A brief period of sustained flexion or extension does not alter lumbo-pelvic repositioning sense in pain-free subjects

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ABSTRACT

Background: Altered proprioception may be a factor in low back pain (LBP). Sustained end-range flexion appears to reduce proprioceptive acuity, as assessed by joint reposition sense, in healthy subjects. However, no study has investigated whether this occurs with shorter periods of lumbo-pelvic flexion or extension. The aim of this study was to examine the effects of a brief period (180 seconds) of sustained lumbo-pelvic spine extension and flexion on repositioning sense in pain-free subjects, compared to immediate repositioning sense (5 seconds).

Methods: Lumbo-pelvic repositioning sense was measured in 17 pain-free subjects. Participants were required to replicate a defined target position of the lumbo-pelvic region after: (a) lumbo-pelvic extension of 5 seconds and 180 seconds; and (b) lumbo-pelvic flexion of 5 seconds and 180 seconds.

Results: Two-way ANOVA’s (duration x direction) found no significant differences (p > 0.05) in repositioning accuracy, in terms of either absolute error (AE) or constant error (CE). There were no significant effects for direction (AE, p=0.244; CE, p=0.298), duration (AE, p=0.756; CE, p=0.657) or their interaction (AE, p=0.340; CE, p=0.288).

Conclusions: Lumbo-pelvic repositioning sense was not altered after a brief period of either sustained extension or flexion. The duration which the postures were sustained for may have been insufficient to alter repositioning sense. While prolonged end-range lumbo-pelvic postures may increase vulnerability to pain and injury, it is unclear what constitutes a safe duration of exposure to end-range postures.

Keywords: Proprioception, position sense, low back, lumbar spine

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INTRODUCTION

Low back pain (LBP) is a very common and costly musculoskeletal disorder, affecting 60-80% of people at some stage in their lives. Consequently, LBP is one of the main reasons for seeking medical treatment. In recent years, considerable evidence has emerged regarding the importance of abnormal motor control and movement patterns in LBP. Normal movement and motor control patterns require normal sensory inputs, including proprioception. Proprioception is the sensation of position and movement at joints; the sense of force, effort and heaviness associated with muscular contraction; or the sensation of perceived timing of muscular contraction. Proprioceptive input is derived from afferent neural information from joints, skin receptors, muscles, tendons and associated deep tissue mechanoreceptors. This afferent information is processed in the central nervous system.

Research has examined the role of proprioception in peripheral musculoskeletal disorders, and in recent years the role of proprioception has also been examined in spinal disorders, both cervical and lumbar. There is some evidence that subjects with LBP have reduced proprioceptive awareness compared with matched controls, although other studies have questioned this. These contradictory findings may be explained by significant differences between these studies, particularly in the way in which proprioception was assessed. Some have assessed lumbo-pelvic proprioception using the ability to detect passive motion or using gross measures of trunk position. Many others have measured lumbo-pelvic proprioception using repositioning sense, which appears to be a more sensitive and appropriate measure of lumbo-pelvic proprioception. Repositioning sense is a measure of position matching accuracy, with altered or inconsistent repositioning indicating a dysfunctional proprioceptive mechanism. The procedure typically involves asking a participant to reproduce a specific target angle or position.

In non-LBP subjects there is also evidence that lumbo-pelvic repositioning sense is altered in flexed postures, such that subjects have difficulty assuming specific target postures when placed into flexion. A recent study investigated the effect of a sustained flexed sitting posture on repositioning sense in subjects without LBP. In this study participants were asked to reproduce a target angle after returning from a flexed posture. These results indicate that lumbo-pelvic repositioning sense was significantly reduced after sustaining a flexed sitting posture for 300 seconds, when compared to immediate lumbo-pelvic spine repositioning sense after only sitting flexed for 3 seconds. It is unclear what minimum duration of exposure to sustained seated flexion is required before repositioning sense is affected, and if even shorter periods of sustained sitting also alter repositioning sense. Since reduced proprioceptive awareness could leave the lumbar spine vulnerable to injury, information on how quickly lumbo-pelvic proprioception is reduced is relevant to preventing LBP. Interestingly, despite the fact that many subjects with LBP report increased pain with extension-related tasks and postures, the
effect of sustained extension on lumbo-pelvic repositioning sense in sitting has not been examined. This is significant, as there is some evidence that spinal flexion and extension affect lumbo-pelvic repositioning sense differently. Therefore, the aim of this study was to investigate the effect of sustained extension and sustained flexion on lumbo-pelvic repositioning sense in non-LBP subjects. It was hypothesised that the accuracy of lumbo-pelvic repositioning would be reduced in subjects after brief periods of both sustained extension and sustained flexion.

