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Vaucher, M.; Isner-Horobeti, M.E.; Demattei, C.; Alonso, S.; Herisson, C.; Kouyoumdijan, P.; van Dieen, J.H.; Dupeyron, A.

published in
Annals of Physical and Rehabilitation Medicine
2015

DOI (link to publisher)
10.1016/j.rehab.2015.01.003

Annals of Physical and Rehabilitation Medicine xxx (2015) xxx–xxx

Available online at
ScienceDirect
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Elsevier Masson France
EM|consulte
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Original article

Effect of a kneeling chair on lumbar curvature in patients with low back pain and healthy controls: A pilot study☆,☆☆

Matthieu Vaucher [a], Marie-Eve Isner-Horobeti [b], Christophe Demattei [c], Sandrine Alonso [c], Christian Hérisson [d], Pascal Kouyoumdjian [e], Jaap H. van Dieën [f,g], Arnaud Dupeyron [a,*,h]

[a] Fédération de médecine physique et de réadaptation, GHU Carémeau, université de Montpellier 1, place du Pr. Robert-Debré, 30029 Nîmes cedex 9, France
[b] Département de médecine physique et de réadaptation, institut universitaire de réadaptation Clémenceau (IURC), 67082 Strasbourg, France
[c] Département de biostatistiques, épidémiologie, santé publique et information médicale (BESPIM), université de Montpellier 1, Nîmes, France
[d] Service central de rééducation, CHU Lapeyronie, université de Montpellier 1, 34295 Montpellier, France
[e] Département de chirurgie orthopédique, GHU Carémeau, université de Montpellier 1, 30029 Nîmes, France
[f] MOVE research institute Amsterdam, faculty of human movement sciences, VU university Amsterdam, Amsterdam, Netherlands
[g] King Abdulaziz University, Jeddah, Saudi Arabia
[h] Movement to Health Laboratory (M2H), Montpellier-1 University EuroMov, 34090 Montpellier, France

ARTICLE INFO

Article history:
Received 17 July 2014
Accepted 18 January 2015

Keywords:
Low back pain
Lumbar lordosis
Sitting
Chair

ABSTRACT

Background: The concept of an ideal sitting posture is often used in practice but lacks a basis in evidence.
Objective: We designed a cross-sectional, comparative, matched study to determine the effects of chair and posture on lumbar curvature in 10 patients with chronic non-specific low back pain (CLBP; mean pain duration 24 ± 18 months) and 10 healthy matched controls.
Methods: Pelvic incidence, sacral slope and lumbar curvature were measured on computed radiographs by 2 blinded clinicians for subjects in 2 postures (upright vs slumped sitting) and on 2 chairs (usual flat chair vs kneeling chair).
Results: The reliability of measures was excellent (intraclass correlation coefficient > 0.9). As hypothesized, the expected sacral slope and lumbar lordosis changed between standing and sitting on a kneeling chair as compared with a usual chair ($P < 0.0001$) and less in patients than controls ($P = 0.046$) for lordosis only. In addition, as expected, changes were more pronounced with slumped than upright sitting ($P < 0.0001$). An interaction between chairs and postures for lumbar lordosis ($P = 0.02$) indicated more pronounced effects of the chair in slumped sitting. Therefore, lumbar lordosis was reduced less when sitting on a kneeling chair as compared with a usual chair.
Conclusions: Although healthy subjects showed more reduction in lordosis between standing and sitting, the chair effect was found in both CLBP patients and healthy subjects.

1. Introduction

The concept of an optimal or ideal sitting posture is often used in practice but lacks a basis in evidence. When moving from standing to sitting, a posterior pelvic tilt is associated with reduced lordosis. The lumbosacral joint can even reach maximum flexion in slumped sitting [1]. Some authors consider that correct sitting is achieved when the lordosis is similar to that in a standing position [2]. However, no study has demonstrated that such sitting postures prevent disc degeneration or low back pain (LBP) [3,4].

Preferred postures in sitting appear to differ between healthy people and patients with chronic LBP (cLBP). Patients could be classified into groups with less or more lordosis than healthy subjects and patients with less-modulated lumbar curvature when instructed to move from upright to slumped sitting [5].

