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Liba Sheeran, Rebecca Hemming, Robert van Deursen and Valerie Sparkes

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*Corresponding author: Liba Sheeran, School of Healthcare Sciences, Cardiff University, 13th Floor Eastgate House, 35–43 Newport Road, Cardiff, CF24 0AB, Wales, UK; Research Centre for Clinical Kinæsiology, Cardiff University, Cardiff, CF14 4XN, UK; Arthritis Research UK Biomechanics and Bioengineering Centre, School of Healthcare Sciences, Cardiff University, Cardiff, Wales, UK
E-mail: SheeranL@cardiff.ac.uk

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Leeds University, China UK

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Can different seating aids influence a sitting posture in healthy individuals and does gender matter?

Liba Sheeran^{1,2,3*}, Rebecca Hemming¹, Robert van Deursen^{1,2,3} and Valerie Sparkes^{1,3}

Abstract: This study determined differences in spinal-pelvic kinematics sitting on (i) mat (ii) block and (iii) novel 10° forward inclined wedge (Buttafly™) in a same-subject repeated measures cross-over design in 60 healthy individuals (34 females). Repeated measures ANOVA revealed statistically significant differences between sitting conditions and lumbar and pelvic sagittal angles. Both, the inclined wedge and the block seating aids reduced overall flexion, but the inclined wedge had a greater influence in the lumbar region whilst the block induced the greatest change in the pelvis. This may be relevant for seating aid design personalised to posture type. Statistically significant gender differences were identified in all 3 seating conditions with males adopting more flexed lumbar spine and posteriorly tilted pelvis. Females flexed less in thoracic spine when sitting on an inclined wedge and a block. These statistically significant differences between males and females may provide first explorative direction for bespoke seating aids design.

Subjects: Assistive Technology; Rehabilitation Medicine; Physiotherapy and Sports Medicine; Women; Chronic Diseases; Assistive Technology; Physiotherapy

Keywords: lumbar; thoracic spine; pelvic tilt; photogrammetry; posture; seating aids; personalised design

ABOUT THE AUTHORS

All authors are members and/or co-applicants of the Arthritis Research Biomechanics and Bioengineering Centre (ARUKBBC) at Cardiff University. Our spine research group within the Centre aims to inform development and delivery of personalised therapies for people with low back pain (LBP). We study variations in spinal posture and movement in people with and without spinal problems to identify the role of movement and posture in perpetuation of LBP and work towards designing bespoke exercise feedback interventions using existing sensor technologies. This study evaluated the impact of seating devices on spinal and pelvic posture in healthy populations and will be further used as a training sample for objective classifiers to eventually train sensor technologies to provide feedback during exercise.

PUBLIC INTEREST STATEMENT

Different seating aids are used to help people adopt more upright and comfortable postures during exercise such as Yoga. However, it is not known if these aids actually achieve this or whether the postural response varies between seating aids.

In this study, sixty healthy people sat on each seating aid (yoga block, inclined wedge and mat) and the angular position of their spine and pelvis was measured.

It was found that people sat more upright on a block and inclined wedge compared to the mat. Sitting on the block had greater effect on the pelvis, whilst the inclined wedge affected the spine position. Interestingly males sat more “slouched” than females regardless of what they sat on.

These findings suggest that seating aids encourage more “upright” postures but differences exist in how seating aids achieve this postural response. This may have important implications for personalising ergonomic aids.

1. Introduction

Seating aids are commonly used to optimise sitting posture and as an adjunct in exercise interventions. These aids include blocks and inclined wedges utilised to optimise sitting posture and to enhance comfort when performing exercise such as Yoga (Saper et al., 2009; Tekur, Singphow, Nagendra, & Raghuram, 2008; Tilbrook et al., 2011; Williams et al., 2009). Seating modifications are thought to have an important role for posture and associated discomfort from prolonged sitting. Forward sloping seating designs, for example, may optimise posture in individuals with habitually flexed posture types. This has been demonstrated in research evaluating individuals reporting flexion related low back pain (LBP) and presenting with flattened lumbar curvatures (O'Keefe, Dankaerts, O'Sullivan, O'Sullivan, & O'Sullivan, 2013). Conversely, individuals who habitually adopt more extended sitting postures may gain limited benefit. Indeed, individuals with extension related LBP who present with hyperlordotic postures reported increased symptoms with seating aids further encouraging lumbar extension (Curran, Dankaerts, O'Sullivan, O'Sullivan, & O'Sullivan, 2014).

