Manual Therapy 17 (2012) 432–437

Contents lists available at SciVerse ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

What do physiotherapists consider to be the best sitting spinal posture?

Kieran O'Sullivan [a,*], Peter O'Sullivan [b], Leonard O'Sullivan [a], Wim Dankaerts [c]

[a] University of Limerick, HS2-025, Health Sciences Building, Limerick, Ireland
[b] Curtin University of Technology, Perth, Australia
[c] Catholic University, Leuven, Belgium

ARTICLE INFO

Article history:
Received 5 December 2011
Received in revised form
31 March 2012
Accepted 19 April 2012

Keywords:
Posture
Back pain
Physiotherapy
Sitting

ABSTRACT

While sitting is a common aggravating factor in low back pain (LBP), the best sitting posture remains unclear. This study investigated the perceptions of 295 physiotherapists in four different European countries on sitting posture. Physiotherapists selected their perceived best sitting posture from a sample of nine options that ranged from slumped to upright sitting, as well as completing the back beliefs questionnaire (BBQ). 85% of physiotherapists selected one of two postures as best, with one posture being selected significantly more frequently than the remainder ($p < 0.05$). Interestingly, these two most frequently selected postures were very different from each other. Those who selected the more upright sitting posture had more negative LBP beliefs on the BBQ ($p < 0.05$). The choice of best sitting posture also varied between countries ($p < 0.05$). Overall, disagreement remains on what constitutes a neutral spine posture, and what is the best sitting posture. Qualitative comments indicated that sitting postures which matched the natural shape of the spine, and appeared comfortable and/or relaxed without excessive muscle tone were often deemed advantageous. Further research on the perceptions of people with LBP on sitting posture are indicated.

1. Introduction

Despite the large amount of research undertaken on low back pain (LBP), it remains a very common and costly musculoskeletal disorder (Woolf and Pfleger, 2003). It is now widely acknowledged that LBP is a complex disorder, with numerous contributing factors, including physical (Mitchell et al., 2010), biological (Moseley, 2007) and psychosocial factors (Jarvik et al., 2005; Campbell and Edwards, 2009), as well as genetic and environmental interactions (Reichborn-Kjennerud et al., 2002).

One of the most common strategies used by physiotherapists in the management of LBP is providing advice on spinal postures (Poitras et al., 2005). Prolonged sitting periods, for example periods exceeding 30 min, are a common aggravating factor for many subjects with LBP (Williams et al., 1991; O'Sullivan, 2005). There is evidence that the sitting spinal posture of some LBP subjects differs to that of matched controls (Dankaerts et al., 2009), and that addressing these postures may help reduce LBP (Dankaerts et al., 2006; Womersley and May, 2006). While there is no clear evidence that prolonged sitting in isolation is a significant risk factor for developing LBP (Lis et al., 2007; Roffey et al., 2010), combined exposure to prolonged sitting, awkward postures and vibration may increase the risk of developing LBP (Lis et al., 2007). Considering the large amount of time spent sitting in modern society, assuming seated spinal postures which are non-provocative may be helpful as part of LBP management.

What constitutes the best seated lumbar posture remains widely debated (Pynt et al., 2001; Claus et al., 2009a; Dankaerts et al., 2009; O'Sullivan et al., 2010). While sitting involves more lumbar flexion than standing (Scannell and McGill, 2003; Dunk et al., 2009; De Carvalho et al., 2010), it is not clear what constitutes an optimal amount of lumbar flexion in sitting (Claus et al., 2009a; O'Sullivan et al., 2010). Increased lumbar flexion in sitting, for example during slumped sitting postures, has traditionally been considered problematic, since sitting in lumbar flexion can increase LBP symptoms (Womersley and May, 2006). Reducing such flexed sitting postures can reduce LBP, such that many authors recommend lordotic seated postures (Williams et al., 1991; Lengsfeld et al., 2000; Womersley and May, 2006; Bettany-Saltikov et al., 2008; Pynt et al., 2008). In direct contrast however, increased lordosis has also been reported in LBP subjects (Christie et al., 1995; Vergara and Page, 2002; Dankaerts et al., 2006; Van Dillen et al., 2009), with relief of pain reported by some LBP subjects in more flexed postures (O'Sullivan, 2005). In addition, lordotic lumbar postures which are associated with higher levels of paraspinal muscle activation may increase fatigue and discomfort (Lander et al., 1987; O'Sullivan et al., 2006; Claus et al., 2009a).

* Corresponding author. Tel.: +353 61 234119; fax: +353 61 234251.
E-mail address: kieran.osullivan@ul.ie (K. O'Sullivan).