METHODS
Participants
Seventeen university students (13 females) completed the study. Ethical approval for the study was obtained from the local university research ethics committee, and written informed consent was obtained prior to testing. Participants' mean (SD) age was 21.5 (1.0) years, mean height was 167.3 (8.5) cm, mean mass was 65.8 (8.0) kg, and mean body mass index was 23.47 (2.0) kg/m². Participants were included if they were aged >18 years, and had no history of inner ear infection or vestibular disorder. Subjects were excluded if they ever had LBP for more than 3 months, or had LBP at any time in the previous year. Those currently experiencing any pain or on pain medication were also excluded.

Instrumentation
Lumbo-pelvic repositioning sense was collected using the Spinal Position Monitoring Device (SPMD) ("BodyGuard", Sels Instruments, Belgium), a wireless method of measuring spinal posture (Figure 1). This minimally-invasive device does not require cumbersome cables, thus facilitating more normal movement. The SPMD incorporates a strain gauge that provides information about the relative distance between anatomical landmarks, estimating flexion/extension range of the lumbo-pelvic region by the degree of strain gauge elongation. Posture is expressed as a percentage of strain gauge elongation, so that the degree of spinal flexion/extension is expressed relative to a referenced range of motion (ROM), rather than being expressed in degrees. Postural data is recorded in real-time at 20Hz. The SPMD has been shown to have very good intrarater and inter-rater reliability (ICC > 0.8) for the measurement of lumbo-pelvic sitting postures.

Procedure
All testing was completed in sitting, as repositioning sense is challenged to a greater extent in weight-bearing. Furthermore, lumbo-pelvic repositioning sense may be better isolated in sitting as feedback from the lower limbs is minimised. Subjects sat on a wooden stool, bare feet on the ground, knees shoulder width apart, arms resting on their thighs, and their knees and ankles at 90°. All participants warmed up initially by performing maximal trunk flexion and extension while sitting on the stool. The spinal levels of L4 and S1 were identified by manual palpation in a slightly flexed sitting posture, and marked using a non-permanent skin marker. These levels were selected since recent research suggests the upper and lower lumbar spine demonstrate functional independence. A 4cm strain gauge was positioned directly over the spine at these levels by a single investigator to ensure consistency of placement using single-sided adhesive tape. No further taping was used to minimise cutaneous mechanoreceptor input. Thereafter, the SPMD was calibrated to full lower lumbo-pelvic ROM in sitting. For this, manual and verbal facilitation was used to guide subjects into a fully extended sitting posture which was set as 100% of their ROM, and then into a fully flexed sitting posture, which was set as 0% of their ROM. Thereafter, five trials of maximum extension and maximum flexion were performed to achieve a representative maximum lumbo-pelvic ROM in sitting for each subject.

