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Abstract: Introduction: The harmful effects of sustained sitting and the health of the spine are well documented. The focus of much of this investigation has been sedentary occupations. However, how people sit during leisure hours can impact on the health of the spine both in and out of working hours. Methods: A literature search was conducted using Amed, Cinahl and OVID Medline databases. Papers published between 1985 and 2007 were selected for review. These included epidemiological and experimental studies that explored the relationships between seated postures and health of the lumbar spine. Until recently there was confusion in the scientific literature as to which seated postures were least harmful; lordosed or kyphosed. This article reviews and analyses these conflicts in relation to leisure sitting. Results: Analysis of the literature demonstrates that kyphosed seated postures when sustained are more harmful to the health of the lumbar spine than lordosed seated postures. There is a misconception amongst designers and users of leisure seating that kyphosed relaxed postures are comfortable and that comfort equates with health. It is argued that sustained kyphosed postures are insidiously harmful to the spine in that they may contribute to disc degeneration in the absence of pain. Sustained kyphosed postures also adversely affect spinal ligaments, muscles and joints and lead to neuromuscular and cumulative trauma disorders and loss of spinal stability. Conclusion. Recent research demonstrates that postures popularly assumed in recreational or leisure seating lead to cumulative damage to soft tissues of the spine. These effects may still be present at the commencement of the following work day. In the prevention of work disability caused by sustained sitting, health professionals must consider the impact of leisure seating design and recreational sitting behavior.

Author Address: jpynt@csu.edu.au jhiggs@csu.edu.au

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TITLE PAGE

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Kyphosed seated postures: extending concepts of postural health beyond the office

Authors:

Jennifer Pynt[1]

Martin G. Mackey[2]

Joy Higgs[3]

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Contact author details:

Jennifer Pynt
The Education for Practice Institute,
Charles Sturt University,
16 Masons Drive,
North Parramatta
2151
Australia
Ph/Fax: 612 9592 6776
Email: jpynt@csu.edu.au

[1] The Education for Practice Institute, Charles Sturt University, 16 Masons Drive, North Parramatta 2151, Australia. Email: jpynt@csu.edu.au

[2] Discipline of Physiotherapy, Faculty of Health Sciences, The University of Sydney, NSW, Australia

[3] The Education for Practice Institute, Charles Sturt University, NSW, Australia

Kyphosed seated postures: extending concepts of postural health beyond the office

Abstract. *Introduction*: The harmful effects of sustained sitting and the health of the spine are well documented. The focus of much of this investigation has been sedentary occupations. However, how people sit during leisure hours can impact on the health of the spine both in and out of working hours. *Methods:* A literature search was conducted using Amed, Cinahl and OVID Medline databases. Papers published between 1985 and 2007 were selected for review. These included epidemiological and experimental studies that explored the relationships between seated postures and health of the lumbar spine. Until recently there was confusion in the scientific literature as to which seated postures were least harmful; lordosed or kyphosed. This article reviews and analyses these conflicts in relation to leisure sitting. *Results*: Analysis of the literature demonstrates that kyphosed seated postures when sustained are more harmful to the health of the lumbar spine than lordosed seated postures. There is a misconception amongst designers and users of leisure seating that kyphosed relaxed postures are comfortable and that comfort equates with health. It is argued that sustained kyphosed postures are insidiously harmful to the spine in that they may contribute to disc degeneration in the absence of pain. Sustained kyphosed postures also adversely affect spinal ligaments, muscles and joints and lead to neuromuscular and cumulative trauma disorders and loss of spinal stability. *Conclusion*. Recent research demonstrates that postures popularly assumed in recreational or leisure seating lead to cumulative damage to soft tissues of the spine. These effects may still be present at the commencement of the following work day. In the prevention of work disability caused by sustained sitting, health professionals must consider the impact of leisure seating design and recreational sitting behavior.

Keywords Posture, lumbar vertebrae, lordosis, kyphosis, sustained flexed sitting, leisure seating

Kyphosed seated postures: extending concepts of postural health beyond the office

Introduction

An estimated 75% of work in industrialized countries is performed while seated, a statistic that warrants the extensive scientific investigations into office seating and seated posture that have been conducted over the past 40 years [1-2]. Interest in occupational health and safety at governmental, managerial and media levels is reflected today in a well informed public which is largely aware of the importance of good office seating and posture in diminishing pain from seated tasks. However, making posturally healthy seating choices and adopting seated postures that optimize spinal health in leisure hours is rarely addressed by health professionals, seat designers or the public. Approximately 87% of Australians over the age of 15 watch television for an average of just over 3 hours/day [3]. Consideration of leisure hour seating as a cause of back pain is therefore important. The question arises: can the manner in which a person sits in leisure hours affect the health of the spine in office hours?