1356-689X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.math.2012.04.007

As a result, while it is clear that sitting postures do not all have the same effect on spinal load and trunk muscle activation (O'Sullivan et al., 2002; O'Sullivan et al., 2006; Claus et al., 2009a; Reeve and Dilley, 2009; O'Sullivan et al., 2010), there is little consensus on the best sitting posture. In recent years, there has been an increased emphasis on adopting "neutral" lumbar spine postures, to avoid potentially painful end-range positions (Scannell and McGill, 2003), and facilitate activation of key trunk muscles (O'Sullivan et al., 2006; Claus et al., 2009b; Reeve and Dilley, 2009).

Interestingly, no study has asked physiotherapists, or any other group of healthcare professionals, about what they perceive as the best sitting posture. There is strong evidence that the beliefs of healthcare professionals strongly influence their LBP management approach (Darlow et al., 2012). Consequently, the beliefs of physiotherapists about sitting postures, and the importance they attach to it, might also influence the advice they provide on spinal sitting posture. For example, we hypothesised that those physiotherapists who select more upright lumbar sitting postures may hold more negative beliefs about LBP, indicating a perceived vulnerability of the lumbar spine to mechanical loads among patients with LBP.

Therefore, the aims of this study were to investigate the perceptions of physiotherapists on the best sitting posture, how these perceptions vary in four different European countries, what characteristics physiotherapists associate with good seated posture, and whether their beliefs about LBP are related to their perceptions on spinal sitting posture.

2. Methods

2.1. Participants

A total of 296 physiotherapists who attended continuing professional development workshops on LBP in four countries (Ireland; $n = 111$, England; $n = 88$, Germany; $n = 41$ and the Netherlands; $n = 56$) participated in this study prior to the workshops commencing. Ethical approval was obtained from a university Research Ethics Committee (Ref EHSREC 09-116).

2.2. Generating photographs of sample postures

A 29 year-old female with no history of LBP and adequate flexibility to assume a variety of spinal postures acted as a model for the generation of the seated posture photographs. The model wore shorts and her bra, and sat on a flat wooden stool without back support. Her knees and ankles were positioned at 90°, with her wrists positioned palms-downward on her thighs. Photo-reflective markers were placed overlying the spinous processes of C7, T12, L3 and S2 using hypoallergenic adhesive tape. These markers facilitate calculation of sagittal-plane angles for the thoracic (C7–T12–L3), lumbar (T12–L3–S2), and overall thoraco-lumbar (C7–T12–S2) regions using a LABVIEW programme. As such, these angles represent simple sagittal-plane spinal flexion, rather than forward tilt or lean of the trunk. The digital camera (Panasonic Lumix TZ3) was positioned on a tripod 80 cm from the floor and 250 cm from the model. The model was aligned such that she was facing perpendicular to the camera (Straker et al., 2009). After consultation with professional colleagues, a range of postures observed in clinical practice between slumped and upright sitting were chosen, including some postures with varying cervical, thoracic and lumbar spine angles, as well as varying degrees of trunk lean. The model was assisted into each of these postures using manual and verbal facilitation, and then maintained each posture for 10 s while the photograph was taken. Three images were taken in each posture, and the one which best reflected each target posture was used for the study. No single posture was considered to constitute the best posture. It was hypothesised that such a mix of postures may facilitate the participating physiotherapists having to prioritise their concepts of optimal sitting. For example, the most lordotic lumbar posture involved significant thoracic flexion along with considerable relaxation of the neck and shoulders. The actual spinal angles associated with each posture are displayed in Table 1.

2.3. Data collection

After explaining the study to participants, and obtaining written informed consent, the nine photographs were displayed in colour via digital projection, prior to the commencement of each workshop. The postures were randomly numbered from one to nine, starting in the top left hand corner (Fig. 1). The model's face was obscured in each photograph. Participants were also given a black/white paper copy of the photographs. They were asked to view all nine postures, and then select the best posture, justifying their selection with some comments on the relative advantages and disadvantages of the selected postures. The specific instruction to participants was to "select the best posture for the spine as a whole, especially the lumbar spine". Participants were asked about their level of experience, qualifications, area of expertise and work location. In addition, all participants, with the exception of those in the Netherlands, completed the Back Beliefs Questionnaire (Buchbinder and Jolley, 2005). Finally, participants were asked to rate how important they thought spinal posture was in the management of non-specific chronic low back pain (N-SCLBP), on a scale of 0–10, where 0 = very unimportant and 10 = very important. Participants were given approximately 10 min to complete this task.

