Reducing lumbar spine stress during lying postures

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Abstract

Deviated spine postures during lying are linked to a variety of disorders. The study reported here investigated the issue of lumbar spine stress during lying postures by assessing the ability of a pneumatic support to restore deviated spine curvature.

Spine curvature in Sixteen (male = 14, female = 2) healthy individuals was measured while lying supine, and repeated with three types of lumbar supports.

Using upright standing as base, lying supine (no support) resulted in 3.4 degrees of lumbar flexion, on average. Using the lying no support condition as base, the sheepskin support extended the spine 3.4 degrees, while the two pneumatic supports, inflated to an optimum level for comfort, extended the lumbar spine 8.9 ($p<0.001$) and 9.8 degrees ($p<0.001$) respectively. Each participant was asked to record a rating of perceived comfort scale after trying each support condition. Every participant preferred a support over a no-support condition but the amount of inflation was variable. While the preferred inflation resulted in a range of extension varying from 0.3 to 12.5 degrees (using standing as base), 8.3 degrees of extension was preferred, unbeknownst to the participants.

In summary, supine lying causes the lumbar spine to flatten or experience flexion bending. Using a pneumatic bladder under the lumbar spine, inflated to a self-selected level based on optimal comfort, reduced spine flexion towards elastic equilibrium. This change in curvature has been linked to reduced annulus stress, reduced hydraulic pressures associated with posterior bulges, and reduced pain.

Introduction

The study reported here addresses the issue of lumbar spine stress during lying postures. The link between posture, back disorders and pain has been studied for standing (Scannell and McGill, 2003), sitting (Dankearts et al, 2006, Endo et al., 2012), and lying and sleeping (Haex, 2007). Spine flexion in each of these postures had been associated with the development of low back disorders (McGill, 2016). Despite the problem, investigations into lying and injury/pain mechanisms are relatively sparse. While not usually a problem for pain-free backs, once a back is sensitive because of tissue damage from repeated, prolonged and otherwise excessive spine flexion, deviated spine postures while lying then appear to trigger pain (Ikeda and McGill, 2012). Essentially, the greater the sensitivity, the smaller the violation in spine posture results in clinical pain. In a general study of sleep quality, Verhaert et al, (2011) investigated how spine support affects sleep in healthy subjects. They found that the relationship between bedding and sleep quality is affected by individual anthropometry and sleep posture noting that in particular, a sagging sleep system negatively affects sleep quality on a variety of metrics.

Low back pain patients sometimes report increases in pain during prolonged lying postures but as with all back pain, patients can be sub-categorized based on specific pain triggers. For example, placing the hands palms down under low back while supine is a test to see if discomfort may be provoked or relieved (after McGill, 2015). Thus there appears to be variability in the response to placing of the hands to result in more or less comfort/pain. Further, the shape of individual in terms of their natural lumbar curvature, the amount of buttock tissue, and the firmness or compliance of the mattress are all variables affecting comfort and spine stress. The principle that influences joint stress as a function of position is governed by “elastic equilibrium”. Every joint, when in its position of elastic equilibrium, has minimal stress. Flexing from this position or angle creates extensor tissue stress and likewise extending from equilibrium results in flexor stress. For the spine, the standing posture was shown to be close to elastic equilibrium or minimal elastic stress in the passive tissues (Scannell and McGill, 2003). In the current study spine joint stress was assessed from measurement of the curvature of the spine while lying supine.

Spine posture is linked to pain from several candidate mechanisms. For example, focal posterior disc bulges result from acute and repeated (Callaghan and McGill, 2001), and prolonged flexion postures. Here, hydraulic pressure is focussed towards the posterior annulus where repeated motion softens the matrix between the collagen fibres that normally act as a pressure vessel wall, allowing them to delaminate under the focussed pressure (Tampier et al, 2007, Schollum et al, 2010). The delamination may be between adjacent fibres and between the concentric layers that form the annulus (Tampier et al, 2007). These “open fissures” then allow flow of the nucleus with violations from non-neutral motions (Scannell and McGill, 2009). Other mechanisms linking pain and dysfunction with deviated postures have included ligament strains and neural pathology (for example intra and supra spinous strain with prolonged flexion Solomonow, 2012), and joint micro-movement associated with instability that trigger pain. All of these remain tenable candidates, with other being possible, to explain patient response to lying and discomfort/pain.

While several lumbar supports are available for sitting and have proved to be valuable for some categories of back pain mechanisms (eg sitting in airplane seats McGill and Fenwick, 2009), this study was designed to test whether a similar support could be helpful for lying postures. A few prototypes were developed that included pneumatic bladders attached to a pump covered with various foam sheets and placed into a sewn cover with waist straps to hold the support in place. Other static materials were also tested including a sheepskin shearling sewn onto a soft leather backing.