Participants then completed the repositioning protocol. Subjects crossed their arms and rested their hands on opposite shoulders, and were blindfolded to eliminate visual cues. The investigator then guided participants to a mid-range lumbo-pelvic posture, similar to previous research, which is referred to as the target position (TP). This posture was chosen as the TP, since previous research indicates that participants have greater difficulty reproducing mid-range postures. Participants were asked to maintain this TP for 10 seconds and advised to remember this position, as they would be expected to reproduce it. Participants then performed both the flexion and extension protocols, with the order depending on randomisation via coin toss. For the extension protocol, they were asked to maximally extend in sitting ('sit up as tall as you can'), and maintain this position for 5 seconds (Figure 2), before reproducing the TP as accurately as possible. They were then immediately asked to maximally extend in sitting again, and maintain this position for 180 seconds before reproducing the TP as accurately as possible once more. For the flexion protocol, the only difference was the direction of movement, with participants being asked to flex their spine ('slouch down') for 5 seconds, and then 180 seconds (Figure 3), before attempting to reproduce the TP as above. The flexion and extension protocols were completed with a one minute rest between tests. In both cases the subject was given 10 seconds to reproduce the TP, and asked to maintain the TP for 10 seconds. Only the last 3 seconds of each repositioning attempt were analysed, to ensure participants were not still trying to assume the TP. Throughout data collection, participants were not given any verbal feedback regarding their ability to replicate the TP.
Figure 2: The sustained lumbo-pelvic extension position adopted during the repositioning test protocol.

Figure 3: The sustained lumbo-pelvic flexion position adopted during the repositioning test protocol.

Data analysis
Repositioning sense accuracy was calculated by analysing the difference between the defined TP and the attempts of participants to match the TP. Constant error (CE) and absolute error (AE) were used as outcome measures. CE is a measure of bias in the error towards a particular direction, as it takes into account overshooting or undershooting of the TP. AE is a measure of bias and variability, and represents an absolute value of the deviation from the TP, irrespective of the direction of the error. The alpha level for statistical significance was set at p<0.05. All data were analysed using SPSS for Windows version 15.0. Data were normally distributed (Kolmogorov-Smirnov, p>0.05). A general linear model repeated measures analysis of variance was used to examine for difference between the postures (TP) and all attempts to match the TP for all times and directions. Separate two-way (direction and duration) ANOVA’s were used to determine AE and CE, and to investigate if there was any significant effect in repositioning error for direction, duration or their interaction.

RESULTS
There was no significant difference between any of the postures for all times and directions (p>0.05). Two-way (duration x direction) ANOVA’s revealed no significant differences in repositioning accuracy for either AE or CE. There were no significant effects for direction (AE, p=0.244; CE, p=0.298), duration (AE, p=0.756; CE, p=0.657) or their interaction (AE, p=0.340; CE, p=0.288) (Table 1).

Table 1: Mean (SD) absolute error (AE) and constant error (CE) after both sustained flexion and extension.

<table>
<thead>
<tr>
<th>Perception of Target Position (TP)</th>
<th>Mean AE (SD)</th>
<th>Mean CE (SD)</th>
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<tbody>
<tr>
<td>After 5 seconds Flexion</td>
<td>9.54 (9.28)</td>
<td>-7.30 (11.24)</td>
</tr>
<tr>
<td>After 180 seconds Flexion</td>
<td>8.30 (8.75)</td>
<td>-3.50 (11.70)</td>
</tr>
<tr>
<td>After 5 seconds Extension</td>
<td>5.47 (4.66)</td>
<td>-1.98 (7.02)</td>
</tr>
<tr>
<td>After 180 seconds Extension</td>
<td>7.90 (7.92)</td>
<td>-3.55 (10.75)</td>
</tr>
</tbody>
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Values expressed as % lumbo-pelvic sagittal range of motion. Negative values for CE indicate assuming a more extended posture than the TP.

