1. INTRODUCTION

Low back pain (LBP) is a very common and costly musculoskeletal disorder (Woolf and Pfleger 2003), with many different contributing factors including provocative spinal posture (Pynt et al. 2001; Pope et al. 2002; Scannell and McGill 2003; Lis et al. 2007). While prolonged sitting in isolation is not a significant risk factor for developing LBP (Hartvigsen et al. 2000; Lis et al. 2007), combined exposure to prolonged sitting, awkward postures and vibration may increase the risk (Kelsey and Hardy 1975; Lis et al. 2007). In addition, prolonged sitting is a common aggravating factor for many subjects with LBP (Williams et al. 1991; O'Sullivan 2005). Considering the amount of time spent sitting in modern society, avoiding provocative seated spinal postures seems intuitively important (Li and Haslegrave 1999).

The sitting posture of some LBP subjects differs to that of matched controls (Dankaerts et al. 2006b; Womersley and May 2006). Reversing these provocative postures may help reduce LBP, and this is commonly advocated in LBP management (Poitras et al. 2005). There is still considerable debate on what the optimal seated lumbar posture is (Pynt et al. 2001; O'Sullivan 2005; Claus et al. 2009a). Sitting postures do not all have the same effect on spinal load and trunk muscle activation (Adams and Hutton 1985; O'Sullivan et al. 2002; Scannell and McGill 2003; O'Sullivan et al. 2006a; Snijders et al. 2008; Claus et al. 2009b). Spinal flexion can negatively affect spinal proprioception (Dolan and Green 2006), and can be associated with LBP (Womersley and May 2006). Addressing these flexed sitting postures can reduce LBP, with many authors recommending lordotic seated postures to reduce pain (Williams et al. 1991; Lengsfeld et al. 2000; Womersley and May 2006; Bettany-Saltikov et al. 2008;

Pynt et al. 2008). Conversely, some studies report increased lordosis in LBP subjects (Christie et al. 1995; Vergara and Page 2002; Dankaerts et al. 2006b; Van Dillen et al. 2009). Consistent with this, some LBP subjects report reduced pain with lumbar flexion (O'Sullivan 2005), possibly related to mechanical and nutritional advantages of flexed postures (Adams and Hutton 1985), relaxation of trunk muscles (O'Sullivan et al. 2006b) and unloading of spinal structures sensitised to extension loading (O'Sullivan 2005).

It has been proposed that an optimal sitting posture for LBP subjects who are sensitised to flexion or extension is a more neutral spine position involving slight lumbar lordosis and a relaxed thorax (O'Sullivan et al. 2006a). This neutral posture avoids potentially painful end-range positions (Scannell and McGill 2003), as well as activating key trunk muscles (O'Sullivan et al. 2006a; Claus et al. 2009b; Reeve and Dilley 2009). However, assuming such a posture may be difficult to adopt (Claus et al. 2009a), questioning its application in clinical practice. The ability to reliably position subjects into a neutral lumbar spine sitting posture has not previously been assessed.

There is evidence of altered proprioceptive awareness in NSCLBP subjects (Brumagne et al. 2000; O'Sullivan et al. 2003). Appropriate performance of postural correction exercises requires an accurate perception of the instructed neutral posture. Therefore, subjective impressions of neutral sitting are important. Although there is evidence that subjects with neck pain display an altered sense of optimal posture (Edmondston et al. 2007; Falla et al. 2007), the perception of neutral posture among NSCLBP subjects has not been studied.

Thus, as a precursor to future studies on NSCLBP subjects, it is important to investigate if subjectively perceived ideal posture (SPIP) and an independent tester perceived neutral posture (TPNP) differ compared to the subject's habitual sitting posture (HSP) in healthy asymptomatic subjects. Such a comparison has not previously been reported. Thus the aim of this study was to investigate the inter-tester reliability of positioning subjects into a neutral sitting posture, and to compare SPIP and TPNP to HSP.

2. METHODS

2.1 Study design

A single session, repeated measures study. The testers were two 4th year physiotherapy students. Prior to testing, the testers received training on positioning subjects into a neutral lumbar spine sitting posture from a musculoskeletal physiotherapist with 10 years clinical experience. This neutral posture aimed to position the lower lumbar spine into slight anterior pelvic tilt and slight lumbar lordosis, while maintaining relaxation of the thoracic spine. Inexperienced testers were used to evaluate if the TPNP could be instructed reliably, even in the absence of significant clinical experience.