The purpose was to quantify changes in spine curve, and therefore joint stress, with the use of a pneumatic bladder. It was hypothesized that using the pneumatic bladder/support would adjust the lumbar curvature towards the neutral curve similar to standing considered to constitute elastic equilibrium. It was also hypothesized that participants would find a preferred amount of inflation greater than no support. From the prototypes, three types of supports were tested: 2 pneumatic supports and the sheep shearling. Given that this was an investigation of mechanism, and ultimately a test of proof of principle, healthy non-pained participants were recruited.

Methods

Participants:

Sixteen (male = 14, female = 2) healthy university aged individuals participated in this study. They were healthy screened for having no history of disabling or previous or current back pain, or musculoskeletal disorder. All participants read and signed the informed consent approved by the University Office of Research Ethics Board.

Study Design:

A cross-sectional repeated measures design was implemented. As such, participants acted as their own control in comparison of lumbar supports.

Sagittal plane lumbar spine kinematics measured via electromagnetic tracking (3Space Isotrak, Polhemus Inc, Colchester, VT, USA) sampled at 32 Hz. The 3Space source, placed on the right hip midway between the iliac crest and the greater trochanter of the femur, emits a low-frequency magnetic field detected by sensors placed over T12/L1 and L5/S1. The source and sensors were mounted on rigid bodies to minimise skin motion artifact and movement caused by mechanical collision. Care was taken to ensure that the rigid bodies did not move from their original application on anatomical landmarks. The zero position was obtained first as the participant adopted an upright standing, neutral posture. Then spine curvature was measured as the participants lay supine, evaluating each test condition. This was followed with a final standing measure. The first test condition was the no-support control test which was followed by the three lumbar support conditions (two pneumatic, one sheepskin) administered in random order.

The supports were XXcm by XXcm and placed with the long axis transversely oriented under the lumbar region. Pneumatic support 1 had a thinner foam sheet while support 2 was the same but had a thicker foam sheet either side of the bladder. Participants were free to adjust the air pressure to their liking with the instruction to be most comfortable.

Participants were given ample time to adjust and "tune" the inflation level in the pneumatic supports to optimize comfort. The spine curvature data was collected over a 10 second window. Pilot work showed this collection period to be of sufficient length for signal stability as the participants did not move (i.e. 10 secs vs 2 mins there was no difference in lumbar angle).

Statistical Analysis:

One way repeated measures ANOVA using a post-hoc Bonferroni Correction. Pairwise comparisons were used to test the hypothesis ($p < 0.05$ level).

Results

Using upright standing as base, lying supine (no support) resulted in 3.4 degrees of lumbar flexion, on average. Using the lying no support condition as base, the sheepskin support extended the spine 3.4 degrees, in other words the original standing curvature was restored. Using the pneumatic support 1 the spine extended 8.9 ($p<0.001$) degrees and the pneumatic support 2 extended the spine 9.8 degrees ($p<0.001$). Both pneumatic supports resulted in more extension than the sheepskin and no support condition ($p<0.01$). A curious observation was made in that the final standing posture had changed 3.9 degrees of more extension than the standing measure taken at the beginning of the study presumably due to the supported postures while lying.

Each participant was asked to record a rating of perceived comfort scale after trying each support condition. Every participant preferred a supported condition over a no-support condition but the amount of inflation was variable. While the preferred inflation resulted in a range of extension varying from 0.3 to 12.5 degrees (using standing as base), 8.3 degrees of extension was preferred, unbeknownst to the participants.

Discussion

Supine lying causes the lumbar spine to flatten or experience flexion bending. Using a pneumatic bladder under the lumbar spine, inflated to a self-selected level based on perceived comfort, reduced spine flexion towards elastic equilibrium. This change in curvature reduces annulus stress and reduces, or even reverses hydraulic pressures, associated with posterior bulges (Scannell and McGill, 2009). Balkovec and McGill, (2012) linked cyclic flexion with posterior migration of the nucleus through delaminations in the annulus collagen fibres and similar observations have been made under static flexion as long as 70% of the disc height remains (McGill, unpublished), meaning this mechanism does not appear to be viable for degenerated or severely injured discs. It appears that the pneumatic supports address the mechanism of posterior disc bulging.

McGill and Fenwick, (2009) documented the influence of a similar pneumatic support to restore elastic equilibrium of the lumbar spine while sitting. Clearly the results of this study show there is variability in individual response. This suggests that the notion of a "tunable" level of support would be better than a static level of support. Each participant was asked to record a rating of perceived comfort scale after trying each support condition. This was achieved with different levels of inflation but 8.3 degrees of extension was preferred.

In summary, many people report discomfort and pain with supine lying. In the clinic, some patients report an intolerance to supine lying due to low back pain. Providing some lumbar support has assisted many, but not all. This data shows than an adjustable pneumatic support influences spine curvature. Changes in curvature are linked with several known pain mechanisms.

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