Despite these observations, public health advice suggests flexed sitting is detrimental to spinal health and encourages more upright sitting with lumbar lordosis (Castanharo, Duarte, & McGill, 2014). This concept has been embraced by chair and seating aids designers modifying the inclination of the seat pan and lumbar support to encourage anterior pelvic tilt and lumbar lordosis (Annetts et al., 2012; Cho et al., 2015).

Research evidence as to the effect of general seating modifications in spinal posture is inconclusive. There is a suggestion that, when compared to flat horizontal surfaces, forward sloped seating designs reduce posterior pelvic tilt (Bettany-Saltikov, Warren, & Jobson, 2008; Dunk, Kedgley, Jenkyn, & Callaghan, 2009; Kim, Kang, Noh, Kim, & Oh, 2014; Makhsous, Lin, Hendrix, Hepler, & Zhang, 2003; O'Sullivan, McCarthy, White, O'Sullivan, & Dankaerts, 2012; Wu, Miyamoto, & Noro, 1998) and lumbar flexion angle (Kim et al., 2014). Conversely, other research showed no difference in lumbar lordosis when sitting on tilted seat pan, with lumbar support or thoracic support compared to standard seating, although the inclined seat pan significantly increased anterior sacral tilt (De Carvalho, Grondin, & Callaghan, 2017). There is limited research investigating the effect of inclined seating design on the thoracic region (Bridger, Von Eisenhart-Rothe, & Henneberg, 1989).

There is growing interest in novel floor seating aid designs such as Butterfly™ wedge that claim to optimise posture, reduce discomfort and improve performance during exercise such as Yoga through altering the degree of hip flexion and pelvic inclination angle (James, 2016; Saper et al., 2009). Yoga and Pilates are frequently utilised forms of exercise with proven benefits for people with chronic musculoskeletal conditions such as LBP (Cramer, Lauche, Haller, & Dobos, 2013; Holtzman & Beggs, 2013). Optimising exercise performance and minimising discomfort is critical for exercise adherence and found to be the important mediator of exercise benefit (Cramer, Haller, Dobos, & Lauche, 2016). To date however, very little work has explored how these seating aids influence sitting posture during exercise. One functional posture commonly adopted during exercise that exposes the spine to flexion load is cross-legged sitting (Lee & Yoo, 2011). Research investigating how different floor seating aids alter the spinal and pelvic position during cross-legged sitting however, is lacking.

This study aimed to investigate the effect of commonly utilised floor seating aids on spinal and pelvic kinematics to explore the individual posture variations across different postural phenotypes in healthy men and women. It is hoped that this information will help to inform practitioners who utilise these seating devices (e.g. in Yoga and Pilates practices) to better understand the influence on spinal posture. The study data will also provide a comparator for research evaluating the utility of these devices in people with range of musculoskeletal conditions.

2. Materials and methods

2.1. Subjects

Sixty healthy individuals with mean age 21.20 years (yrs) (± 4.52 yrs; range: 18–45 yrs) were recruited as a convenience sample. All participants were university undergraduate students. The eligibility criteria were healthy individuals with no history of LBP for a minimum of 3 years and the ability to sit cross-legged for the purpose of testing sitting position using different seating aids. Exclusion criteria were any systemic neurological or inflammatory disease, spinal surgery, trauma or deformity (e.g. scoliosis) and pregnancy. Subjects with a body mass index (BMI) greater than 30 were also excluded to minimise potential for error in spinal angle measures due to increased adipose tissue (Saad, Colombo, & João, 2009). Finally, individuals currently participating in postural training programmes (e.g. pilates) were excluded to minimise any influence on spinal posture (Sheeran, Sparkes, Caterson, Busse-Morris, & van Deursen, 2012; Sheeran, van Deursen, Caterson, & Sparkes, 2013). The School of Healthcare Sciences Research Ethics Committee, Cardiff University approved the study. Data collection took place in the research laboratory of the School of Healthcare Sciences, Cardiff University.