2.2 Subjects

Seventeen participants (13 females) were recruited from within the university campus. Participants' mean (±SD) age was 21 (±1) years, height was 170 (±7) cm, mass was 65 (±8) kg and body mass index was 24 (±2) kg/m^2. Participants were excluded if they had previous LBP, were on any current pain medications, or had undertaken previous postural control training. All participants provided written informed consent. Ethical approval was obtained from the local university research ethics committee.

2.3 Instrumentation

Postural data were collected using the Spinal Position Monitoring Device (SPMD) ("BodyGuard", Sels Instruments, Belgium) (Figure 1). This small wireless device monitors spinal sagital posture without cumbersome cables, facilitating more normal movement in a variety of tasks, inside and outside the laboratory. The SPMD incorporates a strain gauge that provides information about the relative distance between anatomical landmarks, calculating spinal flexion/extension by the degree of strain gauge elongation. Subject posture is expressed as a percentage of strain gauge elongation, so that the degree of spinal flexion/extension is expressed relative to range of motion (ROM), rather than being expressed in degrees. Calculation of posture relative to ROM has been used in previous spinal posture research (Edmondston et al. 2007), and is similar to electromyography normalisation of muscle activity relative to sub-maximal voluntary contraction (Dankaerts et al. 2006a). Postural data was recorded in real-time at 20Hz. The SPMD has been shown to have very good reliability (ICC >0.8) for the measurement of sitting posture (O'Sullivan et al. 2009).

2.4 Procedure

2.4.1. Subject preparation

During testing, participants sat on a wooden stool, wearing shorts, bare feet on the ground, knees shoulder width apart, and arms resting on their thighs. A 4cm strain gauge was positioned directly over the spine at the spinal levels of L4 and S1, since the lower lumbar spine is the most common area for subjects to report NSCLBP (Dankaerts et al. 2006b). Recent research also suggests that the upper and lower lumbar spine regions demonstrate functional independence (Dankaerts et al. 2006b; Mitchell et al. 2008). The spinal levels of L4 and S1 were identified by manual palpation in a slightly flexed sitting posture. Once the SPMD was positioned, subjects performed maximal lumbar ROM to ensure the device was securely attached. To calibrate the SPMD, manual and verbal facilitation was used to guide subjects into a fully lordotic sitting posture which was set as 100% of their lumbar ROM (Figure 2a), and then into a fully flexed sitting posture, which was set as 0% of their lumbar ROM (Figure 2b). Thereafter, five trials of maximum extension and maximum flexion were performed to achieve a representative maximum lumbar ROM in sitting for each subject.

2.4.2 Habitual Sitting Posture (HSP)

Immediately following calibration, subjects were instructed to '*sit as you usually do'*, while looking at a convenient fixed point straight ahead. During this time their HSP was recorded covertly for one minute, such that subjects were not informed that their HSP was being recorded, as per previous studies (Edmondston et al. 2007; Mitchell et al. 2008).

2.4.3 Subjectively Perceived Ideal Posture (SPIP)

Subjects were then asked to '*sit in a posture which you think is the ideal posture*'. They were not given any other instructions, and did not receive any feedback on their posture. This was held for 10 seconds and repeated five times, with a 10 second relaxation period in between each repetition. Both testers were blinded to the attempted SPIP by a screen placed between them and participants.

2.4.4 Tester Perceived Neutral Posture (TPNP)

Subjects were then facilitated into a neutral sitting posture by one tester (TPNP1) using manual and verbal facilitation (Figure 2c). This posture was then held for 10 seconds and repeated five times with a 10 second period of relaxation in between repetitions, similar to the SPIP procedure. Following a one minute rest period the other tester repeated the same procedure (TPNP2). The testers were blinded to each others facilitation of TPNP by a screen.

