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Specific flexion-related low back pain and sitting: comparison of seated discomfort on two different chairs

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No study has examined the effectiveness of prescribing seating modifications according to the individual clinical presentation of people with low back pain (LBP). A dynamic, forward-inclined chair ('Back App') can reduce seated paraspinal muscle activation among pain-free participants. This study examined 21 participants whose LBP was specifically aggravated by prolonged sitting and was eased by standing. Low back discomfort (LBD) and overall body discomfort (OBD) were assessed every 15 min while participants sat for 1 h on both the dynamic, forward-inclined chair and a standard office chair. LBD increased significantly more ($p = 0.005$) on the standard office chair, with no significant difference ($p = 0.178$) in OBD between the chairs. The results demonstrate that, in a specific flexion-related subgroup of people with LBP, increased LBD during sitting can be minimised through modifying chair design. Mechanisms that minimise seated discomfort may be of relevance in LBP management, as part of a biopsychosocial management plan.

Practitioner summary: This study examined low back discomfort (LBD) during a typing task among people with low back pain (LBP). Sitting on a dynamic, forward-inclined chair resulted in less seated LBD than sitting on a standard office chair. Further research is required to examine the long-term effectiveness of ergonomics interventions in LBP.

Keywords: back pain; office ergonomics; biomechanics; seating

1. Introduction

Low back pain (LBP) is a very common and costly musculoskeletal disorder (Woolf and Pfleger 2003). It is a common cause of work absenteeism (Iles, Davidson, and Taylor 2008) with over half of sedentary workers reporting LBP during their lifetime (Lloyd, Gauld, and Soutar 1986). Prolonged sitting in isolation does not cause LBP (Lis et al. 2007; Bakker et al. 2009; Roffey et al. 2010). However, sitting is a commonly reported aggravating factor for LBP (Williams et al. 1991; Vergara and Page 2002; Dankaerts et al. 2006; Womersley and May 2006), with much LBP research undertaken on both individual seated posture (Dankaerts et al. 2006) and ergonomics factors such as chair design (Gadge and Innes 2007; Lengsfeld et al. 2007).

In terms of chair design features, using a backrest may help reduce trunk muscle activation (Andersson, Jonsson, and Ortengren 1974; Kingma and van Dieen 2009) and low back discomfort (LBD) (Vergara and Page 2000). However, backrest use can be limited among common seated tasks (Vergara and Page 2000). Adjustable height furniture that reduces hip flexion in sitting can reduce paraspinal muscle tension and increase paraspinal muscle strength over a 24-month period (Koskelo, Vuorikari, and Hänninen 2007). Similarly, saddle chairs that reduce seated hip flexion through a forward-inclined seat also promote lumbar lordosis (Gale et al. 1989; Gadge and Innes 2007). However, although such forward-inclined saddle chairs may decrease LBD, they can actually increase discomfort in other body regions (Gadge and Innes 2007) such that overall body discomfort (OBD) is similar. Furthermore, similar kneeler chair designs that reduce seated hip flexion may increase rather than decrease paraspinal muscle activation (Lander et al. 1987; Bennett et al. 1989) and LBD (Lander et al. 1987).

It has been proposed that individuals with LBP adopt more static, end-range seated postures, and use large infrequent shifts in posture rather than subtle spinal movements (Vergara and Page 2002; Dankaerts et al. 2006; Telfer, Spence, and Solomonidis 2009). Accordingly, 'dynamic' sitting approaches to facilitate spinal micro-movements and to vary the loading and activation of spinal structures have been advocated (van Deursen et al., 2000; Van Dieen, De Looze, and Hermans 2001; McGill and Fenwick, 2009). However, a recent systematic review (OSullivan et al. 2012c) reported no evidence that dynamic sitting is an effective intervention in isolation for LBP. Therefore, there is relatively little evidence to support most seating modifications in the management of musculoskeletal disorders including LBP (Driessen et al. 2010;