2.2. Materials

Three different seating variations were used to evaluate differences between spinal and pelvic angles: (1) standard Yoga mat (2) a Yoga block (20 × 30 × 5 cm) and (3) a novel seating aid called the Butterfly™ wedge (Height: 5 cm front edge) (Figure 1). This is a device with a 10° forward sloping upper surface and a posterior groove claiming to facilitate optimal spinal and pelvic alignment and prevent pressure points on the coccygeal area.

2.3. Data collection procedure

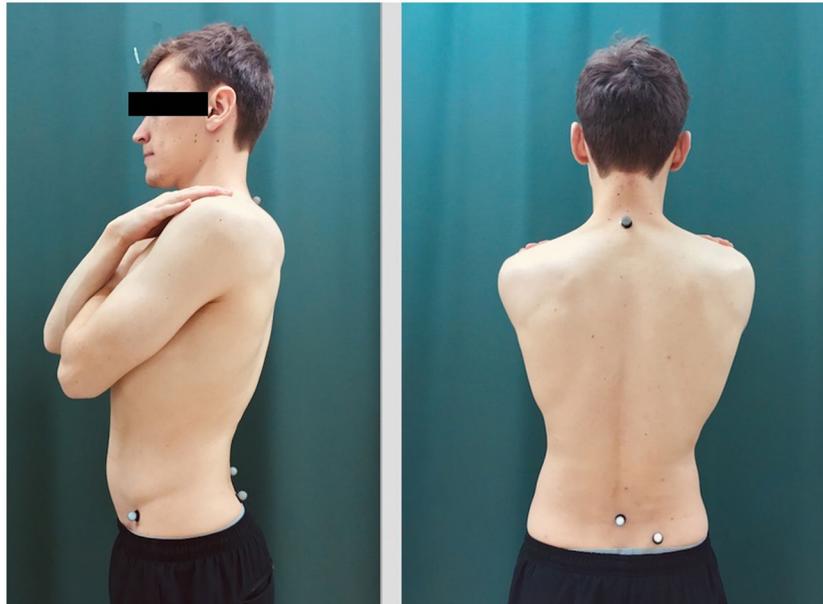
In the same-subject, repeated measures cross-over study design all participants attended a single data collection session with a randomised order of the three seating conditions: (i) Yoga mat (M) (ii) Yoga block (B) and (iii) Butterfly™ wedge (W). Spherical reflective markers were attached on the skin using double-sided adhesive tape over specific bony landmarks; 7th cervical (C7) and 5th lumbar (L5) spinous process, the posterior superior iliac spine (PSIS) and anterior superior iliac spine (ASIS) (Figure 2). All the markers were placed on the bony landmarks with the participant in sitting to minimise any potential skin marker movement. Similar process of bony landmarks surface palpation and placement have been shown to produce excellent reliability when measuring spinal angles in static postures (Annetts et al., 2012; Jones, Sparkes, Busse, Enright, & van Deursen, 2011).

Subjects were given standardized verbal and visual instructions to “sit centrally on the wedge/ Butterfly™/mat, cross your legs, bring your heels as close to you as possible, rest your hands on your knees and sit comfortably”. In each sitting condition 3 consecutive photographs were captured at 2 min into each sitting position. The 2-minute task duration was selected to resemble Yoga and Pilates practice within which the postures (pose) is held typically for 30 to 60 s and not exceeding 2 min (Cramer et al., 2013; Holtzman & Beggs, 2013), thus deemed an appropriate postural

Figure 1. (a) Inclined wedge (Buttafly™) (b) Standard sitting block (30 × 20 × 5 cm).



Figure 2. Marker placement over spinal vertebrae C7 and L5 and posterior and anterior iliac spine (a) lateral view, (b) posterior view.



challenge for this study. To prevent any potential carry-over effects, the participants had a 5-minute break between each of the three seating trials the order of which was randomised. Prior to each seating measurement trial the position of the markers was checked by the researcher to ensure that all markers were still in place and securely attached. Photogrammetry has been found to be a valid and reliable tool for measuring sagittal spinal curvature in sitting (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008; Saad et al., 2009). Each sitting condition was captured using a still camera (Canon VIXIA HF R600 HD, Canon, Canada) placed 1 metre away from the participant (sagittal view). Consecutive photographs were taken to capture 3 images of each participant following the 2 min of sitting.

