a higher rate of expulsion of fluid from the discs when compared to extended postures. One of the laboratory studies carried out by Kirton evaluated the effects of tilt-in-space on changes in the length of the spine *in vivo* (paper in review). The scientists found that even with excessively flexed postures, the spine increased in length. The mechanism responsible for this increase in spinal length is the fluid flow into the discs resulting from a swelling pressure in the unloaded disc, so in the context of tilt-in-space postures Pynt's arguments would seem invalid.

Flexed postures can also reduce spinal nerve root compression. Studies into cadaveric spines have shown that nerve root compression is 15% for flexed postures and 33% for lordotic postures (Inufusa *et al.*, 1996). Based on this, flexed postures could be beneficial for people with spinal stenosis. Spinal stenosis is a medical condition in which the spinal canal narrows and compresses the spinal cord and nerves. This is usually due to the common occurrence of spinal degeneration that occurs with aging. It can also sometimes be caused by spinal disc herniation, osteoporosis or a tumour (Adams *et al.*, 2006). Although flexion would reduce the effects of nerve root compression, it would increase any effects of nerve root tension, especially if the nerve root were tethered to underlying structures by scar tissue.

GE-II Science

Taken as a whole, moderate flexion appears to be preferable for static upright postures (Adams *et al.*, 2006). Those concerns of researchers advocating extended postures are most relevant to upright postures when the spine is loaded and become less important with tilt-in-space where the spine is unloaded and the discs recover (results from in-house lab work, in review). Seating that facilitates moderate flexion is even more important for the comfort of older people where the prevalence of kyphosis increases (Milne & Lauder, 1997).

As mentioned earlier, Schoberth (1969) did not think that lumbar extension was important. He believed that the ergonomic aim in the design of backrests is to support the back of the pelvis, the sacrum and iliac crest, and then the thorax. He did not advocate a lumbar support. Andersson *et al.,* (1974) recommended lumbar support over support to the pelvis on the basis that, with pelvic support, shearing stresses may develop in the lowest discs. Andersson *et al.* did not explain how they came to this conclusion. Using radiographs, Keegan (1953) demonstrated that alterations in lumbar curvature result primarily from changes in trunk to thigh angle. This is mainly due to large passive forces that arise from the posterior thigh and gluteal muscles when the hip flexes, and the anterior trunk to thigh muscles when the hip extends (Keegan, 1953). So, when we sit, the trunk to thigh angle reduces and the pelvis rotates posteriorly. In unsupported sitting this is approximately 30° from standing (Pheasant & Haslegrave, 2006). Use of a lumbar support, which applies a force to the lumbar spine in the opposite direction to the force acting on the lowest vertebrae from the pelvis, is more likely to cause shearing stresses. These shearing stresses are likely to be eliminated when supporting the pelvis directly. In engineering terms, the pelvis and thorax are large structural girdles and should be supported. The spine is simply a flexible link between these two structures. It is the mobility of the spine that keeps it healthy.

Based on this analysis, the GE-II backrest facilitates moderate flexion by focusing support bilaterally, catching the posterior superior iliac spines (PSISs) and the iliac crest of the pelvis, the thorax and shoulder girdle, and head (Figure 1). Supporting the body in this way is better for midline positioning as it cradles the upper body, and this is most important for people with unstable postures.

Figure 1a. *Illustration of anatomical structures. Backrests should support bilaterally to the posterior superior iliac spines and iliac crest (wings) of the pelvis, the thorax and shoulder girdle, and the head.*

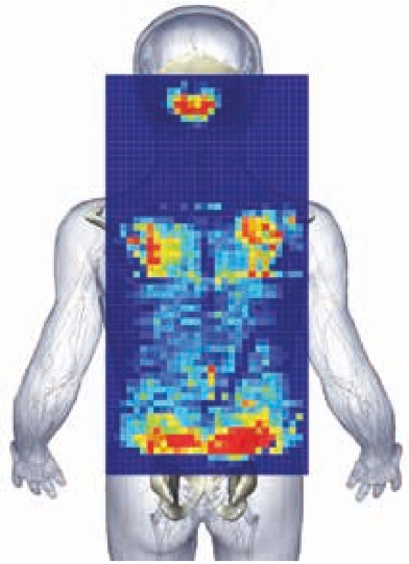


Figure 1b. *Illustration showing the interface pressure distribution of the GE-II backrest. Red areas indicating higher levels of support correspond to the anatomical structures shown in Figure 1a.*

As mentioned earlier, the first tilt-in-space chairs were perceived as a form of restraint and reported as inhuman (Appendix A4 – A5). The predecessor to the GE-II, the Ultima, set out to change people's perspectives on tilt-in-space by good design. One of the changes was to fix the arms so that they did not tilt back with the chair thereby providing a stable physical connection with the environment. This somatosensory information is important and has been inferred by previous research. In several studies, it has been shown that when standing, fingertip contact to a rigid surface helps to stabilise and control posture, with reduced leg muscle activity (Jeka & Lachner, 1994; Holden *et al.*, 1994; Jeka & Lackner, 1995; Lackner & DiZio, 2000). Based on these studies, hand contact on armrests that are fixed relative to the ground during tilt-in-space may play an important role in postural control and position sense.