The angle of the acetabulo-femoral joint affects pelvic rotation and hence lumbar curvature during sitting [6,7]. Thus, ergonomic chairs, such as the kneeling chair, aim to limit hip flexion and promote lumbar lordosis [8]. Whether these chairs can be recommended to prevent or alleviate LBP is unclear. Moreover, non-specific LBP can represent several sources of pain that may

☆ Clinical trials number: NCT01323127.
☆☆ The study was performed in the Physical Medicine and Rehabilitation Department, Carémeau University Hospital of Nîmes, University of Montpellier I.
* Corresponding author.
E-mail addresses: arnaud.dupeyron@univ-montp1.fr, arnaud.dupeyron@gmail.com (A. Dupeyron).

http://dx.doi.org/10.1016/j.rehab.2015.01.003
1877-0657/

even affect sitting behavior in various ways. However, in most cases, the source of pain is not actually known. For a start, whether lordosis is indeed affected by the chair, throughout a range of postures, from upright to slumped sitting, needs to be determined as does whether this effect is present in CLBP patients and healthy people alike. Numerous studies have explored the effect of different sitting positions on lumbar curvature with external measures (inclinometers or external markers) [8,9], but we have no data from radiologic measures including pelvic parameters.

Sitting on a sloping (or kneeling) chair may promote an anterior pelvic tilt and enhance lumbar lordosis as compared with sitting on a flat chair, probably for both slumped (relaxed) and upright (active) sitting. Moreover, CLBP patients may modulate lumbar lordosis less between sitting and standing than healthy controls. In this study, we aimed to study pelvis orientation and lumbar curvature with radiographs from patients with non-specific CLBP and matched controls when sitting upright and slumped on 2 types of chairs: a usual chair ("flat chair"), with a horizontal seat, and a kneeling chair ("sloping chair"). The radiography protocol we used did not allow for investigating large cohorts without formal indications of the usefulness of this method for this goal (pelvic variables in a sitting position for LBP). We therefore studied a relatively small cohort as a pilot study to determine whether CLBP patients responded differently from healthy subjects.

2. Methods

2.1. Subjects

We recruited 10 CLBP patients (mean pain duration 24 ± 18 months) and 10 healthy matched controls from our hospital between April and December 2011. All subjects gave their signed informed consent to be in the study. The study was approved by the local ethics committee and registered at http://www.ClinicalTrials.gov (NCT01323127).

We included LBP patients with pain provoked by or aggravated by mechanical loading for more than 3 months, with degenerative changes of at least one disc as determined by imaging, and excluded children and adolescents < 18 years and patients who had spine surgery or were pregnant. Controls were excluded if they had a history of LBP. We also excluded subjects with any condition that might interfere with sagittal balance of the spine (lumbopelvic malformations or hip disease), having had more than 2 radiographs of the trunk or high-risk scans over the previous year and routine (professional or leisure) exposure to radiation.

3. Radiography

A digital radiography system (Definium 6000, GE Healthcare) was used. The effective radiation dose for the 4 radiographs was 1.8 mSv. Radiographs were captured directly onto a computer. Lateral static computed radiographs of the lumbar spine and pelvis were obtained at a set distance of 180 cm from the X-ray source and centered on L4. One radiograph was taken with the subject standing up (Figs. 1A, 2A) and 4 radiographs were taken with the subject seated in 2 postures in each of 2 chairs: flat chair (height 45 cm, 0° seat inclination; Fig. 1B1, 2, Fig. 2B1, 2) and sloping chair (height 40 cm, 20° forward sloping seat inclination, 20° backward sloping knee support inclination; Fig. 1C1, 2; Fig. 2C1, 2) and upright posture (Fig. 1B1, C1; Fig. 2B1, C1) and slumped posture (Fig. 1B2, C2; Fig. 2B2, C2). Before the experiments, subjects were instructed to maintain postures without touching the back of the chair. Furthermore, they were instructed to obtain the slumped posture by rounding the spine and relaxing the back muscles and put their hands on their thighs.