2.4. Data processing and analysis

The thoracic, lumbar and pelvic angles were calculated using the intersecting circle method by the means of a custom-made code written in MATLAB (The Mathworks Company, Natick, MA, USA). The photographs of subjects' sagittal sitting postures were downloaded into the MATLAB environment. Clicking on the C7, L5 markers on the photograph produced sequence of circles; further clicks on the intersections between the circles and sagittal surface of the spine produced 11 equidistant points along the contour of the spine between C7 and L5 (Figure 3).

The top 7 points produced 6 line orientations in the C7-T12 region; the sum of angular changes between the lines produced the total thoracic angle. The bottom 4 points produced 3 line orientations in the S1-T12 region and the sum of angular changes between these lines produced the total lumbar lordosis angle (Figure 4). Pelvic tilt angle was calculated from the line joining ASIS to PSIS relative to horizontal line. The intersecting circle method was used in previous research and was found to have excellent reliability (ICC 0.70–0.99) for measuring sagittal spinal curvature and pelvic tilt in sitting (Annetts et al., 2012; Jones et al., 2011).

2.5. Statistical analysis

The Statistical Package for Social Sciences (SPSS) (version 20.0, IBM Corp, Armonk, NY) was used to perform all statistical testing. The mean angle (in degrees) for each of the regions (thoracic, lumbar and pelvic) for the three sitting conditions (Yoga mat, Yoga block and Butterfly™ wedge) was calculated (Table 3). The mean difference and 95% confidence intervals for each pairwise comparison were calculated. Based on the normal distribution and homogeneity of variance (Field, 2009), a repeated measure analysis of variance (ANOVA) and post-hoc Bonferroni testing was used to establish

Figure 3. Photograph imported into the custom written MATLAB code calculating the thoracic and lumbar spine curvature angle and pelvic tilt angle using the skin surface markers over the spinous processes of C7, L5 and posterior (PSIS) and anterior iliac spine (ASIS).

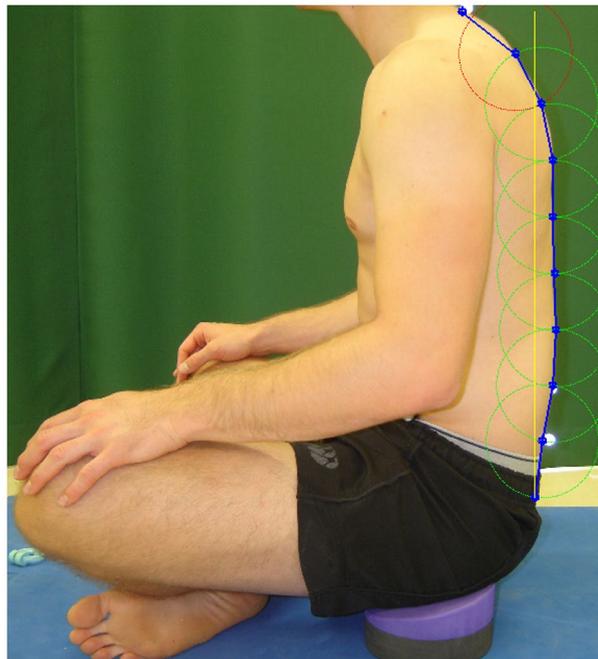
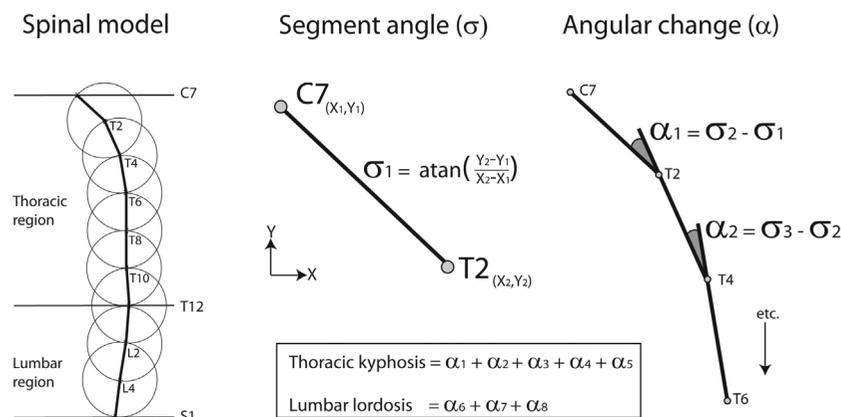