2.4. Data analysis

Data was entered into, and analysed using, SPSS 19.0. The frequency with which each posture was selected was first examined, and chi-square analysis was then used to examine if there were significant differences in the frequency with which specific postures were selected, and if this varied significantly between countries. The qualitative comments justifying selecting each posture as the best sitting posture were categorised into common themes, divided into both positive and negative aspects of each posture. To examine differences in the characteristics of physiotherapists selecting the most common postures, Mann–Whitney *U*-tests were used. The level for statistical significance was set at $p < 0.05$, and was adjusted appropriately using a Bonferroni correction for multiple comparisons.

Table 1
Spinal angles for each of the selected photographs.

Posture	Thoraco-lumbar, (C7–T12–S2)	Thoracic, (C7–T12–L3)	Lumbar, (T12–L3–S2)
1	32.7	28.9	7.6
2	−16.5	−7.0	−16.3
3	24.8	21.4	6.9
4	10.4	9.5	1.7
5	2.1	4.0	−3.4
6	30.6	26.9	7.5
7	14.0	21.9	−16.6
8	18.3	15.5	5.4
9	18.8	23.7	−10.6

C7 – Spinous process of 7th cervical vertebra; T12 – Spinous process of 12th thoracic vertebra; L3 – Spinous process of 3rd lumbar vertebra; S2 – Positioned in midline between both posterior superior iliac spines. Positive values indicate flexion; Negative angles indicate extension; All values in degrees.

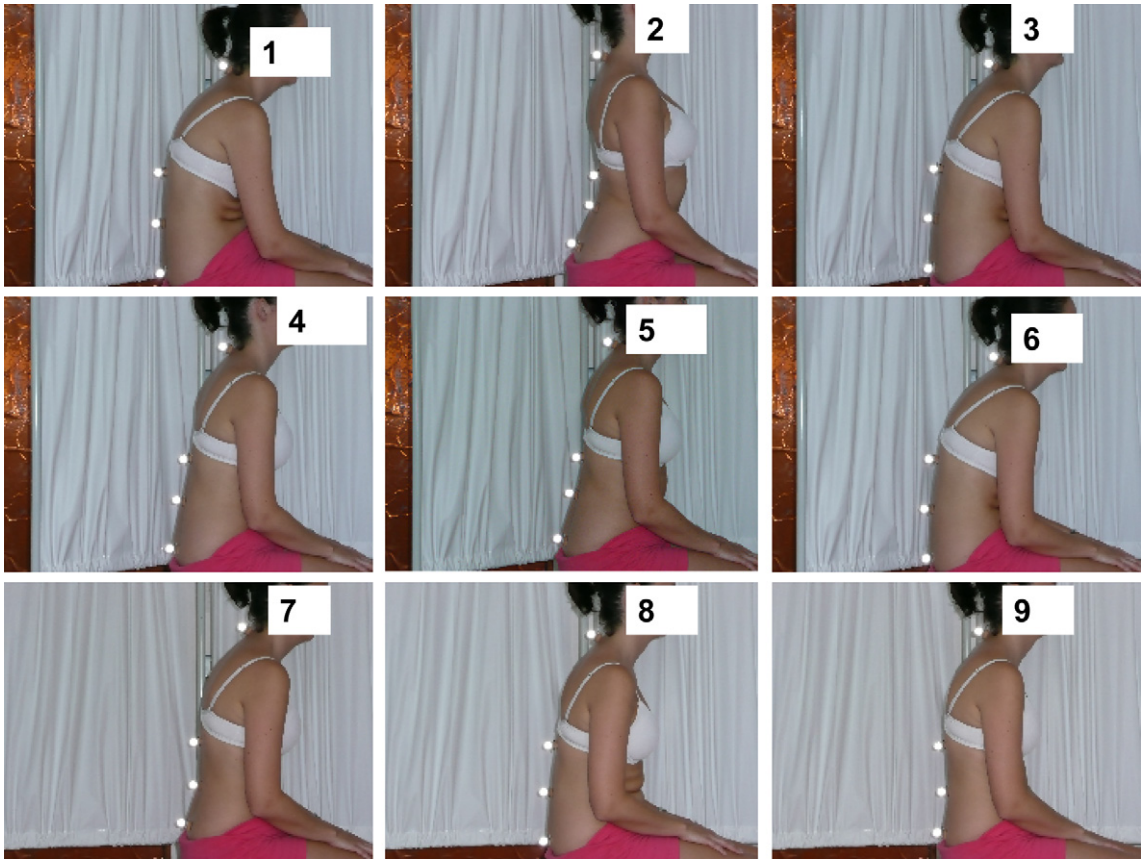

Fig. 1. The nine sitting posture options, numbered according to the descriptions in the main text.