As part of the experimental research by Kirton and scientists from Anglia Ruskin University, Cambridge, and the Hospital for Specialist Surgery, New York, back muscle activity was measured using surface electromyography (EMG) for a variety of postures considered important in specialist seating. The scientists found that EMG activity increased when subjects assumed a mid-range tilt-in-space posture (paper in review). This was difficult to explain mechanically. A biomechanical model had been developed for these postures (paper in review) which had predicted less loading on the spine where force had been transferred from the seat to the backrest. These model predictions were validated with force measurements using an interface pressure mapping system. Furthermore, another investigation into changes in the length of the spine had demonstrated spinal recovery resulting from unloading the discs (paper in review). So, a different explanation was needed for the high muscle activity found for the tilt-in-space posture other than the need for the muscles to be recruited to support and stabilise a loading spine.

In another study, Nwaobi (1986) researched into the effects of tilt-in-space on the tonic muscle activity of patients with cerebral palsy and measured significant increases in back extensor and hip adductor muscles. Nwaobi explained that it is probably because the increased extensor tone is a direct result of the tonic labyrinthine reflex stimulated by the position of the head in the reclined position. Nwaobi explains that the increased tonic activity in the reclined position is a reaction to the loss of the horizontal relationship with the environment, including eye contact. The scientists working in partnership with Kirton went an extra step and took EMG measurements in the tilt-in-space posture but with the backrest articulated to bring the head into a more functional position. This revealed a significant reduction in back muscle activity. Those scientists concluded that a possible explanation for the increase in back muscle activity is not mechanical load, but rather, a discordance of the sensory motor control system which may be rectified with improved head position.

Based on this analysis, backrest articulation has been incorporated into the GE-II. The articulation occurs below the shoulders, which ensures that the head and shoulders are supported together. Articulating the upper body in this way results in increased spinal flexion, which is evenly distributed across the entire length of the spine. Moving the head forwards without supporting the shoulders should be avoided as this will cause localised flexion at the C7/T1 spinal segment where the neck connects to the thorax. An additional improvement with the GE-II is the locking knob for the backrest articulation which improves ease of use while at the same time communicating its function.

With the improvements to the GE-II backrest, there is no need for the large headrest that accompanied the Delta. A range of more discrete headrests for comfort, rather than positioning, have been developed to compliment the GE-II. The headrests are weighted rather than strapped onto the backrest. The backrest also has concealed Velcro which can be used to secure the headrest if required.

The GE-II achieves its unique support by combining different types of support materials and contouring. The backrest contains a formed steel chassis that supports the pelvis and shoulder girdle, and facilitates moderate flexion. Elastomeric materials are utilised with varying tensions to accommodate more flexion when the chair is tilted than when it is upright. Anatomically moulded foam covers the entire backrest and incorporates visco-elastic properties (often referred to as memory foam). The contouring of the foam is quite delicate as much of the distribution of support is provided by the various supporting structures. This is a less aggressive form of support that is more responsive to both the individual and the chair configuration than many other backrests.

References

Adams, M. A, Bogduk, N., Burton, K., & Patricia, D. 2006, *The Biomechanics of Back Pain*, Second edition, Elsevier, London.

Adams, M. A. & Hutton, W. C. 1980, *"The effect of posture on the role of the apophysial joints in resisting intervertebral compressive forces"*, British Journal of Joint and Bone Surgery, vol. 62, pp. 358-362.

Adams, M. A. & Hutton, W. C. 1982, *"Prolapsed intervertebral disc. A hyperflexion injury. 1981 Volvo Award in basic science"*, Spine, vol. 7, pp. 184-191.

Adams, M. A. & Hutton, W. C. 1983, *"The effect of posture on the fluid content of lumbar intervertebral discs"*, Spine, vol. 8, pp. 665-671.

Adams, M. A. & Hutton, W. C. 1986, *"The effect of posture on diffusion into lumbar intervertebral discs"*, Journal of Anatomy, vol. 147, pp. 121-134.

Adams, M. A., McNally, D. S., Chinn, H., Dolan, P. 1994, *"The clinical biomechanics award paper 1993. Posture and the compressive strength of the lumbar spine"*, Clinical Biomechanics, vol. 9, no. 1, pp. 5-14.

Adams, M. A., McNally, D. S., Dolan, P. 1996, *"'Stress' distributions inside intervertebral discs. The effects of age and degeneration"*, The Journal of Bone and Joint Surgery, British Volume, vol. 78, no. 6, pp. 965-72.

Andersson, B., Örtengren, R., Nachemson, A., & Elfström, G. 1974, *"Lumbar disc pressure and myoelectric back muscle activity during sitting. I. Studies on an experimental chair"*, Scandinavian Journal of Rehabilitation Medicine, vol. 6, pp. 104-114.

Dunlop, R. B., Adams, M. A., & Hutton, W. C. 1984, *"Disc space narrowing and the lumbar facet joints"*, British Journal of Joint and Bone Surgery, vol. 66, pp. 706-710.

