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Original article

Can we reduce the effort of maintaining a neutral sitting posture? A pilot study

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ABSTRACT

Neutral sitting postures encouraging lumbar lordosis have been recommended in the management of sitting-related low back pain (LBP). However, prolonged lordotic sitting postures can be associated with increased fatigue and discomfort. This pilot study investigated whether changing the type of chair used in sitting can reduce the effort of maintaining a neutral sitting posture. The muscle activation of six trunk muscles was recorded using surface electromyography in 12 painfree participants. Participants were facilitated into a neutral sitting posture for 1 min on both a standard backless office chair and a dynamic, forward-inclined chair (Back App). Lumbar multifidus activity was significantly lower on the Back App chair ($p = 0.013$). None of the other five trunk muscles measured demonstrated a significant difference in activity between the chairs. There was no significant difference ($p = 0.108$) in the perceived effort of maintaining the neutral sitting posture on the two chairs. This study suggests that the lumbar multifidus activation required to maintain a neutral sitting posture can be reduced by considering the type of chair used. The mechanism through which the Back App chair reduces lumbar multifidus activation is unclear, but the greatest difference between chairs is the degree of hip flexion. The ability to maintain a neutral lumbar posture with less lumbar multifidus activation is potentially advantageous during prolonged sitting. Further investigations of the effects of chair design on longer duration sitting, and among LBP subjects, are warranted.

1. Introduction

Low back pain (LBP) is a common musculoskeletal disorder (Woolf and Pfleger, 2003), with many different contributing factors including provocative spinal postures (Pynt et al., 2001; Pope et al., 2002; Scannell and McGill, 2003; Lis et al., 2007). While daily sitting duration may not be a major factor in developing LBP (Hartvigsen et al., 2000; Lis et al., 2007; Roffey et al., 2010), sitting is a commonly reported aggravating factor (Williams et al., 1991; O'Sullivan, 2005). Therefore, addressing provocative spinal postures is commonly advocated in LBP management (Poitras et al., 2005).

The habitual sitting posture of some LBP subjects differs to that of matched controls, with both increased (Christie et al., 1995; Vergara and Page, 2002; Dankaerts et al., 2006b; Van Dillen et al., 2009) and decreased (Dankaerts et al., 2006b; Womersley and May, 2006) lordosis reported. Different sitting postures have varying effects on trunk muscle activation and spinal loading (Adams and Hutton, 1985; O'Sullivan et al., 2006a; Claus et al., 2009b), and it remains unclear what constitutes an optimal seated lumbar posture. Lordotic seated postures interspersed with movement are commonly advocated (Williams et al., 1991; Lengsfeld et al., 2000; Womersley and May, 2006; Bettany-Saltikov et al., 2008; Pynt et al., 2008), however lordotic sitting has also been associated with increased discomfort (Lander et al., 1987; Bennett et al., 1989; Vergara and Page, 2002).

It has been proposed that assuming a neutral lumbar spine position of approximately 30% from end-range extension which involves some anterior pelvic tilt and lumbar lordosis with thoracic relaxation, may be preferable to end-range postures for subjects with LBP (O'Sullivan et al., 2010). This would avoid end-range postures associated with increased spinal stiffness (Beach et al., 2005), as well as facilitating low-level trunk muscle activation (O'Sullivan et al., 2006a; Claus et al., 2009b; Reeve and Dilley, 2009). Such a neutral sitting posture is commonly considered an optimal sitting posture by physiotherapists (O'Sullivan et al., 2012). While physiotherapists can consistently facilitate this neutral sitting posture (O'Sullivan et al., 2010), it may be difficult to adopt

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without manual or verbal facilitation (Claus et al., 2009a), questioning its clinical applicability. Consequently, methods which reduce the effort of neutral sitting are worthy of investigation.