3. Results

3.1. Characteristics of participating physiotherapists

Only one physiotherapist (in Ireland) stated that there was no best sitting posture, stating that all postures were acceptable options. The remaining 295 physiotherapists completed the questionnaire, and their primary characteristics are displayed in Table 2. 85% worked primarily in musculoskeletal physiotherapy, and 89% worked primarily in clinical practice. The highest degree obtained by participants was most commonly a BSc (59%), followed by an MSc (39%).

3.2. The best sitting posture

The percentage of physiotherapists who selected each sitting posture option as the best sitting posture is displayed in Table 3. Two postures – posture 9 ($n = 162$, 54.9%) and posture 5 ($n = 94$, 30.5%) – were most commonly selected as the best sitting posture.

Table 2
The experience of participants, and their rating on the importance of posture in the management of low back pain (mean ± SD).

	England ($n = 88$)	Ireland ($n = 110$)	Netherlands ($n = 56$)	Germany ($n = 41$)	Overall ($n = 295$)
Experience, (in years)	12.8 ± 8.2	7.6 ± 7.8	15.5 ± 11.6	16.4 ± 6.6	11.9 ± 9.3
Importance of posture, (rated 0–10)	7.4 ± 2.7	7.4 ± 2.7	6.1 ± 3.7	6.5 ± 2.4	7.0 ± 2.9

Posture 9 involves a relatively neutral spine sitting posture with lordosis mainly in the lumbar spine and with relaxation of the thoracic spine, while posture 5 involved extension in both the lumbar and thoracic regions, as well as some forward trunk lean. Posture 9 was significantly more popular than posture 5; $\chi^2(1, N = 252) = 20.57$, $p < 0.001$. Furthermore, posture 5 in turn was significantly more popular than both of the next most commonly selected postures; posture 2; $\chi^2(1, N = 106) = 51.66$, $p < 0.001$, and posture 4; $\chi^2(1, N = 106) = 51.66$, $p < 0.001$.

3.3. Qualitative comments on the postures selected

To summarise the comments on the selected postures, the major themes identified with the two most commonly selected postures

Table 3
Percentage of physiotherapists who selected each posture as the best sitting posture in each country, along with the mean value across all countries.

Posture selected	England ($n = 88$)	Ireland ($n = 110$)	Germany ($n = 41$)	Netherlands ($n = 56$)	Overall ($n = 295$)
1	0	0	0	0	0
2	1.1	6.4	12.2	5.4	5.4
3	1.1	0	2.4	1.8	1.0
4	4.5	3.6	7.3	8.9	5.4
5	28.4	26.4	48.8	28.6	30.5
6	0	0	0	0	0
7	0	1.8	0	1.8	1.0
8	1.1	0	2.4	5.4	1.7
9	63.6	61.8	26.8	48.2	54.9
Total	100.0	100.0	100.0	100.0	100.0

are described here, along with the number of physiotherapists who made similar comments. The main positive theme identified for posture 9 was that the lumbar ($n = 150$) and thoracic ($n = 34$) regions were described as being moderately lordotic and kyphotic respectively, without approaching end-range. This was often described in terms of being advantageous as it "matches the natural shape of the spine". Further positive themes were how the posture appeared "comfortable" and/or "relaxed" ($n = 48$), and did not require too much muscle tone ($n = 14$). The main negative themes identified for posture 9 were that the head was positioned excessively forward with too much cervical extension ($n = 70$), that it involved excessive thoracic kyphosis ($n = 35$) and excessive shoulder protraction ($n = 23$). The major positive theme identified for posture 5 was that the lumbar region appeared moderately lordotic, and not "end-range" ($n = 65$). Furthermore, it looked "comfortable" and/or "relaxed" ($n = 24$), involved good head/neck alignment ($n = 28$) and good thoracic posture ($n = 11$). The main negative themes identified for posture 5 were that it involved "too much forward trunk lean" ($n = 25$), and did not involve sufficient lumbar lordosis and/or anterior pelvic tilt ($n = 24$). It was also thought to involve excessive muscle tone ($n = 20$) and excess thoraco-lumbar extension ($n = 20$).

3.4. Variations between countries

In all countries, postures 5 and 9 were the two most popular choices. However, the ratio at which these two sitting posture were selected as best in the four countries was significantly different; $\chi^2(3, N = 252) = 13.50$, $p = 0.004$. Posture 9 was most commonly selected by physiotherapists in Ireland ($n = 68$, 62%), England ($n = 56$, 64%) and the Netherlands ($n = 27$, 48%), whereas in Germany posture 5 ($n = 20$, 49%) was most commonly selected.

3.5. Factors associated with choice of best sitting posture

While posture 5 was most commonly chosen in Germany, where the mean experience of physiotherapists was the highest, there were no significant differences in the experience, qualifications, area of expertise, work location or perceived importance of posture between those who selected postures 9 and 5 ($p > 0.05$). However, those who selected the more upright posture 5 had significantly more negative LBP beliefs than those who selected posture 9 (mean difference = 1.5 points, $p = 0.045$).