Holden, M., Ventura, J., & Lackner, J. 1994, *"Stabilization of posture by precision contact of the index finger"*, Journal of Vestibular Research, vol. 4, pp. 285-301.

Holm, S. & Nachemson, A. 1982, *"Nutritional changes in the canine intervertebral disc after spinal fusion"*, Clinical Orthopaedics, vol. 169, pp. 243-258.

Inufusa, A., An, H. S., Lin, T. H. *et al.* 1996, *"Anatomic changes of the spinal canal and intervertebral foramen associated with flexion-extension movement"*, Spine, vol. 21, pp. 2412-2420.

Jeka, J. & Lackner, J. 1994, *"Fingertip contact influences human postural control"*, Experimental Brain Research, vol. 100, pp. 495-502.

Jeka, J. & Lackner, J. 1995, *"The role of haptic cues from rough and slippery surfaces in human postural control"*, Experimental Brain Research, vol. 103, pp. 267-276.

Keegan, J. J. 1953, *"Alterations of the lumbar curve related to posture and seating"*, Journal of Bone and Joint Surgery, vol. 35, pp. 589-603.

Lackner, J. & DiZio, P. 2000, *"Human orientation and movement control in weightless and artificial gravity environments"*, Experimental Brain Research, vol. 130, pp. 2-26.

Maroudas, A., Stockwell, R. A., Nachemson, A. *et al.* 1975, *"Factors involved in the nutrition of the human lumbar intervertebral disc: cellularity and diffusion of glucose in vitro"*, Journal of Anatomy, vol. 120, pp. 113-130.

Michel, D. P. & Helander, M. G. 1994, *"Effects of two types of chairs on stature change and comfort for individuals with healthy and herniated discs"*, Ergonomics, vol. 37, no. 7, pp. 1231-1244.

Milne, J. S., Lauder, I. J., 1974, *"Age effects in kyphosis and lordosis in adults"*, Annals of Human Biology, vol. 1, no. 3, pp. 327-337.

Nachemson, A. & Morris, J. M. 1964, *"In vivo measurements of intradiscal pressure"*, The Journal of Bone and Joint Surgery, vol. 46-A, no. 5, pp. 1077-1092.

Nachemson, A., Lewin, T., Maroudas, A. *et al.* 1970, *"In vitro diffusion of dye through the end-plates and the anulus fibrosus of human lumbar inter-vertebral discs"*, Acta Orthopaedica Scandinavica, vol. 41, pp. 589-607.

Nwaobi, O. 1986, *"Effects of body orientation in space on tonic muscle activity of patients with cerebral palsy"*, Developmental Medicine and Child Neurology, vol. 28, pp. 41-44.

Pearcy, M. J. & Tibrewal, S. B. 1984, *"Lumbar intervertebral disc and ligament deformations measured in vivo"*, Clinical Orthopaedics pp. 281-286.

Pheasant, S. & Haslegrave, C. M. 2006, *Bodyspace: Anthropometry, Ergonomics and the Design of Work*, 3rd edn, Taylor and Francis, London.

Pynt, J., Mackey, M., & Higgs, J. 2008, *"Kyphosed seated postures: extending concepts of postural health beyond the office"*, Journal of Occupational Rehabilitation, vol. 18, pp. 35-45.

Schoberth, H. 1969 *"Die Wirbelsäule von Schulkindern - Orthopädische Forderungen an Schulsitze"*, in Sitting Posture, E. Grandjean, ed., Taylor and Francis, London, pp. 98-111.

Shirazi-Adl, A. 1991, *"Finite-element evaluation of contact loads on facets of an L2-L3 lumbar segment in complex loads"*, Spine, vol. 16, pp. 533-541.

Sprigle, S. & Sposato, B. 1997, *"Physiologic effects and design considerations of tilt-and-recline wheelchairs"*, Orthopeadic Physical Therapy Clinics of North America, vol. 6, no. 1, pp. 99-121.

Stairmand, J. W., Holm, S., & Urban, J. P. 1991, *"Factors influencing oxygen concentration gradients in the intervertebral disc. A theoretical analysis"*, Spine, vol. 16, pp. 444-449.

Urban, J. P., Holm, S., Maroudas, A. *et al.* 1977, *"Nutrition of the intervertebral disc. An in vivo study of solute transport"*, Clinical Orthopaedics pp. 101-114.

Appendix

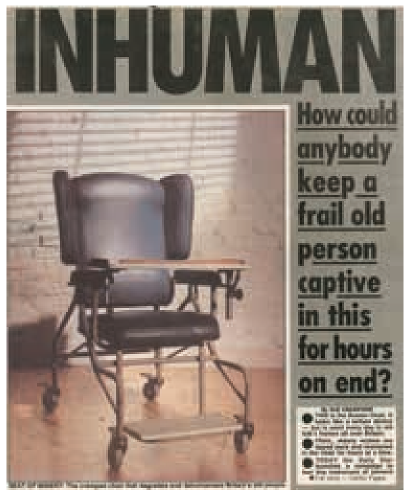
A1. The GE-II

A2. The Ultima

A3. The Delta

A4. The Buxton Chair *(original marketing)*

A5. Daily Star newspaper article, January 23, 1992



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