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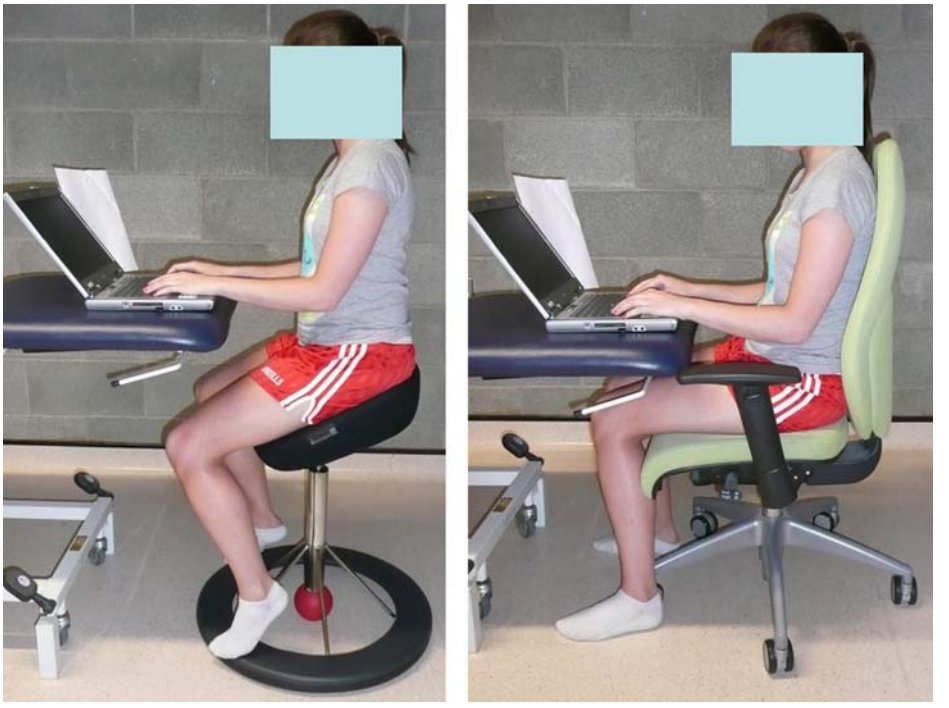

Figure 1. Layout of the simulated workstation, with participant sitting on the dynamic, forward-inclined saddle chair (left) and the standard office chair (right).

Van Niekerk, Louw, and Hillier 2012). This limited effectiveness may be due to the intervention itself being ineffective, or being applied to the wrong people or in the wrong manner, or all of these factors.

Combining some features of existing chair designs might increase effectiveness. The 'Back App' (Figure 1) combines the features of a forward-inclined saddle chair with the principles of dynamic sitting. It is flat under the ischial tuberosities yet forward sloping under the thighs, thereby increasing the trunk–thigh angle, resulting in reduced hip flexion. It does not feature a backrest. The degree of seated motion can be adjusted using a ball located at the base of the chair. For instance, by adjusting the ball at the base of the chair to different colour zones, it can function as a relatively static chair (green zone), a dynamic chair (black zone) or a more unstable training chair (red zone). It differs from other chairs in that the feet are placed on a footplate, rather than on the floor, which allows it to rotate gently around the vertical axis when sitting. This chair can reduce paraspinal muscle activation among pain-free participants during seated tasks (O'Sullivan et al. 2012a, 2012b). Therefore, it offers the potential to reduce the muscular effort and discomfort associated with prolonged sitting for people with LBP. Considering evidence that people with mechanically provoked LBP may present with either excessive lumbar flexion or excessive lordosis (Dankaerts et al. 2006), modifications to seated ergonomics should consider the clinical presentation and aggravating factors of people with LBP. For example, people whose LBP is specifically aggravated by sitting and habitually assuming near end-range flexed postures, and that is less painful in extended postures such as standing and walking, may benefit most from a seated modification reducing lumbar flexion. Therefore, this study aimed to compare seated discomfort among a specific subgroup of people with LBP while sitting on a dynamic, forward-inclined chair and a standard office chair during a controlled typing task.