4. Discussion

There is a lack of studies that investigate the perceptions of physiotherapists on what is the best sitting posture. The results of the current study indicate that physiotherapists believe that spinal sitting posture is important in the management of LBP. Thereafter, the results are partly contradictory. On one hand, there is considerable agreement among physiotherapists on what constitutes a good sitting posture, with 85% picking one of the two most common postures as the best sitting posture. However, another interpretation is that the two most commonly selected postures are actually very different when analysed quantitatively. As a result, it appears that while most physiotherapists picked one of these two postures, there is still considerable disagreement on what is the best sitting posture.

While posture 5 involves less lumbar lordosis than posture 9, it also involves considerably greater thoracic extension and forward trunk lean. Therefore, posture 5 is likely to be associated with higher levels of muscle activation, particularly of muscles such as thoracic erector spinae, iliocostalis longissimus pars thoracis and external oblique (O'Sullivan et al., 2006; Claus et al., 2009b; Reeve and Dilley, 2009). As a result, posture 5 may be associated with greater fatigue and potential discomfort (Lander et al., 1987). In contrast, posture 9 was the closest approximation to a neutral sitting posture, and was not an end-range posture, being the third most lordotic in the lumbar region, the third most kyphotic in the thoracic region, and the fourth most kyphotic in overall thoraco-lumbar curvature. This is consistent with physiotherapist descriptions of it as a comfortable and relatively natural spinal posture. On the other hand, posture 5 was the most extended posture for the thoracic spine and thoraco-lumbar regions overall, and the second most extended in the lumbar region, suggesting it does not reflect a relaxed, mid-range or neutral spine. The authors agree with the majority of physiotherapists surveyed that posture 9 has several potential advantages. This is not to suggest that posture 9 should automatically be considered the best sitting posture. Indeed, the qualitative comments highlight several aspects of posture 9 that the physiotherapists did not like, especially regarding the cervical, thoracic and shoulder region. In addition, it is important to highlight that there is no evidence that assuming any specific static sitting posture is effective in the management of LBP.

It is noteworthy that while only four of the nine sitting postures had lordotic lumbar angles, these four postures comprised 91.8% of the best postures selected. This suggests that there is a strong tendency among physiotherapists to select lordotic sitting postures, which is likely to influence their clinical practice. This is consistent with much of the published literature on the proposed benefits of lordotic sitting (Pynt et al., 2001), despite a lack of evidence for clear superiority of lordotic sitting over other sitting postures for LBP. Interestingly, while the most popular posture involved significant lumbar lordosis, other postures (postures 2 and 7) which involved even greater lumbar lordosis were selected very infrequently. This data, supported by the qualitative comments, suggest that while physiotherapists believe lordosis is beneficial and/or necessary in the lumbar spine, the relationship of the lumbar region to the rest of the spine is also considered to be important. Posture 2 involved extension into the thoracic spine, while posture 7 involved an extreme kypho-lordotic posture along with some forward trunk lean which, while maintaining lumbar lordosis, could require far greater paraspinal muscle activation. The fact that physiotherapists avoided selecting these postures, along with the qualitative comments provided, suggest physiotherapists weigh up the relative merits of different sitting postures. This may include balancing the desire for maintaining lumbar lordosis with the aim of selecting a posture which does not require large amounts of muscle activation, and appears relatively relaxed and comfortable. This is supported by the fact that twice as many physiotherapists described posture 9 as comfortable and/or relaxed compared to posture 5.

As hypothesised, those who selected the more upright posture 5 had more negative LBP beliefs than those who selected the more relaxed posture 9. Selecting the more upright posture 5 perhaps reflects concern among these physiotherapists about the need to support and protect a vulnerable spine among patients with LBP, although this is merely speculation. From this perspective, it would be interesting to assess whether patients with LBP who assume more tense or upright sitting postures have more negative or fearful LBP beliefs.