Figure 4. Intersecting circle method of thoracic and lumbar angle calculation.



significance (Table 3). To analyse gender as a factor, mean difference and 95% confidence intervals between genders was calculated. Gender was then included as a between subject factor within the repeated measures ANOVA test (with post-hoc Bonferroni testing) to explore the regional kinematic variations between genders across the 3 sitting conditions (Table 4). The significance level was set at $p < 0.05$. In addition, inter-tester reliability of the 3 researchers processing data in this study was calculated using intra-class correlation coefficient (ICC) with 95% confidence intervals (95%CI) were calculated using a two-way mixed effects model with agreement ($n = 20$). ICC level of >0.80 was considered to demonstrate excellent reliability (Field, 2009). Finally, standard error of measurement (SEM) within each spinal region and across all three seating conditions was calculated as follows $SEM = SD \times \sqrt{(1 - r)}$, where SD is standard deviation and r refers to reliability score (ICC) (Wyrwich, 2004).

3. Results

Sixty subjects (34 females and 26 males) participated in the study. Table 1 presents the demographic data (mean and standard deviation) for the participants' age, weight, height and BMI.

Table 1. Subject baseline characteristics

Variable	Total n = 60	Males n = 26	Females n = 34	Range	
				Min	Max
Age (years)	21.20	21.35	21.09	18	45
	(3.74)	(2.43)	(4.52)		
Mass (kg)	68.28	76.16	62.25	48.8	103.0
	(10.96)	(10.79)	(6.35)		
Height (m)	1.69	1.76	1.65	1.50	1.89
	(0.08)	(0.07)	(0.06)		
BMI (kg/m ²)	23.66	24.61	22.93	19.66	29.75
	(2.20)	(2.55)	(1.59)		

Notes: BMI = Body mass index (mass (kg)/height (m)²), kg = kilogrammes, m = metres.

3.1. Inter-tester reliability

The inter-rater reliability scores in this study demonstrate excellent reliability within the pelvis, lumbar and thoracic spine and across all three sitting conditions (inclined wedge, block and a mat) with ICC scores all above 0.973 (Table 2). SEM ranged between 0.6 to 1.2° (Table 2).

3.2. Interaction between sitting conditions and thoracic, lumbar and pelvic tilt angles

The repeated measures ANOVA comparing the overall effect of the 3 sitting conditions on the mean lumbar, thoracic and pelvic tilt sagittal angles are presented in Table 3. In the lumbar spine the positive values indicate flexion and negative values indicate extension relative to zero degree relative to the pelvis. In the pelvis the positive values refer to anterior pelvic tilt and negative values posterior pelvic tilt. A statistically significant interaction was demonstrated between the sitting condition and the lumbar and pelvic angles. Specifically, sitting cross-legged on an inclined wedge reduced lumbar flexion compared to sitting on a mat ($p < 0.009$), and sitting on a block significantly reduced the posterior pelvic tilt compared to mat sitting ($p < 0.05$). There was no significant difference in the spinal and pelvic angles between sitting on the inclined wedge and a block. No significant difference was demonstrated in the thoracic spine sagittal angles sitting on any surface (Table 3).

3.3. Interactions between gender and sitting conditions

Repeated measures ANOVA results comparing the gender effect are presented in Table 4. There was a highly statistically significant effect of gender on the lumbar spine and pelvis in all 3 seating conditions ($p < 0.0001$). Females tended to have significantly less lumbar flexion compared to males (0.94 to 2.06° and 17.43 to 20.11°, respectively) and less posteriorly tilted pelvis (-3.93 to -5.20° and -13.09 to -14.99°, respectively) regardless of the seating surface. Statistically significant differences were also demonstrated in the thoracic spine with females sitting in less thoracic flexion compared to males when sitting on an inclined wedge ($p < 0.005$) and a block ($p < 0.025$). No gender differences were shown in the thoracic spine angles when sitting on the mat.

4. Discussion

This study investigated the effect of Yoga mat, Yoga block and a novel design Butterfly™ wedge on a spinal curvature and pelvic tilt during cross-legged sitting in healthy individuals. This is a first study to date evaluating the influence of different floor seating aids, designed for the same purpose and branded as “optimising posture” and reducing discomfort, on spinal and pelvic kinematics during commonly practised exercise posture tasks. In light of the paucity of existing research evaluating floor seating devices comparisons will be drawn from literature evaluating chair seating designed for the similar purpose.