Many different chair designs have been advocated in the management of seated LBP. Forward-inclined chairs increase lumbar lordosis closer to that observed in standing (Bennett et al., 1989; Gale et al., 1989). Interestingly, both decreased (Koskelo et al., 2007) and increased (Lander et al., 1987; Bennett et al., 1989) lumbar muscle activation have been reported using these chairs. Dynamic chair designs have also been advocated, with a view to increasing spinal motion (Van Dieen et al., 2001) and altering trunk muscle activation (Gregory et al., 2006; Kingma and van Dieen, 2009). However, most studies suggest dynamic sitting has little effect on trunk muscle activation (McGill et al., 2006; O'Sullivan et al., 2006b) or seated discomfort (Beach et al., 2003; Aota et al., 2007; Lengsfeld et al., 2007). The Back App combines these two approaches, as it involves both a forward-inclined seat and a dynamic base of support. Both the chair height and the degree of motion available can be adjusted. It has the potential to reduce the effort of lordotic sitting, however this has not yet been investigated. Thus this pilot study aimed to investigate whether this dynamic, forward-inclined chair can reduce the effort of maintaining a neutral sitting posture among painfree participants.

2. Methods

2.1. Study design

A single session, repeated measures study. All participants completed the same protocol apart from the order of testing, which they randomly selected from a sealed opaque envelope. Ethical approval was obtained from the local university Research Ethics Committee.

2.2. Participants

Twelve (7F, 5M) pain-free participants were recruited from the local community. All participants provided written informed consent. Participants were aged >18 years, were not pregnant, had no LBP in the last two years, no previous spinal surgery, no current pain medications, had not received previous postural control training, and could speak/understand English. Participants mean(± SD) age was 23.3(±3.6) years, height was 169.5(±5.7) cm, mass was 65.9(±10.2) kg and body mass index was 22.9(±3.2) kg/m^2.

2.3. Instrumentation

2.3.1. Kinematics

Lumbo-pelvic posture was monitored using a wireless posture monitor (BodyGuard, Sels Instruments, Belgium) which incorporates a strain gauge that analyses the relative distance between anatomical landmarks. Posture is expressed as a percentage of strain gauge elongation, so that spinal flexion/extension is expressed relative to lower lumbar range of motion (ROM) (O'Sullivan et al., 2010). Postural data were recorded continuously in real-time at 1 Hz. This posture monitor has very good reliability (O'Sullivan et al., 2011) and validity (O'Sullivan et al., 2012) for the measurement of spinal posture. A strain gauge was positioned over the spinal levels of L3 and S2, since the lower lumbar spine is the most common reported area for LBP (Dankaerts et al., 2006b) and the upper and lower lumbar spine regions demonstrate functional independence (Dankaerts et al., 2006b; Mitchell et al., 2008). The spinal levels of L3 and S2 were identified by manual palpation in a slightly flexed sitting posture. Participants then performed maximal lumbar ROM to ensure the device was securely attached. To calibrate the posture monitor, manual and verbal facilitation were used to guide subjects through full ROM. Subjects were placed into maximum anterior pelvic tilt and lumbar lordosis in sitting which was set as 0% of their lumbar ROM, and then into a fully flexed sitting posture with maximum posterior pelvic tilt, which was set as 100% of their lumbar ROM (O'Sullivan et al., 2010). This was repeated five times, to obtain a representative ROM value.