It would be interesting to further evaluate what physiotherapists interpret as "neutral" and "not end-range", as many physiotherapists considered posture 5 to be comfortable and/or relaxed. It would appear that physiotherapists differ on whether a neutral spine is in fact straight or curved in the "natural shape of the spine". Firstly, a neutral sitting posture is likely to be different to neutral standing posture, such that neutral sitting should involve greater posterior pelvic tilt and flexion that standing (Scannell and McGill,

2003; Dunk et al., 2009; De Carvalho et al., 2010). A key consideration is what position in the available seated ROM constitutes the neutral position. Posture is influenced by a wide range of factors including genetics (Seah et al., 2011), gender (Dunk and Callaghan, 2005; Smith et al., 2010), physical factors such as body mass index (Smith et al., 2011) and muscle endurance (Smith et al., 2010), as well as psychological factors (O'Sullivan et al., 2011). Furthermore, we know that an individual's neutral position is influenced by their static posture (Scannell and McGill, 2003). Range of motion (ROM) is highly variable between individuals, as well as being influenced by factors such as age (Kuo et al., 2009) and pathology (McGregor et al., 1997). In this regard, examining how close to their end-range an individual sits may be as useful as examining the specific spinal angle they assume in sitting (Dankaerts et al., 2006), and comparison to their habitual standing posture may also be worthy of investigation. An individual with greater thoraco-lumbar flexion ROM could require higher levels of trunk muscle activation to maintain the same neutral spinal angle as someone with less flexion ROM. The flexion moment of the spine which must be counterbalanced by such muscle activation is also influenced by individual stature. Furthermore, since painfree people tend to vary their posture during prolonged sitting rather than choose a single static posture (Callaghan and McGill, 2001), whereas people with LBP assume more static postures with only large, infrequent shifts in posture (Vergara and Page, 2002; Telfer et al., 2009), the ability to vary posture easily and regularly may be as important as maintaining any specific postural angle. In contrast, in the event of a specific directional sensitivity to movement (Williams et al., 1991; O'Sullivan, 2005), adopting a posture involving more or less spinal flexion may then be indicated. As a result, the best sitting posture for any specific individual with LBP may need to consider all these factors, rather than adhering rigidly to any specific prescribed angle of spinal curvature. For example, individual variations in specific aggravating/easing factors which take into account the presence of any underlying pathology should be used to discriminate between adaptive and maladaptive postures among those with LBP (O'Sullivan, 2005; Dankaerts et al., 2009). Thereafter, it is the contention of the authors that once a posture is not maintained too close to an individual's end-range, does not involve inappropriately high levels of muscle activation, and allows for movement and variation in posture, that several seated postures may be acceptable. This multitude of considerations may partly explain the variation seen between physiotherapists, along with the aforementioned variation in beliefs between the participating physiotherapists.

The differences between countries are interesting but difficult to explain. The proportions in England and Ireland who selected the neutral sitting posture as the best posture were very similar, with the Netherlands selecting this posture slightly less frequently. In contrast, physiotherapists in Germany preferred the more upright posture 5. While the physiotherapists in Germany were the most experienced, there was no difference in experience across countries between those selecting these two postures. One possible explanation is that physiotherapists in Germany simply place a greater emphasis on extension of the trunk as a whole, which is partly supported by the observation that physiotherapists in Germany selected an extremely upright posture (posture 2) as the best sitting posture more than twice as often as the other countries selected it. While variation across countries may reflect differences in undergraduate or postgraduate training, this cannot be confirmed based on the current data.

There are several limitations to this study. Posture was only considered during static sitting, and confined to a sagittal-plane view, although other sitting postures and observational views are obviously possible. Other seated postures, such as squatting and cross-legged sitting on the floor, are common in some countries and were not considered in this study. Prolonged standing is also a common aggravating posture, and perceptions of the best standing posture should also be conducted. Physiotherapists may have selected different postures for a male model, based on gender differences in sitting posture (Dunk and Callaghan, 2005; Smith et al., 2010). Similarly, the posture selected may have differed for an older model, especially considering changes in ROM which occur with age (Kuo et al., 2009). All postures involved unsupported sitting to allow clear visualisation of the spine, such that perceptions of optimal sitting might have been different for supported sitting. This is particularly relevant since there is evidence that the use of backrests can reduce muscle activation and discomfort in sitting (Andersson et al., 1979; Vergara and Page, 2002). The degree of trunk lean relative to the vertical varied between the different posture options, but was not quantified. The instructions to "select the best posture for the spine as a whole, especially the lumbar spine", may have influenced the results, as there is evidence that lumbar posture influences the posture and muscle activation of other spinal regions (Falla et al., 2007; Caneiro et al., 2010). Participating physiotherapists were not given any information about the pain status of the model, or the presence of any particular spinal pathology, and it would be interesting to evaluate how such information would influence the findings. While the beliefs of healthcare professionals strongly influence their management approach (Darlow et al., 2012), the posture selected may not truly reflect the posture actually prescribed to LBP patients. Clearly, since LBP is a multidimensional problem (Campbell and Edwards, 2009), management must consider multiple aspects other than sitting posture. Future studies investigating the perceptions of people with LBP on good sitting posture are planned, and may shed more light on this area.