This study results showed that compared to cross legged sitting on a mat, Butterfly™ inclined wedge sitting significantly reduced lumbar flexion angle and Yoga block sitting significantly reduced

Table 2. Inter-rater reliability measures of thoracic, lumbar and pelvic sagittal angles during sitting on an inclined wedge, block and a mat

Region	Seating aid	ICC (95% CI)	SEM (Degrees)
Pelvis	IW	0.998 (0.995–0.999)	0.7
	B	0.997 (0.994–0.999)	0.6
	M	0.998 (0.996–0.999)	0.8
Lumbar	IW	0.994 (0.987–0.997)	1.2
	B	0.993 (0.985–0.997)	1.2
	M	0.994 (0.988–0.997)	1.1
Thoracic	IW	0.984 (0.967–0.993)	1.0
	B	0.973 (0.943–0.988)	0.8
	M	0.987 (0.973–0.994)	1.0

Notes: IW = Inclined wedge, B = Block, M = Mat, CI = confidence interval; Standard error of measurement (SEM) = $SD \times \sqrt{1 - r}$, where SD is standard deviation and r refers to reliability score (ICC).

posterior pelvic tilt angle (Table 3). These results concur with previous research demonstrating similar postural changes, albeit in sitting on a chair, where a reduction in lumbar flexion when sitting on a forward inclined seat compared to a flat or a backward reclining surface was observed (Kim et al., 2014). Similarly, a reduction in posterior pelvic tilt and increase in lumbar lordosis was reported when using inclined chair designs (Annetts et al., 2012; Cho et al., 2015). This study results show the limited effect of the tested seating aids on thoracic spinal angle. This is in accordance with previous research similarly detecting no significant effect in the thoracic region despite difference detected in the lumbar region with inclined seating (Bridger et al., 1989).

Whilst there was no appreciable mean angular difference between sitting cross legged on the inclined wedge and the Yoga block (Table 2) the overall trend was that seating aids in this study led to more upright postures compared to sitting on a mat. Interestingly, the Butterfly™ wedge reduced lumbar flexion but had no demonstrable effect on the pelvic tilt, whilst Yoga block sitting only decreased posterior pelvic tilt with little effect on the lumbar spine angle. This suggests that despite the close anatomical inter-relations between the lumbar spine and pelvis, the processes by which these structures relate to each other dynamically are complex. Further work is required to perhaps focus more on the experience of postural discomfort in relation to postural changes when using seating devices.

Relatively high standard deviations in the mean spinal and pelvic angles in this current study indicate a degree of variation within the sample. Considering the excellent reliability (ICC > 0.973) and low measurement errors ranging between 0.7 and 1.2° shown in this study (Table 2) this variation is likely to be due to the natural variation in sitting postures that healthy individuals tend to adopt rather than measurement error. Indeed, large variations in sitting and standing postures was observed in previous research and attributed to the heterogeneity of spinal posture and movement behaviours in healthy and LBP individuals (Dankaerts, O’Sullivan, Burnett, & Straker, 2006; Sheeran, Sparkes, Busse, & van Deursen, 2010; Smith, O’Sullivan, & Straker, 2008).

Closer examination of the differences between males and females found statistically significant effect of gender on the pelvic, lumbar and the thoracic angle. Compared to females, after 2 min of cross-legged sitting the males had up to 18.4° more lumbar spine flexion, up to 9.8° more posterior pelvic tilt across all 3 seating conditions and 7.1° greater thoracic flexion during Butterfly™ wedge and Yoga block sitting. Whilst to our best knowledge, this is a first study evaluating the impact of seating devices used during exercise such as Yoga, the findings are in agreement with previous work evaluating gender differences when sitting on a chair of different seat pan inclinations. Males were invariably found to flex at the lumbar spine relative to their female counterparts during sitting on a

Table 3. Overall effects of the 3 sitting conditions on the mean pelvic tilt and lumbar and thoracic spine sagittal angles using repeated measures ANOVA