Many advertisements for lounge seating encourage a lack of postural restraint, equating comfort with kyphosed, relaxed, semi-recumbent sitting postures in modular lounges or seating with concave back rests (Figures 1 & 2). Promotional material highlights aesthetic dimensions, focusing on architectural trends, designs, and designers. Furniture designers, some of whom have achieved cultic status, base their designs on a variety of concepts, particularly those concepts that appeal to the perceptual senses [4]. Some designers have championed concave contoured design because such a shape is perceived by people as being pleasing to the body (comfort) and pleasing to the eye (aesthetic) [5]. Others who follow the Bauhaus design concepts of marrying geometry of form and technology with an economy of ornament [6] described their seats as functional despite either a lack of stability such as Breuer's [7] cantilevered chair (Figure 3), or a lack of adjustment, padding, recline and contouring such as Judd's right angled wooden office chair.(Figure 4). Ascribing functionality to Bauhaus concepts of simplicity and clarity of design encapsulates the divergent approaches between health professionals and some seat designers to the use of the term "functional". Still other designers have expressed the opinion that the anatomical configuration of the seated body is too complex, too unstable and too variable to be considered in seat design [8-9].

Galena Cranz, Professor of Architecture at the University of California, Berkeley, expresses the opinion that ergonomic researchers make incorrect assumptions that right angle seating, comfort and back support are the rational grounds on which to base seat design. Cranz favours stool sitting or perching on backless seats with active maintenance of a neutral lumbar spine posture. She argues that the ergonomic literature is confusing and contradictory [10]. Until the beginning of this century the latter statement was warranted. From the 1950s to 2000 there were two schools of thought regarding the least harmful seated postures. One school of thought argued that kyphosed sitting postures were less harmful to the health of the spine than lordosed postures [11-22]. On the other hand Keegan [23], Mandal [24-27], McKenzie [28], McGill [29-31] and Solomonow [32-33] argued that lordosed seated postures were less harmful than kyphosed.

If one considers that much of our leisure time is spent in the seated position and that recreational seat design is often designed to invite kyphosed postures (Figures 1, 2, 5-6) then there is a need to extend the understanding of the effects of sitting and seating beyond the scope of the office. This paper aims to: a) review the current scientific knowledge in order to determine the effect of kyphosed seated postures on the health of the lumbar spine both at the time of sitting and in the hours following sustained sitting in slouched postures.[4] b) analyze the contradictions in the literature regarding the ramifications of kyphosed and unsupported seated posture in order to address the comments by Cranz [10] and by so doing c) encourage designers in the domain of leisure seating to consider postural health as well as aesthetics in design and d) suggest to health professionals that advice to the public regarding sitting postures be extended beyond the office setting to include the potential for spinal ill health from poor recreational seating and postures.

Based on these criteria a search was made of the relevant electronic databases including Amed, Cinahl and OVID Medline using a number of keywords. These keywords included: posture, lumbar lordosis, kyphosis, sustained flexed sitting, leisure/lounge/dining seating. Relevant studies from the reference lists of reviewed papers were also included.

[4] This review does not consider the effect of seated posture on those with spondylolisthesis or severe degenerative changes whose spines for reasons of anatomical configuration prefer flexion

The effect of kyphosed sitting posture on intradiscal pressure

The amount of hydrostatic pressure within the intervertebral disc (IVD) nucleus is affected by the manner in which one sits, with the trunk either flexed or erect. Nachemson [34] found that there was 40% more intradiscal pressure at L3 in unsupported slumped (kyphosed) sitting compared with intradiscal pressure in erect standing. He also reported an increase of 85% in intradiscal pressure if the subject leant forward in a kyphosed sitting posture.