5. Conclusion

Most physiotherapists consider sitting spinal posture important for the management of LBP. The majority (85%) of physiotherapists in four European countries selected one of two postures as the best sitting posture. However, these two sitting postures were very different from each other, indicating a lack of agreement. The choice of best sitting posture varied between countries, and was related to the LBP beliefs of the physiotherapists. Overall, there remains disagreement on what constitutes the best sitting posture, and on interpretation of neutral posture. Further research on the effect of different sitting postures on LBP, and the perceptions of people with LBP on good sitting posture, is indicated.

Acknowledgement

The Health Research Board of Ireland funded the principal investigator (KOS) during the study.

References

Andersson G, Murphy R, Ortengren R, Nachemson A. The influence of backrest inclination and lumbar support on lumbar lordosis. Spine 1979;4(1):52.
Bettany-Saltikov J, Warren J, Jobson M. Ergonomically designed kneeling chairs are they worth it?: comparison of sagittal lumbar curvature in two different seating postures. Studies in Health Technology and Informatics 2008;140:103–6.
Buchbinder R, Jolley D. Effects of a media campaign on back beliefs is sustained 3 years after its cessation. Spine 2005;30(11):1323–30.
Callaghan JP, McGill SM. Low back joint loading and kinematics during standing and unsupported sitting. Ergonomics 2001;44(3):280–94.
Campbell CM, Edwards RR. Mind-body interactions in pain: the neurophysiology of anxious and catastrophic pain-related thoughts. Translational Research 2009; 153(3):97–101.