2. Methods

2.1 Study design

A single session, repeated measures, crossover study design was used, in line with previous, similar studies (Reinecke, Hazard, and Coleman 1994; Van Dieen, De Looze, and Hermans 2001; Gregory, Dunk, and Callaghan 2006). All participants completed the same protocol on a single day, with the order of testing randomised by tossing a coin. The dependent variable was seated discomfort, and the independent variable was chair type. Ethical approval was obtained from the local university Research Ethics Committee, and written informed consent was obtained from all participants.

2.2 Participants

Twenty-one (15 F and 6 M) participants with LBP were recruited from the local community. Participants' mean (SD) age was 22.1(3.2) years, height was 1.7(0.9) m, mass was 65.3(16.2) kg and body mass index was 22.5(4.4) kg/m^2.

2.3 Eligibility criteria

Participants were included in this study if they had LBP aggravated by >1 h of sitting or other spinal flexion activities (e.g. driving and bending) and relieved by spinal extension (walking and/or standing), consistent with a flexion-related pain disorder (O'Sullivan 2005; Dankaerts et al. 2009). Participants were aged >18 years, and had experienced LBP in the 2 weeks prior to testing. Participants were excluded if they were pregnant, had neurological symptoms such as pins and needles and numbness (Lengsfeld et al. 2007), had a specific spine disorder/tumour/fracture (van Deursen et al. 1999) or had previous spinal surgery (Lengsfeld et al. 2007).

2.4 Chairs

The dynamic, forward-inclined saddle chair was adjusted to allow hip flexion of 55° with feet placed on the footplate for all participants (Figure 1), in line with previous research (O'Sullivan et al. 2012a, 2012b). The ball underneath the chair was adjusted to allow a slight degree of instability (black zone), in line with previous research (O'Sullivan et al. 2012a, 2012b). The standard office chair (Figure 1) had a moveable backrest, was height adjustable and had wheels. The office chair was adjusted to allow an angle of 90° for both hips and knees with feet placed on the floor (Gregory, Dunk, and Callaghan 2006). As a result, there was a 35° difference in hip flexion between the two chairs. The instructions used were 'sit as you normally would' on the standard office chair and 'try to balance yourself' on the dynamic, forward-inclined saddle chair. A rest period of 2 min was provided between chairs, during which time participants could walk or stand. Adjustment time (2 min) was provided to allow participants to become familiarised with the chairs (Kingma and van Dieen 2009).

2.5 Procedure

During testing, participants wore shorts and no shoes. A workstation was created for the typing task (Figure 1). As self-selection of workstation set-ups can be linked to the adoption of less than optimal sitting postures (Gadge and Innes 2007), participants' elbows were maintained at an angle of 90–100° while typing. The height of the typing surface was adjusted to maintain this elbow angle. The distance of participants from the typing surface was standardised, with the edge in line with the radial styloid process and a distance of 30 cm to participants' greater trochanter. A laptop with a self-touch mouse was placed directly in front of the participants. The document to be typed was positioned to the right of the screen. All participants typed the same literature (Van Dieen, De Looze, and Hermans 2001) for 1 h on each chair, with an investigator turning the pages as required. This aided standardisation during testing, limiting the potential for confounding factors affecting the findings. The office chair was randomised as the first chair for 12 of the 21 participants.

2.6 Questionnaires

At baseline, every 15 min and on completion of each sitting exposure, participants rated their perceived discomfort on the body part discomfort scale (BPDS). The BPDS (Corlett and Bishop 1976) uses a chart with 12 body parts. In this study, a version using a six-point scale was used (Vergara and Page 2002), where 0 represents 'no discomfort', 1 represents 'light discomfort' and 5 represents 'pain/extreme discomfort'. Both LBD and OBD were monitored due to previous research demonstrating that forward-inclined saddle chairs can reduce LBD, but at the cost of increasing discomfort in other body areas (Gadge and Innes 2007). OBD comprised the mean rating of all 12 sites for each time (Fenety, Putnam, and Walker 2000), whereas LBD was rated using the single lumbar discomfort score on the BPDS.