2.3.2. Trunk muscle activation

The activation of six trunk muscles was analysed using surface electromyography (sEMG). A Motion Lab Systems MA-300 multichannel EMG system (Motion Lab Systems Inc., Baton Rouge, Louisiana, USA) collected sEMG data using bipolar, pre-amplified, circular electrodes 12 mm in diameter, with a fixed interelectrode distance of 18 mm. The sample rate was 1000 Hz per channel, with a bandwidth of 0–500 Hz, and a gain setting of 2000. The common mode rejection ratio was >100 dB at 60 Hz. Three abdominal and three back muscles of the right hand side of the trunk were analysed, after preliminary testing had demonstrated no significant difference between right and left sides in pain-free participants during such a relatively static task. The skin was prepared for electrode placement by abrading the skin with fine sandpaper, shaving any hair and cleansing the skin with isopropyl alcohol solution to reduce skin impedance, in line with recommendations (Hermens et al., 2000). Pairs of surface electrodes were positioned parallel to the fibre direction of each muscle (O'Sullivan et al., 2006a), and secured with clear adhesive tape. The muscles studied were superficial lumbar multifidus (LM) (L5 level, parallel to a line connecting the PSIS and L1–L2 level); iliocostalis lumborum pars thoracis (ICLT) (L1 level, midway towards the lateral border of the trunk); thoracic erector spinae (TES) (5 cm lateral to T9 level); external oblique (EO) (below the rib cage, along a line connecting the inferior costal margin and the contralateral pubic tubercle); internal oblique (IO) (1 cm medial to the ASIS); and rectus abdominis (RA) (1 cm above umbilicus and 2 cm lateral to midline). A common earth electrode was placed over the ulnar styloid. Good electrode contact was confirmed by visually examining the sEMG output while applying manual resistance. EMG data were normalised to maximum voluntary isometric contraction (MVIC). To generate MVIC for the abdominal muscles, three exercises were used (O'Sullivan et al., 2006a). First, the participant lay supine with their legs straight and strapped with a belt. A resisted curl-up with maximal manual isometric resistance applied symmetrically through their shoulders was used for RA. A resisted crossed curl-up, with the right shoulder moving towards the left and maximal manual isometric resistance applied through the right shoulder was used for EO. For IO, the same procedure was repeated on the opposite side. One exercise was used for all back muscles (O'Sullivan et al., 2006a). The participant was positioned prone, legs straight, and strapped with a belt. The participant, with their hands behind their neck, lifted their head, shoulders and elbows off the examination table and symmetrical maximal manual resistance was provided to their scapular region. To avoid fatigue, contraction time for all MVIC trials was 5 s (Soderberg and Knutson, 2000) with a 3 min rest between trials (McLean et al., 2003). The middle 3 s of EMG data, from the 5-s testing period, were analysed. The highest contraction from any of the abdominal tests was taken as the MVIC for each abdominal muscle, and the highest generated MVIC from three repetitions of the back muscle test was taken for each back muscle (O'Sullivan et al., 2006b).

2.3.3. Chairs

The Back App facilitates dynamic sitting in multiple planes through an unstable ball positioned at its base (Fig. 1), whose

Fig. 1. Neutral sitting on the Back App.

Fig. 2. Neutral sitting on the standard chair.

prominence can be altered to vary the degree of motion allowed. The degree of motion is dampened through a circular base, allowing for smooth variation in loading. For testing, participants placed their feet on the footplate at the base of the chair, to prevent them stabilising their feet on the floor. The degree of motion allowed was standardised at the 'green' zone, which involves a mild degree of motion and is recommended by the manufacturers for use during prolonged sitting. The standard chair was adjustable, backless and had wheels (Fig. 2). The standard chair was adjusted to allow an angle of 90° for both the hips and knees with the feet placed firmly on the floor (Fig. 1), while the Back App was adjusted to allow a 125° hip angle with their feet placed on the circular footplate at the base (Fig. 1). Limb angles were confirmed by goniometry. Participants were blinded as to when posture and sEMG recordings were occurring.

2.4. Neutral sitting task

Each participant was facilitated into a neutral sitting posture using manual and verbal facilitation. The neutral sitting posture involved positioning participants into a spinal posture 30% away from end-range spinal extension, similar to that previously defined as neutral sitting (O'Sullivan et al., 2010). In other words, the neutral posture was defined relative to each individual's available ROM. This posture was obtained through some anterior pelvic tilt and lumbar lordosis with thoracic relaxation. This was cross-referenced with the real-time posture monitor output until the 30% value was obtained. Once positioned, participants were instructed to stay in this position while on the standard chair, and to stay in this position while maintaining their balance when sitting on the Back App. Participants maintained this posture for one minute during which posture was recorded continuously, and sEMG was recorded for 5 s (at time interval 30 s) on both chairs. Participants then rated the perceived level of effort to maintain this sitting posture on both chairs, using a verbal numerical rating scale (VNRS) where $0 =$ "no effort to maintain this posture" and $10 =$ "extreme effort to maintain this posture".