Region	Sitting condition	Mean degree angle (SD) n = 60	Pairwise comparisons	Mean difference of the pair comparisons (degrees)	95% CI of the difference		Repeated measures ANOVA	
					Lower bound	Upper bound	Post Hoc Bonferroni	P value
Pelvis	IW	-8.08 (8.225)	IW v M	1.271	-0.500	3.043		0.246
	B	-7.88 (8.148)	IW v B	-0.200	-1.600	1.208		1.000
	M	-9.35 (9.235)	M v B	-1.467	-2.937	-0.005		0.050*
Lumbar	IW	7.02 (12.776)	IW v M	-2.869	-5.127	-0.590		0.009*
	B	8.75 (11.870)	IW v B	-1.729	-3.857	0.400		0.150
	M	9.88 (11.586)	M v B	1.130	-0.795	3.055		0.460
Thoracic	IW	32.18 (9.868)	IW v M	0.172	-2.105	2.448		1.000
	B	32.20 (9.779)	IW v B	-0.016	-2.070	2.038		1.000
	M	32.02 (8.779)	M v B	-0.188	-2.568	2.193		1.000

Notes: IW = Inclined wedge, B = Block, M = Mat, SD = standard deviation, CI = confidence interval; Pelvis: Positive values indicate anterior pelvic tilt and negative values indicate posterior pelvic tilt. Spine: Negative values indicate extension and positive values indicate flexion (relative to neutral lordosis).
 *Significant ($p < 0.05$).

Table 4. The effect of the 3 sitting conditions on the mean pelvic tilt and lumbar and thoracic spine angles between genders

Region	Sitting condition	Angle (degrees) mean (SD)		Mean difference between genders	95% CI of the difference		Repeated measures ANOVA	
		Females (n = 34)	Males (n = 25)		Lower bound	Upper bound	Post Hoc Bonferroni	P value
Pelvis	IW	-3.93 (6.75)	-13.72 (6.57)	-9.792	-13.315	-6.269		0.000*
	B	-4.05 (6.88)	-13.09 (6.79)	-9.046	-12.657	-5.434		0.000*
	M	-5.20 (8.47)	-14.99 (7.05)	-9.796	-13.968	-5.624		0.000*
Lumbar	IW	-0.94 (10.04)	17.43 (7.298)	18.372	13.698	23.045		0.000*
	B	1.34 (9.46)	18.43 (6.48)	17.093	12.757	21.428		0.000*
	M	2.06 (8.10)	20.11 (6.18)	18.046	14.220	21.872		0.000*
Thoracic	IW	29.13 (9.33)	36.18 (9.24)	7.052	2.204	11.900		0.005*
	B	30.00 (8.29)	35.09 (8.70)	5.094	0.675	9.513		0.025*
	M	29.95 (9.78)	34.72 (9.06)	4.768	-0.178	9.713		0.059

Notes: IW = Inclined wedge, B = Block, M = Mat, CI = confidence interval, SD = standard deviation; Pelvis: Positive values indicate anterior pelvic tilt and negative values indicate posterior pelvic tilt. Spine: Negative values indicate extension and positive values indicate flexion (relative to neutral lordosis).
 *Significant ($p < 0.05$).

chair with flat surface (Bridger et al., 1989; Dunk & Callaghan, 2005), forward inclining and backward reclining surface (Bridger et al., 1989).

The reason for these gender differences is not known; it could be argued that morphological differences in height and weight may have contributed to the identified postural differences between sexes with generally taller and heavier male participants perhaps finding the posture task of cross legged sitting more of a motor control challenge than the shorter and lighter female participants. Interestingly, the gender analysis in this study demonstrate gender-specific variations occur across all of the studied regions; the pelvis, lumbar and the thoracic spine. It has been previously proposed that gender may in fact be an intrinsic and unmodifiable factor that cannot be significantly altered by simply changing seating conditions (Dunk & Callaghan, 2005; Nguyen & Shultz, 2007). This study results support this view demonstrating little difference in the spine and pelvic angles in males or females irrespective of what they were sitting on. Equally however, the overall results revealing significant differences in the lumbar spine and pelvis when sitting on the Yoga block and Butterfly™ wedge compared to a mat sitting (Table 3) may indicate, that individuals' postures may respond differently to seating aids. Further research exploring the utility of gender specific seating aids designs and how this may relate to sitting comfort and LBP may be warranted.

4.1. Limitations and future research

Previous research has highlighted that sitting cross-legged on a chair can cause asymmetrical rotation of the pelvis which only significantly affects pelvic tilt on the ipsilateral side of the crossed leg (Lee & Yoo, 2011). Participants' preferred way of crossed one leg over the other could be standardised in future research in an attempt to control for this potential confounding factor.