2.5 Data analysis

Subjects' mean posture recorded over the one minute period was taken as their HSP. Similar to previous studies (Edmondston et al. 2007; Claus et al. 2009a), data at the start or end of the other sustained postures were excluded, to reduce the risk of data contamination due to beginning or ending movements. Therefore, data were extracted for the middle three seconds of each sustained posture, and averaged over the five measurements for each posture.

Data were analysed using SPSS 15.0. The data were normally distributed (Kolmogorov-Smirnov, $p>0.05$). To assess the reliability of TPNP, a two-way mixed intraclass correlation coefficient (ICC) and Bland and Altman methods were used (Bland and Altman 1986). A repeated measures ANOVA (with Bonferonni post hoc comparisons) compared the four sitting postures; HSP, SPIP, TPNP1, TPNP2. The alpha level for statistical significance was set at $p<0.05$.

3. RESULTS

3.1. Inter-tester reliability of positioning in a neutral sitting posture

The inter-tester reliability for positioning subjects into a neutral sitting posture (TPNP) was very good (ICC = 0.91, 95%CI: 0.74 → 0.97). The mean difference between testers was only 3.3% (95%CI 6.6→ -0.6) of lower lumbar ROM.

3.2. Perceptions of optimal sitting posture.

HSP was significantly more flexed than all three other postures; SPIP, TPNP1, and TPNP2 ($p=0.001$, $p=0.007$ and $p=0.002$ respectively) (Figure 3). There were no significant differences between any of the other sitting postures (all $p>0.05$), although SPIP was slightly more lordotic than both TPNP measurements.

4. DISCUSSION

4.1. Inter-tester reliability of positioning subjects into a neutral sitting posture

The reliability of positioning pain-free subjects in a neutral lumbar spine sitting posture based on the ICC values obtained was “almost perfect” (Landis and Koch 1977). Furthermore, the mean difference values indicated that there was only a relatively small degree of variation, and no bias, between testers. The reliability of TPNP was greater than that reported previously when determining lumbar lordosis from photography (Fedorak et al. 2003) and numerous other physiotherapy procedures (Hicks et al. 2003; Johansson 2006; Luomajoki et al. 2007).

4.2. Differences in Sitting Postures

Although the HSP was significantly more flexed than all other postures, it was still an approximately mid-range posture, supporting the hypothesis that pain-free subjects do not habitually sit in end-range postures (Dankaerts et al. 2006b). Subgroups of NSCLBP subjects adopt near end-range provocative postures (Dankaerts et al. 2006b).

Assuming more neutral mid-range postures may help normalise spinal loading and trunk muscle activation in these patients (O'Sullivan 2005; O'Sullivan et al. 2006a), although we did not evaluate muscle activation in these postures. Rehabilitation involving postural advice, as well as exercise, and relearning motor patterns, can modify lumbar posture such that it reduces passive tissue strain (Scannell and McGill 2003) and pain (Dankaerts et al. 2007). However, a recent study suggested that even pain-free subjects may find assuming this neutral posture difficult without feedback (Claus et al. 2009a). We used both manual and verbal feedback to facilitate TPNP, to reflect clinical practice, as simply providing handouts may not be sufficient to facilitate neutral sitting postures. In addition, postural training would normally be accompanied by examination of the pain response of NSCLBP subjects, which may actually facilitate assuming TPNP more easily. It is encouraging that following only a brief period of training two relatively inexperienced testers could reliably position subjects in a neutral sitting posture.

There were no significant differences in lumbar posture between SPIP and TPNP. Other studies have shown that neutral spine sitting (TPNP in this study) activates key trunk muscles without significant activation of large, torque-producing muscles (O'Sullivan et al. 2006a; Claus et al. 2009b; Reeve and Dilley 2009). This neutral posture also modifies activation of key thoracic and cervical muscle groups (Falla et al. 2007; Caneiro et al. 2010). This effect on muscle activation, although not measured in the current study, is important as spinal posture needs sufficient muscle activation to aid postural stability, without excess muscle activation imposing large compressive penalties and leading to fatigue (Gardner-Morse and Stokes 1998; Granata and Marras 2000; McGill et al. 2003; Kavcic et al. 2004; Claus et al. 2009b). SPIP was not significantly different to TPNP, although it was slightly more lordotic. During testing

SPIP was often associated with thoracic extension, however these thoracic observations cannot be quantified. Since even minor changes in spinal sagital alignment can significantly alter trunk muscle activation (O'Sullivan et al. 2006a; Claus et al. 2009b; Reeve and Dilley 2009), these variations in posture may be associated with significantly different levels of spinal load and are worthy of further study.