Nachemson's findings have subsequently been validated by in vivo studies in which pressure sensors were inserted into IVD at the level of L4-L5. Using this method Sato et al. [35] found a mean (±SD) intradiscal pressure of 1.13 ±0.25 MPa in the flexed sitting position and 0.74 ± 0.17 MPa in the actively extended sitting position. Wilke et al. [36] also reported lower mean intradiscal pressure at the L4-5 interspace in upright unsupported sitting (0.45-0.50 MPa) compared with unsupported kyphosed positions (0.83-0.90 MPa) with the body leaning forward over the knees. In kinematic studies of cadaveric spines Adams et al. [21] showed that when an intact lumbar motion segment was compressed with 500N at 50% of the total range of lumbar spine flexion, there was 12% (SEM ± 6%) increase in intradiscal pressure compared with the intradiscal pressure in the loaded neutral position. When the motion segment was loaded with the same compression force at 75% of lumbar spine flexion, there was 45% increase (SEM ± 8%) and in full flexion a 110% increase (SEM ± 17%). Therefore, when a cadaveric motion segment is compressed, there is a greater increase in intradiscal pressure in flexed postures compared with postures which maintain the lumbar spine in the neutral or lordosed position.

Not all studies have demonstrated an association between increased intradiscal pressure and kyphosed sitting postures. Two in vivo studies have been conducted which purport to demonstrate a lowering of intradiscal pressure in the kyphosed posture. The first was by Wilke et al. [36] who found mean intradiscal pressure was reduced to 0.27-0.30 MPa in a reclined slouched position compared with 0.33 MPa in a relaxed erect position supported by a backrest. However, there were a number of limitations of this study. Limitations included evaluation of intradiscal pressures in only one subject and a lack of specifications regarding the seat shape, degree of backrest recline and alterations of lumbar curvature. The second study by Sato et al. [35] found a lower intradiscal pressure in the neutral position of the lumbar spine than in the lordosed position. This finding may be flawed by the fact that subjects were required to actively assume and maintain a lordosed position. In vitro [36] and in vivo [37] studies conclude that if lordosis is maintained actively by the posterior spinal musculature then intradiscal pressure is higher than if the lordosis is maintained passively by lumbar support. Therefore the intradiscal pressure reported by Sato and colleagues may have been lower had lordosis been passively maintained.

Consideration must also be given to the effects of muscle and ligamentous tissue tension on intradiscal pressure. In the living subject an increase in intradiscal pressure in flexed sitting postures is caused by alterations in the centre of gravity, load sharing and ligamentous tension [37-38]. These alterations occur in the following manner. When the lumbar lordosis is flattened, loading on the anterior surface of the IVD is increased by the weight of the trunk acting downwards causing deformation of the disc [39]. Deformation of the disc stretches the posterior anulus, creating an increase in the tensile force of the posterior surface of the anulus [40-42]. At the same time the anterior anular surface is compressed with a concurrent increase in compressive stress [37] and load in the anterior anulus [43-44], accompanied by the appearance of significant stress peaks [21].

Intradiscal pressure is further increased by the effect of the flexed sitting posture on the ligamentous structure. The posterior ligaments resist a considerable amount of the forward bending moment in flexion, generating a combined tension of 300–3000N in full flexion depending on the cadaveric specimen size and age [44]. The resultant tensioning caused by flexion of the lumbar spine [37] increases the posterior ligament force approximately three times more than that of the anterior ligament in extension [41]. In terms of potential damage to the posterior ligaments and the disc, the aggregate posterior ligament and force escalation which occurs from loading in the flexed position has been termed "alarming" by Hedman and Fernie (p. 746).

The relevance of elevated intradiscal pressure to the health of the spine

Concave backrest design such as tub chairs, lounges that lack support because of soft upholstery and modular lounges inviting semi-recumbent sitting enforce and/or encourage kyphosed postures. Intradiscal pressure is increased in kyphosed postures. The ramifications of raised intradiscal pressure on the health of spinal structures have been demonstrated in a series of investigations as follows.

Lotz and co-authors [45-46] demonstrated, albeit in mice models, that IVD degeneration was induced by sustained compressive loading alone. The loading applied to mice IV discs was similar to that which occurs in unsupported upright sitting, as demonstrated by Sato et al. [35] and the resultant degenerative changes in mice spines were the same as those observed in humans. Although Urban [47] suggested that these results required further verification, she agreed that cell death in the inner anulus and cartilaginous endplates of vertebral bodies as demonstrated by Lotz and Chin [46] appears to correlate with alterations in magnitude and duration of applied stress.

In a later study, Ariga et al. [48] reported that endplate cartilage cell death in mice occurred when coccygeal IV discs were compressed for 24 hours with a sustained load of 1.0 MPa (less load than that achieved in kyphosed sitting). Associated findings observed by Ariga and colleagues were bulging of the disc and narrowing of IVD spaces.