Caneiro J, O'Sullivan P, Burnett A, Barach A, O'Neil D, Tveit O, et al. The influence of different sitting postures on head/neck posture and muscle activity. Manual Therapy 2010;15(1):54–60.
Christie H, Kumar S, Warren S. Postural aberrations in low back pain. Archives of Physical Medicine and Rehabilitation 1995;76:218–24.
Claus A, Hides J, Moseley GL, Hodges P. Is "ideal" sitting real?: measurement of spinal curves in four sitting postures. Manual Therapy 2009a;14:404–8.
Claus AP, Hides JA, Moseley GL, Hodges PW. Different ways to balance the spine: subtle changes in sagittal spinal curves affect regional muscle activity. Spine 2009b;34(6):E208–14.
Dankaerts W, O'Sullivan PB, Burnett A, Straker LM. Differences in sitting postures are associated with non-specific chronic low back pain disorders when subclassified. Spine 2006;31(6):698–704.
Dankaerts W, O'Sullivan P, Burnett A, Straker L, Davey P, Gupta R. Discriminating healthy controls and two clinical subgroups of nonspecific chronic low back pain patients using trunk muscle activation and lumbosacral kinematics of postures and movements: a statistical classification model. Spine 2009;34(15):1610–8.
Darlow B, Fullen BM, Dean S, Hurley DA, Baxter GD, Dowell A. The association between health care professional attitudes and beliefs and the attitudes and beliefs, clinical management, and outcomes of patients with low back pain: a systematic review. European Journal of Pain 2012;16(1):3–17.
De Carvalho D, Soave D, Ross K, Callaghan J. Lumbar spine and pelvic posture between standing and sitting: a radiologic investigation including reliability and repeatability of the lumbar lordosis measure. Journal of Manipulative and Physiological Therapeutics 2010;33(1):48–55.
Dunk NM, Callaghan JP. Gender-based differences in postural responses to seated exposures. Clinical Biomechanics 2005;20(10):1101–10.
Dunk N, Kedgley A, Jenkyn T, Callaghan J. Evidence of a pelvis-driven flexion pattern: are the joints of the lower lumbar spine fully flexed in seated postures? Clinical Biomechanics 2009;24(2):164–8.
Falla D, O'Leary S, Fagan A, Jull G. Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. Manual Therapy 2007;12:139–43.
Jarvik JG, Hollingworth W, Heagerty PJ, Haynor DR, Boyko EJ, Deyo RA. Three-year incidence of low back pain in an initially asymptomatic cohort: clinical and imaging risk factors. Spine 2005;30(13):1541–8.
Kuo YL, Tully EA, Galea MP. Video based measurement of sagittal range of spinal motion in young and older adults. Manual Therapy 2009;14(6):618–22.
Lander C, Korbon G, DeGood D, Rowlingson J. The Balans chair and its semi-kneeling position: an ergonomic comparison with the conventional sitting position. Spine 1987;12(3):269–72.
Lengsfeld M, Frank A, van Deursen D, Griss P. Lumbar spine curvature during office chair sitting. Medical Engineering and Physics 2000;22(9):665–9.
Lis A, Black K, Korn H, Nordin M. Association between sitting and occupational LBP. European Spine Journal 2007;16:283–98.
McGregor A, McCarthy D, Dore C, Hughes S. Quantitative assessment of the motion of the lumbar spine in the low back pain population and the effect of different spinal pathologies on this motion. European Spine Journal 1997;6(5):308–15.
Mitchell T, O'Sullivan PB, Burnett A, Straker L, Smith A, Thornton J, et al. Identification of modifiable personal factors that predict new-onset low back pain: a prospective study of female nursing students. Clinical Journal of Pain 2010; 26(4):275–83.
Moseley GL. Reconceptualising pain according to modern pain science. Physical Therapy Reviews 2007;12(3):169–78.
O'Sullivan K, O'Dea P, Dankaerts W, O'Sullivan P, Clifford A, O'Sullivan L. Neutral lumbar spine sitting posture in pain-free subjects. Manual Therapy 2010;15(6): 557–61.
O'Sullivan P. Diagnosis and classification of chronic low back pain disorders: maladaptive movement and motor control impairments as underlying mechanism. Manual Therapy 2005;10(4):242–55.
O'Sullivan P, Dankaerts W, Burnett A, Farrell G, Jefford E, Naylor C, et al. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. Spine 2006;31(19):E707–12.
O'Sullivan P, Grahamslaw KM, Kendell M, Lapenskie SC, Moller NE, Richards KV. The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. Spine 2002;27(11):1238–44.
O'Sullivan PB, Smith AJ, Beales DJ, Straker LM. Association of biopsychosocial factors with degree of slump in sitting posture and self-report of back pain in adolescents: a cross-sectional study. Physical Therapy 2011;91(4):470–88.
Poitras S, Blais R, Swaine B, Rossignol M. Management of work-related low back pain: a population-based survey of physical therapists. Physical Therapy 2005; 85(11):1168–81.
Pynt J, Higgs J, Mackey M. Seeking the optimal posture of the seated lumbar spine. Physiotherapy Theory & Practice 2001;17(1):5–21.
Pynt J, Mackey MG, Higgs J. Kyphosed seated postures: extending concepts of postural health beyond the office. Journal of Occupational Rehabilitation 2008; 18(1):35–45.
Reeve A, Dilley A. Effects of posture on the thickness of transversus abdominis in pain-free subjects. Manual Therapy 2009;14(6):679–84.
Reichborn-Kjennerud T, Stoltenberg C, Tambs K, Roysamb E, Kringlen E, Torgersen S, et al. Back–neck pain and symptoms of anxiety and depression: a population-based twin study. Psychological Medicine 2002;32(06):1009–20.
Roffey D, Wai EK, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational sitting and low back pain: results of a systematic review. The Spine Journal 2010;10(3):252–61.
Scannell JP, McGill SM. Lumbar posture-should it, and can it, be modified? a study of passive tissue stiffness and lumbar position during activities of daily living. Physical Therapy 2003;83(10):907–17.
Seah SHH, Briggs AM, O'Sullivan PB, Smith AJ, Burnett AF, Straker LM. An exploration of familial associations in spinal posture defined using a clinical grouping method. Manual Therapy 2011;16(5):501–9.
Smith AJ, O'Sullivan PB, Campbell AC, Straker LM. The relationship between back muscle endurance and physical, lifestyle, and psychological factors in adolescents. Journal of Orthopaedic & Sports Physical Therapy 2010;40(8):517–23.
Smith A, O'Sullivan P, Beales D, De Klerk N, Straker L. Trajectories of childhood body mass index are associated with adolescent sagittal standing posture. International Journal of Paediatric Obesity 2011;6(2):e97–106.
Straker L, O'Sullivan P, Smith A, Perry M. Relationships between prolonged neck/shoulder pain and sitting spinal posture in male and female adolescents. Manual Therapy 2009;14(3):321–9.
Telfer S, Spence W, Solomonidis S. The potential for actigraphy to be used as an indicator of sitting discomfort. Human Factors 2009;51(5):694–704.
Van Dillen L, Maluf K, Sahrmann S. Further examination of modifying patient-preferred movement and alignment strategies in patients with low back pain during symptomatic tests. Manual Therapy 2009;14(1):52–60.
Vergara M, Page A. Relationship between comfort and back posture and mobility in sitting-posture. Applied Ergonomics 2002;33:1–8.
Williams MM, Hawley JA, McKenzie RA, Van Wijmen PM. A comparison of the effects of two sitting postures on back and referred pain. Spine 1991;16: 1185–91.
Womersley L, May S. Sitting posture of subjects with postural backache. Journal of Manipulative and Physiological Therapeutics 2006;29(3):213–8.
Woolf A, Pfleger B. Burden of major musculoskeletal conditions. Bulletin of the World Health Organization; 2003.