At baseline, average LBP during the last week was measured using the 0–10 numerical rating scale (Childs, Piva, and Fritz 2005), fear of physical activity was measured using the physical activity subscale of the fear-avoidance beliefs questionnaire (Waddell et al. 1993) and functional disability was measured using the Roland-Morris disability questionnaire (Roland and Morris 1983). Across all participants, mean (SD) baseline pain was 2.2 (1.3), fear was 9.9 (6.6) and functional disability was 2.1 (1.7).

2.7 Data analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS version 17.0). Statistical significance was set at $p < 0.05$. Data were non-normally distributed (Shapiro–Wilks, $p < 0.05$). To determine whether the discomfort increased

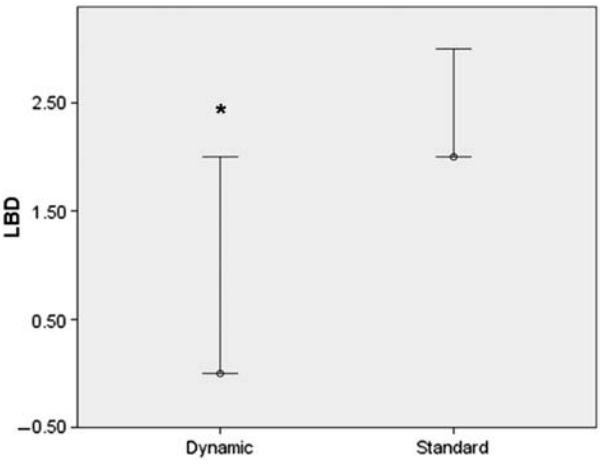

Figure 2. Median (95% CI) change in LBD during 1 h of sitting on the dynamic, forward-inclined saddle and standard office chairs. *Statistically significant difference overall ($p < 0.05$).

to a greater degree on either chair, the change in LBD and OBD from baseline to the end of testing on each chair was calculated and compared between chairs using Wilcoxon signed-ranks tests. To determine whether the discomfort differed at each time point between the chairs, Wilcoxon signed-ranks tests were used for all five time periods (with Bonferroni adjustment for multiple comparisons).

3. Results

3.1 Low back discomfort

Over the hour of sitting, there was a significantly ($Z = -2.793$, $p = 0.005$) greater increase in LBD on the standard chair (median change = 2) than on the dynamic, forward-inclined chair (median change = 0) (Figure 2). Looking at each time interval, LBD was significantly lower on the dynamic, forward-inclined chair after 45 min ($p = 0.005$) and 60 min ($p = 0.01$) (Table 1).

3.2 Overall body discomfort

Although there was a trend for OBD to increase more on the standard chair (median change = 0.25) than on the dynamic, forward-inclined chair (median change = 0.17) over the hour of sitting, this difference was not statistically significant ($Z = -1.346$, $p = 0.178$) (Figure 3). Looking at each time interval, OBD was significantly lower on the dynamic forward-inclined chair after 60 min ($p < 0.001$) (Table 2).

4. Discussion

These results demonstrate that, in a subgroup of people with sitting-related LBP consistent with a flexion-related pain disorder (O'Sullivan 2005), LBD in sitting was lower on the chair designed to reduce lumbar flexion and enhance mobility. Furthermore, the lack of an increase in LBD during sitting was achieved without an increase in OBD, avoiding the increased

Table 1. Median (range) of LBD values at each time interval.

	Standard office chair	Dynamic saddle chair
LBD0	1 (0–3)	1 (0–2)
LBD15	1 (0–3)	1 (0–3)
LBD30	1 (0–4)	1 (0–2)
LBD45*	2 (1–4)	1 (0–3)
LBD60*	3 (1–5)	1 (0–4)

*Statistically significant difference at this time interval.