There are limitations in extrapolating results from mice studies to humans. However the overall findings of these studies are of interest for the following reasons. While disc degeneration in humans is not fully understood it is known that endplate damage is a precursor to degenerative changes. Current best knowledge indicates that the endplate may be compromised by sustained loads which are lower than those produced by sitting in flexed postures sustained over 24 hours [48], or by other everyday events such as a sudden lifting activity, pulling roots from the garden, or falling directly onto the buttocks [49-50]. Endplates are a primary source of nutrition to the disc [51]. In response to endplate damage, production of proteoglycan is decreased [52] and pH in the disc is reduced [22, 50]. This reaction causes progressive degradation of the nucleus [50] and a decrease in the nucleus volume [22]. As a consequence of the decrease in nucleus volume there is greater transference of load from the nucleus to the posterior anulus [22, 53]. In turn the posterolateral anulus broadens, indicating that the anulus has altered role from restraining pressure to weight bearing [53]. Anulus weakened by degeneration demonstrate stress peaks in the posterior surface in both flexed and extended postures [21, 54]. The accompanying high stress peaks in the anulus adjacent to the depressurized nucleus may cause the anulus to collapse into the nucleus [55]. This internal disc disruption narrows the disc space and alters the function of the zygapophysial joints and the anulus of the compromised segment [50].

If the disc is compromised by sustained increases in intradiscal pressure such as occur from sustained sitting in chairs with concave backrests or unsupportive upholstery, progressive degeneration of the IVD may result. Therefore there is a link between extended periods of raised intradiscal pressure, as may occur in sustained kyphosed sitting, and disc degeneration. Pain provocation studies demonstrate that pain can be reproduced by mechanical stimulation of degenerated IVDs [53, 56]. On the other hand internal disc disruption is asymptomatic until the radial fissures accompanying the degeneration extend to the nociceptive nerve endings of the outer anulus [50]. It is this absence of pain that facilitates the misconception of equating health with the comfort that may be achieved by sinking into a “cloud of cushions” or relaxing semi-recumbent on modular lounges.

Consideration must also be given to the effect that increased intradiscal pressure and kyphosed sitting posture has on the position of the nucleus in the anulus. Cadaveric, discographic and MRI studies have shown that in flexed postures the nucleus migrates posteriorly [57]. In the kyphosed sitting posture the combination of posterior migration of the nucleus and increased intradiscal pressure renders the IVD vulnerable to posterior herniation. [57]

The effect of kyphosed sitting posture on viscoelastic creep

When compressive loading is sustained there is a gradual deformation of collagenous structures over time [50]. This phenomenon, called creep, is a normal diurnal occurrence in mammals. The scientific literature is replete with studies demonstrating that flexed postures sustained at constant load cause creep in the discs, zygapophysial joint capsules, and ligaments (i.e. the viscoelastic tissues) in human, porcine and feline experiments [41, 58-60] beyond that of the normal diurnal occurrence. In addition, it has generally been concluded that a sustained flexed sitting posture induces more creep as a result of IVD compression than an erect sitting posture [19, 55, 61, 62].

Creep in the IVD associated with sustained flexed postures occurs when the posterior anulus stretches and thins. The resultant attenuation is unable to prevent fluid loss from the IVD [19]. Creep is also exacerbated by increased intradiscal pressure from the tensioning of ligaments. In addition, in flexed sitting postures weight is transferred from the zygapophysial joints to the discs, further increasing intradiscal pressure and creep [19, 22, 61, 62]. Thus the amount of creep from constant load compression on the disc is greater in flexed postures than in erect sitting. Compressive loads associated with a flexed lumbar spine when seated, sustained over 6 hours, can decrease the IVD height by an average of 2.1 mm [19, 22, 62] and the fluid content is decreased in all parts of the disc except the posterior 2 mm of the anulus [62].

In contrast, several in vivo studies have shown an increase in disc height following sustained sitting [63-64]. However, these studies measured muscle activity with surface EMG which may not be a reliable indicator of the activity of deep muscles such as multifidus [65]. It is feasible that multifidus may have been activated during sustained sitting in an attempt to control small changes in flexion and extension of the trunk. These attempts at stabilization by multifidus could possibly create changes in intradiscal pressure, thus preventing intradiscal creep and maintaining disc height [66].

The effect of creep and hysteresis on the health of the spine

When sitting in a kyphosed posture for prolonged periods without movement there is sustained compression of the IVD. As a result fluid loss associated with creep increases and the disc becomes severely dehydrated [62]. Nutrition to the disc is then decreased and the process of disc degeneration accelerated [52, 67]. Concomitant with the loss of disc fluid is a loss of shock absorbing capacity with increased risk of injury to the disc and other structures of the spine [68]. In addition, as the IVD height diminishes, narrowing of the IVF occurs [19] with resultant potential for nerve entrapment. McGill [31] stresses the importance of movement while sitting to avoid these ill-effects of prolonged static sitting.