2.5. Data analysis

Data were analysed using SPSS 18.0. Mean posture, and variation (SD) in posture, for each participant on each chair were exported for analysis. Both mean RMS activation, and variation (SD) in RMS activation, were also analysed for each muscle on each chair. Data were tested for normality using the Shapiro-Wilks test. Any data which were not normally distributed were transformed using a natural log transformation in SPSS. Paired *t*-tests were used to compare mean posture and variation in posture, mean muscle activity and variation in muscle activity, as well as perceived effort of neutral sitting between the chairs. Statistical significance was set at $p < 0.05$.

3. Results

Mean posture across all participants in neutral sitting did not differ significantly ($p = 0.709$) between the standard ($\text{Mean} + \text{SD} = 31.3 + 2.5\%$ flexion) and Back App ($\text{Mean} + \text{SD} = 31.9 + 4.1\%$ flexion) chairs. Similarly, postural variation across all participants was $<2\%$

on each chair, and did not differ significantly ($p = 0.345$) between the chairs. Mean LM activity was significantly lower on the Back App compared with the standard chair ($p = 0.013$) (Table 1). No other muscles were significantly less active on the Back App (Table 1). There was no difference in the degree of trunk muscle variation between the chairs (all $p > 0.05$). There was no significant difference in the perceived level of effort to maintain this sitting posture on both chairs (Fig. 3) ($p = 0.108$).

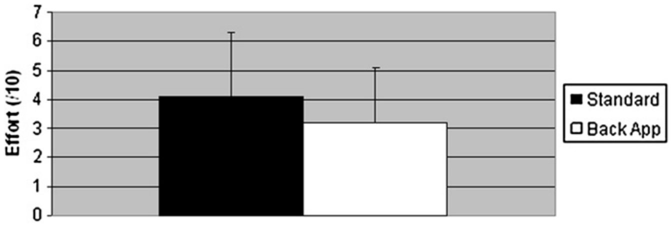

Fig. 3. Mean (+SD) effort required to maintain neutral sitting on both the standard backless chair and the Back App. Participants rated the effort on a verbal numeric rating scale (VNRS) from 0 to 10. The difference was not statistically significant ($p = 0.108$).

4. Discussion

The results of the current study demonstrate that a dynamic, forward-inclined chair reduces lumbar paraspinal muscle activity, specifically LM activity, while painfree participants maintain a neutral sitting posture. The differences observed could be due to some key differences between the chairs. Firstly, the reduction in hip flexion and use of a forward-inclined seat pan appears to be the most likely mechanism. A similar design has previously been shown to reduce paraspinal muscle tension over a 24-month period (Koskelo et al., 2007). Nevertheless, a similar kneeler-chair design increases, rather than decreases, paraspinal muscle activation (Lander et al., 1987; Bennett et al., 1989). An important factor in clarifying this potential confusion may be the lack of forward trunk lean in this study, which could increase paraspinal muscle activation (Vergara and Page, 2002) on such chairs if not monitored closely. Secondly, the increased motion in sitting facilitated by the Back App could explain the differences. However, while some dynamic sitting studies have reported changes in trunk muscle activation, in these studies trunk muscle activation actually increased rather than decreased (Gregory et al., 2006; Kingma and van Dieen, 2009). Furthermore, a greater number of studies report no difference in trunk muscle activation (Van Dieen et al., 2001; Beach et al., 2003; McGill et al., 2006; O'Sullivan et al., 2006b) and no reduction in seated discomfort (Beach et al., 2003; Aota et al., 2007; Lengsfeld et al., 2007) with dynamic sitting. Thirdly, the foot position differs on the Back App, which could influence the pattern of weight transfer through the spine and lower limbs. Therefore, it is difficult to identify which component of the Back App is responsible for the differences in muscle activation observed, although the reduction in hip flexion and use of a forward-inclined seat pan would seem the most likely mechanism.