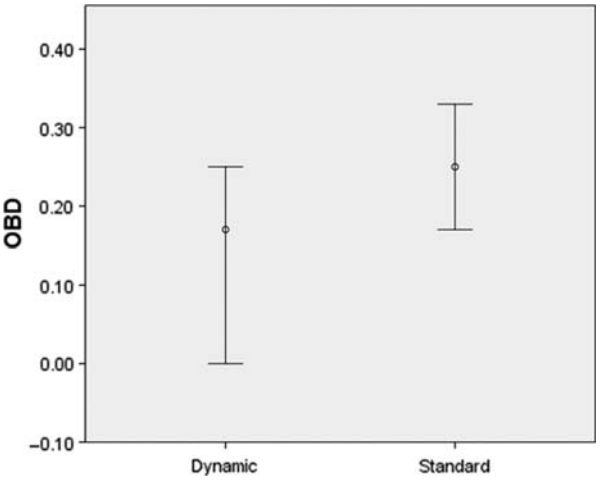

Figure 3. Median (95% CI) change in OBD during 1 h of sitting on the dynamic, forward-inclined saddle and standard office chairs. No statistically significant difference ($p > 0.05$).

discomfort reported in other body areas previously observed using similar forward-inclined saddle chairs (Gadge and Innes 2007).

The likely mechanism of effect using the modified dynamic, forward-inclined chair, based on previous research using this same chair among pain-free participants (O'Sullivan et al. 2012a, 2012b), is a reduction of lumbar flexion while requiring less paraspinal muscle activation. Although lordotic sitting is commonly advocated for sitting-related LBP (Pynt, Mackey, and Higgs 2008), it is linked to higher paraspinal muscle tension (O'Sullivan et al. 2006a; Claus et al. 2009). Because trunk muscle fatigue occurs if contractions as low as 2–5% maximum voluntary contraction (MVC) are sustained for as little as 30 min among pain-free volunteers (van Dieën et al. 2009), the ability to reduce trunk muscle activation is potentially advantageous in moderating spinal loads (Reeves, Narendra, and Cholewicki 2007).

There are several elements to this dynamic, forward-inclined saddle chair that may explain the lack of an increase in LBD during sitting, relative to the standard chair. These include a reduction in hip flexion angle, greater mobility in sitting and an alteration in foot position. The most likely mechanism is the reduction in seated hip flexion. The dynamic, forward-inclined chair passively assists lumbar lordosis, without requiring an increased level of paraspinal muscle activation (O'Sullivan et al. 2012a, 2012b). This is consistent with other data showing similar saddle chairs and adjustable height chairs can increase lumbar lordosis (Gale et al. 1989; Gadge and Innes 2007; Koskelo, Vuorikari, and Hänninen 2007) and reduce paraspinal muscle tension (Koskelo, Vuorikari, and Hänninen 2007). There is some previous evidence that such chairs may be associated with reduced LBD (Gadge and Innes 2007), but the enhanced lordosis and reduced paraspinal muscle tension possible on such chairs does not always reduce LBP (Koskelo, Vuorikari, and Hänninen 2007). Furthermore, this contrasts with data on kneeler chairs that also reduce hip flexion in sitting. Kneeler chairs also increase lumbar lordosis (Bennett et al. 1989; Bettany-Saltikov, Warren, and Jobson 2008), but do not appear to reduce paraspinal muscle activation (Lander et al. 1987; Bennett et al. 1989), and might actually be associated with increased LBD (Lander et al. 1987), in direct contrast to this study. Using kneeler chairs may result in more static sitting, which could explain the findings. In addition, the varying degree of forward trunk lean between studies which have examined reduced seated hip flexion may be relevant. For example, the chair used in this study maintains the trunk in a relatively vertical position, whereas kneeler chairs are possibly more likely to facilitate forward trunk lean, which could explain the increased paraspinal muscle activation and

Table 2. Median (range) for OBD values at each time interval.