Disc hydration also affects the compressive strength of motion segments. In vitro porcine experiments by Gunning et al. [69] demonstrated that in full flexion the ability for dehydrated motion segments to sustain compressive loads is reduced by 43-47% in comparison with the point of failure of dehydrated motion segments in the neutral posture. In addition the point at which the tissues began to lose stiffness and yield prior to compressive failure occurred 53-63% earlier in flexed postures than in neutral postures. These findings conflicted with those of Adams et al. [21] who had previously been unable to demonstrate a difference in ultimate strength between human motion segments compressed in flexion and those compressed in neutral. The findings of Adams et al. however may have been flawed in that prior to failure the specimens had been loaded in the neutral position for several hours. Such loading history would have already brought the motion segments to a point of relative dehydration in neutral. When the loading history is taken into account therefore the results are most comparable to those specimens dehydrated in neutral in the study by Gunning and colleagues [69]. Gunning et al. demonstrated that failure occurred earlier in both hydrated and dehydrated flexed specimens than it did in dehydrated specimens in neutral postures. Although these findings are yet to be tested in humans, the similarities in disc hydration between humans and pigs are sufficient to make comparison credible [69].

The process of creep has also been shown to be associated with loss of multifidus reflexivity [68, 70, 71] and myoelectric hyperexcitablity [71-73] acute inflammation and microdamage in the posterior ligaments, dorsolumbar fascia, discs and capsules of the zygapophysial joints [74-76]. These findings have been demonstrated in both feline and human studies.

In feline studies investigating the effect of sustained flexion Solomonow et al. [32, 33] found that creep was associated with laxity in the viscoelastic tissues which affects stability of the spine in the following manner. A reflex exists from the afferents in the posterior ligaments of the spine and IV discs to multifidus and longissimus muscles. This reflex is responsible for stabilization of the spine. As laxity proceeds in the ligaments a decrease in the reflexive muscle activity of multifidus occurs due to desensitization of the mechanoreceptors in the ligament, discs and joint capsules [74]. Williams et al. [68] proposed that this significant diminishing of multifidus muscle activity occurs in human subjects within 15 minutes of sustaining a flexed posture. In this way when kyphosed postures are prolonged (either because of the shape of the backrest, the lack of support of upholstery or postural behaviour of the sitter) the stiffness of the spine and associated stability provided by multifidus is significantly reduced and spinal structures are at risk of damage.

In addition Solomonow et al. [70] have demonstrated that creep occurs in the viscoelastic tissues in sustained end of range kyphosed sitting over 10 minutes, with resultant interference of the relaxation phenomena of erector spinae in flexion. This human in vivo study reported that as the erector spinae muscles relax when fully flexed postures are adopted the compressive load on the spine is sustained by the posterior ligaments, dorsolumbar fascia, discs and capsules. After 10 minutes of sustained flexion of the lumbar spine, creep develops in these viscoelastic tissues and continues over the following 7 hours. The longer the subjects sat the more flexion was achieved because of increasing creep in viscoelastic tissues.

In response to progressive increase in flexion over 20 minutes feline multifidus demonstrated neuromuscular abnormalities such as spasm and hyperexcitability [77]. Solomonow et al. [70] explained this transient hyperexcitability in multifudus in the first hour following static loading as an attempt to compensate for increasing length in the supraspinous ligament. This hyperexcitability continued and increased for the next 2-6 hours of rest following sustained flexion [75] and was accompanied by inflammation in the supraspinous ligaments [74]. This concomitant inflammation of the ligaments signifies micro damage within viscoelastic tissues [68, 77]. The degree of inflammation in the supraspinous ligament dictated the time to recovery from hyperexcitability of the musculature [72].

It may be seen that static kyphosed sitting postures even as short as 10 minutes impose severe penalties on viscoelastic tissues due to creep. As sitting is sustained the posterior ligaments become increasingly disadvantaged in an attempt to stabilize spinal joints because of the cumulative effects of creep [74] and hysterisis. Hysterisis is the gradual deformation and recovery exhibited by viscoelastic structures when subjected to loading and unloading [78]. In vivo human experiments by McGill and Brown [60] tested the deformation and recovery response of viscoelastic structures in the lumbar spine to prolonged full range flexion in sitting. These authors concluded that maintaining such a position increases joint laxity. McGill and Brown [60] also found that after 2 minutes of rest following a 20 minute period of sustained sitting in flexion there was only 50% recovery of resting joint stiffness. After 30 minutes of rest there was still some degree of laxity evident in the joints. Indeed full recovery of the posterior structures from viscoelastic hysterisis was slow, during which time the spine was vulnerable to injury.