While sitting involves more lumbar flexion than standing (Dunk et al., 2009; De Carvalho et al., 2010), it is unclear how much flexion this should involve. Previous studies demonstrate that a neutral sitting posture activates certain trunk muscles considered important in LBP management (O'Sullivan et al., 2006a; Falla et al., 2007; Claus et al., 2009b; Reeve and Dilley, 2009; Caneiro et al., 2010). Spinal posture requires sufficient muscle activation to aid postural stability, without excess muscle activation causing fatigue and exerting large compressive spinal loads (Granata and Marras, 2000; McGill et al., 2003). Determining an "appropriate" level of muscle activation during low load tasks such as sitting is difficult however. There is considerable evidence of increased superficial muscle activation among LBP subjects in low load tasks (Sihvonen et al., 1998; Van Dieën et al., 2003; Dankaerts et al., 2006a). Furthermore, trunk muscle fatigue occurs if contractions as low as 2–5% MVIC are sustained for as little as 30 min among painfree volunteers (van Dieën et al., 2009). Therefore, while the "ideal" level of trunk muscle activation is unclear, and caution is required in the absence of supporting clinical outcome data such as seated discomfort, there may be occasions when facilitation of less muscle activity while maintaining appropriate spinal alignment is advantageous. For example, it has been proposed that trunk muscle activation varies according to the context and complexity of the task being performed (Reeves et al., 2007). Dealing specifically with seated trunk muscle activation, LBP has been linked to both increased and decreased trunk muscle activation (Dankaerts et al., 2009). As such, there may be situations where a reduction in paraspinal muscle activation is desirable, and other situations where facilitation of greater paraspinal muscle activation is desirable.

Table 1
Mean (SD) trunk muscle activation (expressed as %MVIC) while sitting in a neutral sitting posture on a standard office chair and the back app chair.

Muscle	Standard	Back App	*p*
EO	6.0 (5.1)	4.8 (2.8)	0.220
IO	6.7 (5.6)	7.4 (5.9)	0.455
RA	4.8 (3.3)	5.4 (4.5)	0.323
TES	6.4 (5.2)	6.0 (3.1)	0.693
ICLT	9.9 (5.2)	8.5 (4.7)	0.146
LM	9.7 (5.9)	7.1 (4.2)	0.013*

%MVIC = percentage of Maximum Voluntary Isometric Contraction; EO – external oblique; IO – transverse fibres of internal oblique; RA – rectus abdominis; TES – thoracic erector spinae; ICLT – iliocostalis lumborum pars thoracis; LM – superficial fibres of lumbar multifidus (LM); * – $p < 0.05$.

A recent study suggested that even pain-free subjects may find assuming neutral postures difficult without manual or verbal feedback (Claus et al., 2009a). Since subjects with LBP may have deficits in proprioception (Brumagne et al., 2000; O'Sullivan et al., 2003), and alterations in their body schema (Moseley, 2008; Bray and Moseley, 2011; Luomajoki and Moseley, 2011), it might be even more difficult for LBP patients to assume and maintain prescribed neutral spinal postures. Therefore, methods of facilitating neutral postures more easily during LBP rehabilitation are worthy of investigation. Rehabilitation which involves retraining of neutral spinal postures has been shown to improve LBP outcomes (Suni et al., 2006; Dankaerts et al., 2007). However, while they appear to be considered advantageous by physiotherapists (O'Sullivan et al., 2012), neutral sitting postures have not demonstrated clear superiority to other sitting postures. In fact, advice on an optimal sitting posture may differ between subgroups with LBP, depending on their individual vulnerability to abnormal spinal loading (O'Sullivan, 2005; Dankaerts et al., 2009).