We acknowledge that the neutral sitting posture used in this study has not demonstrated superiority to other sitting postures in clinical trials. There is broad agreement that sitting involves more flexion than standing (Scannell and McGill 2003; Claus et al. 2009a; Dunk et al. 2009; De Carvalho et al. 2010), but disagreement on how much flexion this should involve (Claus et al. 2009b). It is possible that advice on an optimal sitting posture will differ between subgroups with NSCLBP (O'Sullivan 2005; Dankaerts et al. 2009).

There are few, if any, published studies on subjective impressions of optimal posture in NSCLBP. Edmondston et al (2007) found no significant differences in cervical HSP in neck pain subjects compared to healthy controls, but interestingly SPIP differed significantly between the groups. Another study on neck pain subjects (Falla et al. 2007) demonstrated that subjective perceptions of optimal posture differed from physiotherapist perceptions, although that study quantified muscle activation and not spinal posture. While the current study involved only pain-free subjects, if differences between SPIP and TPNP are present in NSCLBP subjects, this may have implications for rehabilitation.

Finally, there is no suggestion that any sitting posture must always be maintained, as this could result in fatigue, discomfort and pain (Magnusson and Pope 1998; Kavcic et al. 2004; Claus et al. 2009b). Instead, a neutral sitting posture may load the spine well during static low-load tasks, while allowing for normal movement. The ability to vary posture, so that neither rigid upright nor passive slumped postures are sustained, may help minimise the pain some NSCLBP subjects experience in sitting.

4.3 Limitations

The sample size was small, but similar to previous postural studies (O'Sullivan et al. 2002; Claus et al. 2009a; Claus et al. 2009b). The subjects were primarily young and female, and habitual posture may vary across age and gender. The level of agreement on TPNP may differ in NSCLBP subjects, although pain relief may act as a guide and actually improve reliability. Reliability may vary according to the experience and training of those involved, although excellent reliability was obtained in this study with inexperienced physiotherapy students.

Postural data were not expressed in degrees, although calculating lumbar posture relative to ROM is useful in NSCLBP research (Dankaerts et al. 2006b). The reliability of identifying spinal levels was not assessed. Similar to all skin mounted systems, the SPMD does not directly calculate spinal posture. Despite this, any error in spinal posture would be consistent across all postures measured. Only lower lumbar posture was calculated. Measurement of upper lumbar and thoracic movement patterns should be studied in the future.

Only sagital, unsupported sitting postures were analysed, and investigations of other planes and types of sitting posture are needed. Analysis of HSP in a laboratory setting has inherent limitations, but its significance has previously been demonstrated (Szeto et al. 2002; Dankaerts et al. 2006b; Mitchell et al. 2008). Using adhesive tape could have increased postural awareness; however this was consistent across all subjects and does not explain the differences observed.

While postural factors may be significant for subgroups of NSCLBP subjects (Dankaerts et al. 2006b), it is acknowledged that NSCLBP should be considered within a biopsychosocial framework where numerous factors other than posture and movement patterns must be considered (McCarthy et al. 2004; Linton et al. 2007).

5. CONCLUSION

Pain-free subjects can be reliably positioned in a neutral lumbar spine sitting posture. In this current study HSP was significantly more flexed than both SPIP and TPNP. There was no significant difference between any of the other postures. Further research to investigate this neutral sitting posture in NSCLBP subjects is warranted.

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Figure legends:

Figure 1: The spinal position monitoring device (SPMD)

Figure 2: Calibration to (a) maximum extension and (b) maximum flexion, and positioning into (c) neutral lumbar sitting posture

Figure 3: Mean (± SD) lumbar posture of all sitting postures; habitual sitting posture (HSP), subject perceived ideal posture (SPIP), and tester 1 and 2 perceived neutral postures (TPNP1 and TPNP2). All values expressed in % of lumbar ROM, where 0% = full flexion and 100% = full extension.

* = HSP was significantly more flexed than all 3 other postures ($p<0.05$).