This vulnerability of the spine to injury is compounded by the effect sustained kyphosed sitting postures have on the multifidus reflex, as previously described. Dolan & Green [79] demonstrated an inability in human subjects to reposition the lumbar spine in neutral following slouched sitting periods as brief as five minutes. The study authors attributed this loss of postural repositioning to a combination of creep in viscoelastic tissues, interference of mechanoreceptor sensitivity and loss of multifidus reflex as demonstrated by Solomonow et al. [75, 80].

Therefore it is evident that sustained slouched postures alter the response ability of multifidus. Multifidus is considered to play an important role in humans in providing stability of the motion segment of the lumbar spine [30, 81-84]. Solomonow et al. [75], McGill [31] and Beach [66] all warn of the inherent dangers to the stability and protection of joints following sustained periods of kyphosed sitting due to ligamentous laxity. Loss of stability during or following sustained loading that occurs in lounge or dining chairs enforcing/encouraging kyphosed positions therefore poses significant risk of injury to the lumbar spine.

The potential for harm from sustained kyphosed sitting postures is further compounded by studies demonstrating that creep and muscular disorder are not resolved even by generous rest periods. Solomonow et al [76] demonstrated that the viscoelastic effects of creep and muscular disorder were evident for a period 60 times longer than the time it took for them to develop. Even with a 1:1 workload: rest ratio, (e.g. 10 minutes work:10 minutes rest), creep has been shown to still be present in human viscoelastic tissues as long as 7 hours post loading [85]. Solomonow et al [76] proposed that residual tissue creep from a working day may still be present at the start of the next working day thus predisposing the viscoelastic tissues to cumulative trauma. This situation is compounded if leisure hours after work are spent in lounge or dining seating in sustained kyphosed postures.

Similarly, hyperexcitability in muscles as a response to sustained flexion is long lasting and, contrary to popular advice, not necessarily reduced by rest. Experiments by LaBry et al. [73] in feline models demonstrated that a 3:1 workload : rest ratio, e.g. 30 minute work: 10 minute rest, 30 minute work, even with low static load of 20N in sustained flexion, led to cumulative neuromuscular back disorder developing over the ensuing 7 hours of rest. Extrapolating findings from feline to human spines is considered acceptable by Williams et al. [68] and Solomonow et al. [33] who proposed respectively that a) the adverse response to sustained flexed positions in humans was similar to that of cats, taking 15 rather than 3 minutes to begin and b) that humans demonstrate the same physiological mechanism of creep and mechanoreceptor response to prolonged flexion as cats.

In summary sustained kyphosed sitting postures are unhealthy in that they induce greater creep in the viscoelastic tissues than lordosed sitting postures [20, 55, 61, 62]. A dehydrated (or hydrated) motion segment in flexion is less able to withstand compression loads than a dehydrated motion segment in neutral [69]. Sustained flexed sitting postures also cause relaxation and passive stretch of the erector spinae and posterior ligaments leading to loss of multifidus reflex and joint stability. In the hours following sustained flexion there is accrual of creep and multifidus hyperexcitability indicating microdamage. Creep may not clear from the tissues with rest periods or prior to return to work, (particularly if leisure hours are spent in kyphosed postures), resulting in cumulative trauma disorders. There is also an accrual of damaging anterior shear loads from the stretched posterior ligaments which are unopposed by the erector spinae [86]. In addition considerable generation of elastic forces occurs [86]. These passive forces in turn increase joint compression in the flexed seated position [87]. This potential for damage from kyphosed seating design and sustained sitting postures emphasizes a) the need for recreational furniture design that supports the lumbar lordosis and b) the role that health professionals have in advising frequent movement and the passive maintenance of lumbar lordosis while sitting both inside and outside the office.