Neutral sitting may not be the same for all participants, potentially varying according to their gender (Dunk and Callaghan, 2005), genetics (Seah et al., 2011), body composition (Smith et al., 2011) and physical characteristics (Smith et al., 2010). In addition, assuming any static spinal posture for a prolonged duration could result in fatigue, discomfort and pain (Nelson-Wong and Callaghan, 2010). The ability to maintain a stable base of support during low load tasks, and still vary posture so that neither rigid upright nor passive slumped postures are sustained, may help minimise seated discomfort. Finally, while postural factors may be significant for subgroups of NSCLBP subjects (Dankaerts et al., 2006b), it is abundantly clear that LBP is a complex, multidimensional disorder where numerous factors other than posture and movement patterns must be considered (Rees et al., 2011; O'Sullivan, 2012). However even in LBP subjects with high levels of fear, stress or anxiety, facilitation of less painful postures may help as part of a comprehensive functional rehabilitation programme (Lewis et al., 2012; O'Sullivan, 2012).

In this study the Back App chair was compared to a chair without a backrest to avoid the possible confounding influence of a backrest affecting the results (Gregory et al., 2006; Kingma and van Dieen, 2009). Most standard office chairs have backrests which may also decrease the muscular effort and discomfort of sitting (Andersson et al., 1974; Vergara and Page, 2002). Therefore, future comparison of the Back App to a standard chair with a backrest is required as a backrest could be equally effective at reducing the effort of sitting. Future research should also examine whether similar reductions in paraspinal muscle activation occur in a range of lordotic sitting postures, and among participants with LBP. Ongoing research by the current research group is examining whether this chair can help reduce seated discomfort among a subgroup of subjects with LBP. The specific subgroup studied consists of those who report increased LBP when sitting on a flat chair, reduced LBP in standing, and have difficulty maintaining a neutral sitting posture, as described elsewhere (Dankaerts and O'Sullivan, 2011). The effect of such chairs on other spinal regions is also worthy of investigation, as is examination of the influence of varying degrees of seated motion. The current results suggest that LM activation is more specifically influenced by changes in hip flexion angle than the other trunk muscles studied, which is consistent with previous research suggesting that LM is more specifically influenced than the other paraspinal muscles by local variations in lumbar lordosis (Claus et al., 2009b). Future research may provide further insight into how this relates to the role of these muscle groups in functional tasks with different hip flexion angles.

4.1. Limitations

Similar to many previous postural studies, this study involved only a small sample of young, painfree participants which reduces the statistical power of the findings. Clearly examination of subjects with greater levels of pain and disability is required. Neutral sitting was maintained for only a relatively short duration, which may explain the lack of a significant difference in subjective perceived effort despite significant changes in LM activation. Studies are necessary to evaluate if the slight reduction in perceived effort on the Back App is more significant when maintained for longer periods. Participants may not all have interpreted the effort scale consistently, depending on what they perceived to be representative of extreme effort. The BodyGuard does not directly calculate spinal posture, similar to all skin mounted spinal motion-analysis systems. Postural data were not expressed in degrees, and muscle activation was limited to analysis of the superficial trunk muscles. Neutral posture was not expressed relative to habitual or relaxed, slump posture, limiting interpretation of the data.

5. Conclusion

Neutral sitting postures are commonly advocated in the management of LBP, yet maintaining these postures may require high levels of paraspinal muscle activation. In this study, pain-free participants could maintain a neutral lumbar spine sitting posture with less activation of LM, but not the other paraspinal muscles, when sitting on a dynamic, forward-inclined chair compared to sitting on a standard chair with a flat seat pan. The mechanism through which the chair reduced LM muscle activation is unclear, but the greatest difference between the two sitting conditions was the degree of hip flexion. The ability to maintain a neutral lumbar posture with less muscle activation is potentially advantageous during prolonged sitting. Further studies of longer duration in people with LBP are required.

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