	Standard office chair	Dynamic saddle chair
OBD0	0.08 (0–0.75)	0.08 (0–0.33)
OBD15	0.17 (0–0.67)	0.08 (0–0.58)
OBD30	0.17 (0–0.83)	0.17 (0–0.83)
OBD45	0.25 (0–0.83)	0.17 (0–1.58)
OBD60*	0.33 (0.08–1.17)	0.25 (0–1.58)

*Statistically significant difference at this time interval.

discomfort observed on such chairs if not closely monitored (Lander et al. 1987). Despite the standard chair having a backrest that is known to reduce paraspinal muscle activation (Hardage, Gildersleeve, and Rugh 1983), it was still not as comfortable as the dynamic forward-inclined chair. This suggests that either backrest use was suboptimal during the task on the standard chair, or there were additional factors beyond a reduction in muscle activation such as increased motion, or facilitation of lordosis, involved in the lack of an increase in LBD observed on the dynamic, forward-inclined chair.

Dynamic sitting may increase the overall amount of spinal motion in sitting (O'Sullivan et al. 2006b; Kingma and van Dieen 2009). However, the evidence for most existing dynamic sitting devices suggest that they have a negligible effect on LBP (O'Sullivan et al. 2012c), spinal shrinkage (Van Dieen, De Looze, and Hermans 2001; Kingma and van Dieen 2009), mean spinal posture (Van Dieen, De Looze, and Hermans 2001; McGill, Kavcic, and Harvey 2006; O'Sullivan et al. 2006b) and trunk muscle activation (Van Dieen, De Looze, and Hermans 2001; Gregory, Dunk, and Callaghan 2006; McGill, Kavcic, and Harvey 2006; O'Sullivan et al. 2006b; Kingma and van Dieen 2009). Therefore, the dynamic element is unlikely to be a significant contributor to the observed benefits of the modified chair. Consequently, if dynamic sitting has a benefit, it may be through preventing static spinal loading (Vergara and Page 2002) rather than by altering trunk posture or trunk muscle activation (van Deursen et al. 1999; Van Dieen, De Looze, and Hermans 2001; O'Sullivan et al. 2006b). Finally, foot position differed between the chairs, which could also have contributed to the differences in LBD observed between the chairs. Participants distributed more weight through the front of their feet, and were in greater ankle plantar flexion while sitting on the dynamic, forward-inclined chair. There is only limited data published on the effect of foot position during sitting (Carlsoo 1961), which suggests that changes in foot position can affect lower leg muscle activation but are unlikely to significantly influence trunk muscle activation (Carlsoo 1961). Therefore, although the differences in foot position could contribute to differences in lower leg discomfort, they are unlikely to explain the differences in seated LBD observed in this study.

The lack of an increase in LBD on the modified chair, compared with the significant increase in LBD on the standard chair, observed in this study is consistent with a recent systematic review on the effectiveness of chair interventions in the workplace at reducing musculoskeletal symptoms (Van Niekerk, Louw, and Hillier 2012). However, the effect sizes reported in that review (Van Niekerk, Louw, and Hillier 2012) were small, and most clinical trials (Haukka et al. 2008; Driessen et al. 2011) and systematic reviews (Driessen et al. 2010) suggesting modifications to seated ergonomics are ineffective in the prevention and management of musculoskeletal disorders such as spinal pain. There are several potential reasons why the results of this study are more positive about the role of sitting interventions.

First, we specifically selected those participants with LBP who reported sitting-related LBP, and who subjectively reported less pain in postures involving spinal extension such as walking and standing. This was done to match people with lumbar flexion sensitivity to a seating device that reduced lumbar flexion and reduced the effort of sitting. In other words, the ergonomics intervention was specifically matched to the perceived needs of the people reporting discomfort, rather than being prescribed to every person with LBP. Despite the clinical relevance of this approach, matching interventions to specific categories of people with LBP has been used infrequently in LBP research (Fersum et al. 2010). This was done because the response of people with LBP to chair design modifications may vary according to their individual aggravating factors and clinical presentation (Dankaerts et al. 2009). Consequently, the effect seen in this study is probably a 'best-case scenario' because the participants were specifically selected as those most likely to benefit from the intervention. Although physiotherapists and other healthcare professionals appear to consider lordotic sitting postures as being optimal for the lumbar spine (O'Sullivan et al. 2012d), the effect of the current chair design in other LBP populations may be quite different (Dankaerts et al. 2009). For example, those LBP patients with extension sensitivity who present with increased lumbar lordosis (Dankaerts et al. 2006) and have relief during spinal flexion postures and activities may respond differently to such a seating device.