The effects of kyphosed sitting postures on the zygapophysial joints

It has been argued in the literature that in the kyphosed sitting position compressive loading on the zygapophysial joints is relieved, while in the lordotic posture zygapophysial joint loading leads to impingement and articular damage, particularly in the presence of IVD degeneration [18, 20]. This argument may be invalid for the following reasons. First, while flexed sitting postures relieve the zygapophysial joints of weight bearing, the impact of the compression load is borne solely by the IVD. The sustained increase in intradiscal pressure which occurs in flexed sitting postures ultimately promotes disc degeneration as previously described. Narrowing of the disc space increases loading in the zygapophysial joints [88] and alters the function of the zygapophysial joints and the anulus of the compromised segment. As a reaction to altered function, osteophytes occur in the zygapophysial joints [50]. Zygapophysial joint degeneration follows quickly on disc degeneration [89, 90].

Second, when investigating the ramifications of compression on the zygapophysial joints, consideration must be given to the effect of the seated posture on both intra-articular and extra-articular impaction. The zygapophysial joints show two areas of intra-articular impaction [50, 91-92]. One is the medial lower portion of the superior articular process. Impaction in this area has been shown to be the result of simulating extension in lumbar vertebrae [91]. The other area of impaction is on the medial upper portion of the superior articular process [50]. Swanepoel et al. [92] demonstrated damage to the superior zygapophysial joint surface in a study which used computer-aided image processing of degenerated zygapophysial joints stained with ink,. The authors postulated that such damage was correlated to tension in the fibres of the joint capsule sustained during prolonged flexion, as occurs in sustained sitting in kyphosed positions. Bogduk [50] proposed that this area of impaction occurs when the zygapophysial joints are resisting anterior-sagittal translation, which is a component part of lumbar flexion. Therefore, both flexion and extension postures are associated with intra-articular zygapophysial impaction.

As well as the intra-articular zygapophysial joint compression described above, extra-articular compression may also occur during sitting. This type of compression loading involves the transmission of pressure from the tips of the zygapophysial joints inferiorly to the lamina, or superiorly to the pars interarticularis [91]. In cadaveric lumbar motion segment studies with IVD of normal height, extra-articular impingement was reported in both flexed and extended postures when the disc space was narrowed artificially both by the addition of compressive loading and the removal of disc material [91, 93].

Therefore, both the lordosed and kyphosed postures of the lumbar spine cause impaction of the zygapophysial joints when disc height is narrowed, as may occur in static sustained sitting or in circumstances of IVD degeneration. These findings highlight the potential importance of movement or posture change in maintaining spinal postural health.

In summary, the rationale of advocating flexed sitting postures to relieve potentially damaging loads on the zygapophysial joints, thereby preventing pain, is not substantiated by the evidence. In flexed sitting postures the compressive and shear loads are transferred to the IVDs, thereby increasing pressure and ultimately leading to disc degeneration, which is also capable of provoking pain.

Are lordosed or kyphosed sitting postures more harmful to spinal postural health?

It has been argued in the literature that kyphosed sitting postures may be beneficial to spinal health because they decrease posterior anulus compression and unload the zygapophysial joints [12, 14, 18, 20]. In addition, in motion segment studies simulating the moderately flexed lumbar spine, compressive stresses across the disc were equalised whereas in the simulated lordosed lumbar posture, compressive stress peaks were increased in the posterior anulus and reduced in the anterior anulus [94]. Compressive stress peaks in the posterior anulus are potentially dangerous because this is the area that the disc is weakest due to degeneration [94]. However these negative findings must be offset against the more extensive harmful effects of kyphosed sitting postures.

Kyphosed sitting postures serve to increase IVD shear force [41], increase posterior anulus tensile forces [41], increase anterior anulus load [42], increase hydrostatic pressure in the nucleus of the disc [35], and increase loading of the posterior ligamentous system and the posterior fibres of the IVD [60]. If loading is sustained it will increase creep in posterior spinal structures, [60], decrease ultimate compressive strength of motion segments [69] decrease nutrition [62], may ultimately contribute to disc degeneration [45] and consequently be a cause of pain. In addition sustained flexed postures increase laxity in the discs, ligaments and joint capsules of the lumbar spine [68] and desensitize the mechanoreceptors in these structures [33]. These effects decrease or eliminate the multifidus reflex, thereby decreasing stability in the spine [70-72, 79]. The effects of flexed postures on ligaments and muscles last far longer than the time the posture is sustained [74]. It is not only office posture, but posture assumed in leisure hours that contributes to the potential for cumulative trauma in viscoelastic tissues.

Findings of delayed recovery of intervertebral joint stiffness following sustained flexion of 20 minutes motivated McGill [31] to advise against performance of physically demanding tasks following prolonged fully flexed sitting, a suggestion reiterated by Solomonow et al. [33, 75]. Beach et al. [66] also proposed that after 1 hour of sitting individuals can be at increased risk of injury if full flexion movements are attempted.