DISCUSSION
These results indicate that lumbo-pelvic repositioning sense was not significantly reduced after a brief period of sustained extension or flexion. The degree of repositioning error after 180 seconds was relatively small, and was not significantly different to the repositioning error measured after only 5 seconds of the sustained end-range postures. These results contrast with a recent study which demonstrated that a period of sustained seated flexion resulted in significantly greater repositioning error than immediate repositioning. A key difference between the studies may be the length of time the flexed posture was sustained for, as the other study sustained the end-range posture for 300 seconds. It is possible that sustaining the posture for 180 seconds is not long enough to alter lumbo-pelvic proprioceptive input. The fact that only the lower lumbo-pelvic region was analysed in the current study resulted in a smaller ROM being evaluated, which may have limited the ability to detect subtle differences in repositioning sense compared to Dolan and Green who evaluated the entire lumbo-pelvic spine. Finally, another possible reason for the different findings is the lack of practice attempts in the current study. Using practice attempts may reduce data variability, and facilitate greater precision of performance. Dolan and Green included ten practice repositioning attempts with manual facilitation and verbal feedback prior to testing. The accuracy of the initial repositioning attempt in the current study may have been further improved by allowing such practice attempts. However, we avoided using practice attempts, as the use of unfamiliar target positions has been recommended to reduce the risk that the TP might be reached simply through familiarity with a routine movement. Unlike sustained flexion, the effect of sustained extension on lumbo-pelvic repositioning sense had not been previously studied in sitting. Similar to sustained flexion, there was no effect on lumbo-pelvic repositioning sense with this very short period of sustained extension. Unfortunately, it is difficult to interpret whether this means the effect only occurs with flexion, or whether the duration of exposure to sustained end-range postures in this study was simply insufficient.

Proprioceptive input is derived from multiple sources, with contributions varying according to the position of, and load placed on, the spine. In end-range postures joint
mechanoreceptors are most active, whereas muscle spindles provide most afferent proprioceptive input throughout range.8,16,19 Numerous mechanisms by which sustained postures could influence repositioning sense have been proposed, by affecting either contractile or non-contractile tissues. Sustained end-range postures may stretch viscoelastic tissues, such that they do not resume their normal properties immediately after the removal of this load.35 This “creep” phenomenon has been demonstrated in studies looking at lumbar flexion in human and feline experiments.15,33.37 The alteration in viscoelastic tissue properties may result in a short-term change in afferent input to the motor control system, including proprioceptive afferent feedback.34 There is little consensus in the literature regarding the duration a posture must be maintained before this occurs. Several studies have demonstrated that sustained flexed postures result in spinal “creep” within 5 to 30 minutes.5,36,39,44 In this current study, 180 seconds of sustained end-range may have been an inadequate period of time to induce creep and challenge the proprioceptive system, explaining the results obtained. However, since Dolan and Green27 demonstrated altered repositioning sense after only 300 seconds of sustained flexion, it appears that only a relatively short period of time may be needed to alter repositioning sense. It is possible that the amount of time required to impair repositioning sense is shorter in subjects with LBP, although this has not yet been examined.

In addition to the “creep” phenomenon, sustained postures may also be associated with modified mechanoreceptor sensitivity and altered reflex muscle activity.45–46 Poor lumbo-pelvic repositioning sense in LBP subjects may reflect altered paraspinal muscle spindle afferent activation.19,29 Reports of altered muscle spindle function in LBP correlate with numerous findings of disturbed trunk muscle function in subjects with LBP.42 This hypothesis is further supported by research indicating that fatigue,47 and paraspinal muscle vibration,19,48 alter the repositioning sense of both subjects with LBP and healthy controls by influencing muscle spindle output. However, central nervous system factors including sensory processing and motor planning4 are also clearly linked to altered repositioning sense in subjects with LBP.

Studies investigating the presence of proprioceptive deficits in LBP have reported contrasting findings. Many report that subjects with LBP have reduced proprioceptive awareness, compared with matched controls,16,18,21 whereas others have reported no alteration in proprioceptive acuity.9,17,25 Even studies who agree on the presence of altered repositioning sense in subjects with LBP report contrasting findings on whether LBP subjects adopt more lordotic or kyphotic postures when trying to match the TP.16,19 In one study where evidence of reduced repositioning sense in flexion among subjects with LBP was reported, the subjects with LBP actually had better repositioning sense in extension compared to the matched control subjects,20 though the significance of this is unclear. Therefore, it is clear the role and relevance of lumbo-pelvic proprioceptive awareness in LBP is still poorly understood. While poor lumbo-pelvic proprioceptive awareness could predispose to LBP subjects assuming provocative postures, future studies may need to focus on specific subgroups of LBP subjects who are likely to demonstrate impairments in motor control and proprioception.16 In addition, differences may be explained by the methodologies used to assess proprioception, with some studies using the ability to detect motion,18,22 which may not be as sensitive as repositioning sense, since it does not test the ability to actively adopt a defined posture. In other studies, a gross measure of trunk posture which depends on a large number of sensory inputs was used,5,24,25,27 instead of localising the movement to the lumbo-pelvic region,16,19,22 as in the current study.