Reduced hip mobility has been reported to influence spinal posture and cause asymmetrical pelvic rotation (Kim et al., 2014) with previous work has also objectively screening or excluding participants with reduced hip mobility when evaluating cross-legged sitting postures (Cho et al., 2015; Claus, Hides, Moseley, & Hodges, 2009; Kuo, Tully, & Galea, 2009; Lee & Yoo, 2011). Given the relatively young mean age of this study participants (approximately 21 years), degree of hip mobility has not been evaluated in this study, although may be considered important in research including older population, thus should be considered in future study designs.

Whilst the 2-minute trial duration may limit relevance of this research to prolonged sitting in today's sedentary lifestyles, the trial duration appropriately reflects the duration of the postures adopted within exercise practices such as Yoga used for healthy and LBP individuals typically between 30 to 60 s in length and not exceeding 2 min (Cramer et al., 2015; Cramer, Ostermann & Dobos, 2018).

The sample in this study was recruited from healthy populous of university students and staff between 18 and 45 years of age with balanced representation of males and females. Whilst this is still a relevant population, the generalisability of this research to wider population is limited.

5. Conclusions

This is a first study that evaluated the effect of novel floor seating devices designed to reduce discomfort during exercise such as Yoga and Pilates frequently utilised in LBP management. The study showed that both Butterfly™ wedge and Yoga block reduced the respective lumbar flexion and posterior pelvic tilt compared to mat cross-legged sitting. Such seating aids may therefore bring benefits to those who tend to adopt flexed postures with discomfort during seated exercise posture tasks. Both seating aids showed a general trend towards reducing overall spinal flexion, however the results suggest the inclined wedge has greater influence in the lumbar region whilst the block induced the greatest change in the pelvis. This may carry significant relevance for industries and research developing seating aids designs personalised to posture type. The highly statistically significant differences between male and female thoracic, lumbar and pelvic tilt sagittal angles across all sitting conditions may provide first explorative direction for these bespoke seating designs.

6. Key points

- This first study to date investigated the effect of seating aids on spinal-pelvic posture during cross-legged sitting frequently adopted during exercise such as Yoga and Pilates.
- Sitting on a novel inclined wedge reduced lumbar flexion whilst sitting on a block reduced posterior pelvic tilt; indicating variation in how seating aids influence posture in pain-free individuals, potentially bringing into question their indiscriminate use in practice.
- Seating aids investigated in this study may have a justification for posture optimisation in individuals who tend to feel discomfort whilst sitting flexed.
- Statistically significant differences were found between male and female thoracic, lumbar and pelvic tilt sagittal angles across all sitting conditions with males adopting more flexed postures compared to females irrespective of what they sit on.
- This research has important relevance for industry research and development with the aim to design bespoke seating devices personalised to posture type.

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Practitioners summary

This paper investigated the effect of novel seating aids used in Yoga and Pilates on spinal-pelvic posture during cross-legged sitting. Inclined wedge and block seating reduced lumbar flexion and posterior pelvic tilt, respectively. Males adopt more flexed postures irrespective of the seating aids compared to females.

Author details

Liba Sheeran^{1,2,3}

E-mail: SheeranL@cardiff.ac.uk

ORCID ID: <http://orcid.org/0000-0002-1502-764X>

Rebecca Hemming¹

E-mail: HemmingRL@cardiff.ac.uk

ORCID ID: <http://orcid.org/0000-0002-8708-5638>

Robert van Deursen^{1,2,3}

E-mail: VandeursenR@cardiff.ac.uk

ORCID ID: <http://orcid.org/0000-0002-9461-0111>

Valerie Sparkes^{1,3}

E-mail: SparkesV@cardiff.ac.uk

ORCID ID: <http://orcid.org/0000-0003-4500-9327>

¹ School of Healthcare Sciences, Cardiff University, 13th Floor Eastgate House, 35–43 Newport Road, Cardiff, CF24 0AB, Wales, UK.

² Research Centre for Clinical Kinesiology, Cardiff University, Cardiff, CF14 4XN, UK.

³ Arthritis Research UK Biomechanics and Bioengineering Centre, School of Healthcare Sciences, Cardiff University, Cardiff, Wales, UK.

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