In a randomized control trial designed to address chronic non-specific low back pain Snook et al. [95] required their subjects to desist from spinal flexion in the early morning by, amongst other strategies, avoiding flexed sitting for the first two hours after rising. These authors reported 29% decrease in subjects' pain intensity and 23% decrease in the number of painful days recorded. In a followup 3 years later there was a further 51% decrease in the number of days in which pain was experienced in those subjects who had maintained compliance with the regimen [96]. The efficacy of this protocol may be explained by the effect that hydration has on flexed postures. During 8 hours rest in the recumbent position the lumbar discs on average gain 10.6% of their volume [97]. The compressive strength of motion segments is reduced in flexed postures in the presence of full hydration [69], as may occur when first rising in the morning. Thus if a person rises with hydrated discs and sits in a sustained kyphosed posture the spine is at risk.

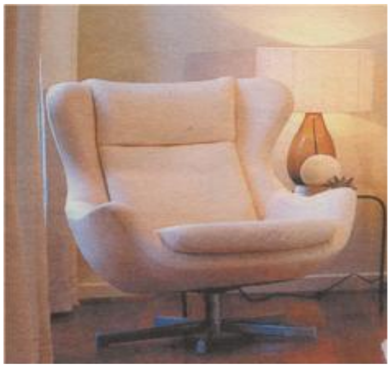
The role of behaviour and the sitter in healthy sitting posture

Individuals may adopt kyphosed sitting postures for a number of reasons. These reasons include chair design, habitual practice, lack of motivation to adhere to principles of good seating practiced in the office, and perceived comfort. It is important that health professionals stress to patients that the onset of their back pain is often insidious, and seated postures perceived as comfortable in the short term may be detrimental to the health of the spine in the long term. The principles of healthy seating apply in leisure hours just as they do in office hours. In particular it is important to educate the public that the current fashion for semi-recumbent sitting while watching television or working on a laptop places the spine in a kyphosed posture with potential for spinal ill health that may extend into the following working day. The onus is also on the health professional to impart knowledge regarding leisure seat design choices that will support postural health and function (relaxation) as well as fulfill concepts of aesthetics. Existing leisure seat design that encourages kyphosed postures can sometimes be modified by the insertion of portable lumbar contoured back supports and wedge shaped seat pan pillows. Such improvements can also be made to restaurant dining chairs and plane, train, car and bus seats. Choosing lounge chairs that are available in a range of sizes can solve anthropometric incompatibility within the family unit while maintaining aesthetic expectations. Finally, it is essential to educate the public regarding the importance of movement during sitting, in particular on long haul flights and road trips. A long period of sustained kyphosed sitting followed by retrieval of heavy luggage using a flexed and rotated spinal maneuver is potentially hazardous to spinal structures.

Conclusion

Lounge chair design which encourages long sitting, unsupportive modular seating, beanbags and seat design icons such as the concave bubble and egg chairs all facilitate kyphosed postures. There is a misconception amongst designers and users of lounge seating that kyphosed relaxed postures are comfortable and that comfort equates with health. However the maintenance of such postures creates spinal ill health. Sustained kyphosed postures are insidious in that they contribute to degeneration but pain does not occur until degenerative changes appear. Sustained kyphosed postures affect ligaments, muscles and joints and lead to cumulative traumatic disorders. Sustaining a kyphosed posture while dining, viewing TV or traveling can compound the ill effects from the working day, creating further potential for damage. The past thrust of ergonomic investigation and intervention into seated posture has focused on the office. The onus is on health professionals to extend education of the public regarding concepts of good sitting and seating choices beyond the office to leisure hours.

Figures



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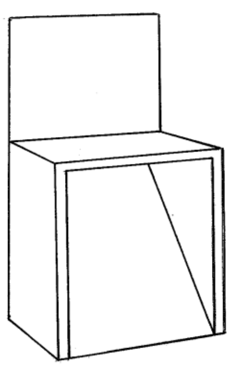

4.

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6.

Captions

Figure1. Popular lounge chair design that encourages kyphosis

Figure 2. Popular modular lounge design that encourages kyphosis

Figure 3. Breuer's cantilever dining chair is unstable when the sitter's weight is forward as occurs when dining

Figure 4. Judd's office chair fulfils Bauhaus concepts

Figure 5. Popular camping chair design that encourages kyphosis

Figure 6. Popular dining chair design that encourages kyphosis

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