Even in studies of healthy subjects, the literature is contradictory regarding the effect of different postures on proprioception. It has been demonstrated that healthy subjects are more accurate at reproducing gross trunk flexion movements further into flexion range than they are at reproducing inner range flexion.24 However, this is not to be confused with the fact that in flexed postures, the ability to find or maintain a specific lumbar curvature, especially mid-range postures, is greatly reduced.31 In other words, while subjects can reliably reproduce a forward-leaning trunk posture, the ability to reproduce a mid-range lumbar spine curvature is reduced in such flexed postures, which may be a significant factor in LBP. Reduced proprioceptive awareness may be an important factor in LBP, due to the potential for abnormal loading of spinal structures, particularly among those that report vulnerability in the neutral zone.10 However, there is currently no evidence that proprioceptive deficits precedes the development of LBP in pain-free subjects. There remains a great deal that is unclear regarding the presence of, and nature of, proprioceptive deficits in LBP.

While proprioceptive sense may be influenced by sustained end-range postures in subjects with LBP, it is important to remember that repositioning sense is just one of many factors which may be affected by such postures, including muscle activation and compressive load.49,52 It is clear that not all sitting postures have the same effect on spinal load and trunk muscle activation.49,56,58 Lumbo-pelvic flexion can be associated with LBP,5,59,61 and reversal of flexed postures can reduce LBP.12,62 Conversely, some studies have reported increased lordosis in LBP subjects,8,63,65 with less pain experienced during lumbo-pelvic flexion.7,65 Therefore, there remains considerable debate about what sitting posture is optimal.34,56,59,62 Healthy pain-free subjects do not appear to habitually position their spines in end-range postures, unlike subjects with LBP,6 so it appears reasonable to recommend not adopting end-range lumbo-pelvic postures. Furthermore, LBP should be considered within a biopsychosocial framework where numerous factors other than posture, muscle activation and repositioning sense must be considered.7,67,68

There are several limitations to the current study. The sample size was relatively small, but was in line with previous similar studies.29 Only lower lumbo-pelvic repositioning sense was analysed, however this is the most common area for subjects to report LBP, and analysing the lower lumbar region separately reflects recent research suggesting the upper and lower lumbar spine regions demonstrate functional independence.4,49 As previously mentioned, the small ROM involved in the lower lumbo-pelvic region may limit the ability to detect differences in that region. Lumbo-pelvic movement was measured relative to ROM, rather than in angular values. However, calculation of posture relative to ROM has been
used in previous spinal posture research, and is similar to electromyography normalisation of muscle activity relative to maximal or sub-maximal voluntary contraction. While the lack of angular data limits our ability to compare the degree of repositioning error to other studies, not all repositioning studies have used angular data in their calculations. Only sagittal plane motion was analysed, and other planes of motion are certainly of interest in LBP. The repositioning test was only assessed for one repetition of one TP. Some have suggested there is a risk of noisy and biased results if very few repetitions are used, however previous research has demonstrated a significant difference can be measured using only one repositioning attempt. The TP may not have been identical in the different protocols; however the results indicate the postures were not significantly different. It has been suggested that assessing the variable error (VE) in repositioning may be important, however CE and AE are the most commonly researched measures of repositioning accuracy, and have the strongest link with proprioceptive deficits in LBP. Finally, the study only included subjects without LBP, and further analysis in subjects with LBP is required.

CONCLUSION
There was no difference in lumbo-pelvic repositioning sense after a brief period of sustained lumbo-pelvic extension or flexion, when compared to immediate repositioning after these postures. Further investigations are needed to clarify the duration of exposure required before repositioning sense is affected, the spinal postures which have this effect, and the significance of repositioning sense acuity in LBP.

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