Second, LBD was only monitored for 1 h, with no data on whether using such a chair design for prolonged periods would make a clinically meaningful difference to participants' LBP.

Finally, the included participants had only mildly disabling LBP, with relatively low levels of fear-avoidance and functional disability. Although this type of LBP population reflects that used in many other studies of ergonomics interventions (Lengsfeld et al. 2007; Driessen et al. 2011), it does not reflect those LBP patients with more complex and disabling pain disorders. For example, the predominant pain mechanism of the LBP group studied here was likely to be a peripheral nociceptive mechanism, as their LBP displayed a mechanical behaviour (O'Sullivan 2005; Smart et al. 2010), with the participants likely to be at 'low risk' (Hill et al. 2011) of chronicity or severe disability. Although postural factors may be significant for subgroups of people with LBP such as this (Dankaerts et al. 2006), LBP is clearly a complex, multidimensional disorder by which numerous factors other than posture must be considered (Rees et al. 2011; O'Sullivan 2012). In our opinion, it is highly unlikely that this chair, or indeed any one-dimensional physical or ergonomics intervention, provided in isolation would significantly reduce LBP in the medium-term, and particularly among people with severely disabling LBP associated with significant central sensitisation (Smart et al. 2010). However, even in people with

LBP who report high levels of fear, stress or anxiety, facilitation of less painful postures and less intense muscle activation may help (Lewis et al. 2012), possibly as part of a comprehensive cognitive functional therapeutic approach to management (Fersum et al. 2013; O'Sullivan 2012), and is worthy of investigation.

4.1 Limitations and recommendations

This study involved a small sample of one specific subgroup of people with mildly disabling LBD, and as stated earlier this may not reflect the effectiveness of this chair in other LBP populations. Although participants were randomly allocated, the novel appearance of the chair used makes participant blinding difficult, and could enhance the placebo effect. A randomised controlled trial design would reduce the risk of subject bias further, but crossover design studies are commonly used in the initial evaluation of novel chair designs (Reinecke, Hazard, and Coleman 1994; Van Dieen, De Looze, and Hermans 2001; Gregory, Dunk, and Callaghan 2006). The assessor of seated discomfort was not blinded to the order of allocation. Another limitation is the duration of testing. Longer sitting durations are worthy of investigation, although 1 h was sufficient to observe increases in both LBD and OBD. Testing each chair on different days would reduce the risk of discomfort being greater on the second seated exposure. Examining the effect of this chair design in 'real-world' occupational settings is required. Evaluating secondary outcome measures, such as spinal kinematics or trunk muscle activation, could shed further light on the mechanism of effect. However, based on previous research (O'Sullivan et al. 2012a, 2012b), a reduction in the effort of sitting via passive facilitation of lumbar lordosis was the most likely mechanism of effect. Also, based on this study, the relative contribution of the various components of the dynamic, forward-inclined chair is still unclear. Future studies could compare the effect of controlling some of these parameters. Even though the dynamic, forward-inclined chair was associated with less LBD, both LBD and OBD increased over time on both chairs, in line with previous research (Gadge and Innes 2007). This suggests any sustained static seated posture and any chair design may still aggravate LBP, and factors other than physical ergonomics should be considered in LBP management.

5. Conclusion

In a subgroup of people with sitting-related LBP, there was a significantly greater increase in seated LBD while sitting on a standard chair compared with sitting on a dynamic, forward-inclined chair designed to facilitate lumbar lordosis. The lack of an increase in LBD during sitting on the dynamic, forward-inclined chair was achieved without an increase in OBD. Ergonomics interventions that are targeted to the specific aggravating factors, and clinical presentations, of people with LBP may have a role to play in the management of LBP. Notwithstanding these encouraging results, LBP should be considered from a biopsychosocial perspective, in which changes in mechanical factors such as seated posture are only one aspect of management.

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