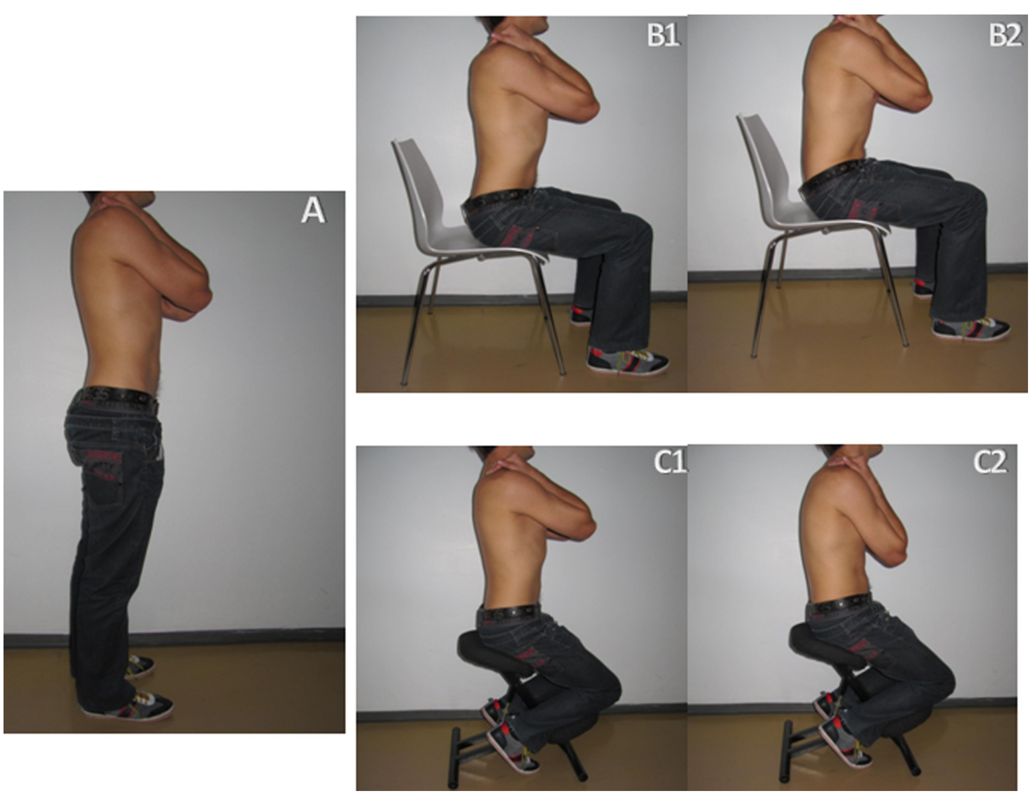

Fig. 1. Standing position and the 4 sitting conditions analysed (B1: flat chair, upright; B2: flat chair, slumped; C1: sloping chair, upright; C2: sloping chair, slumped).

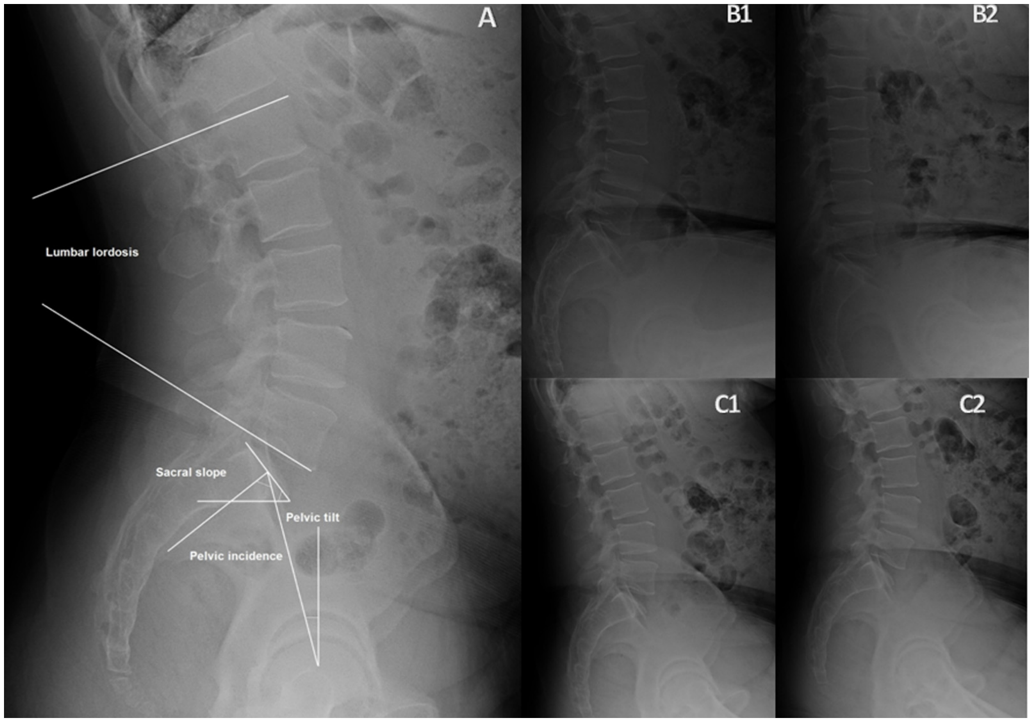

Fig. 2. Radiographs taken under all conditions and variables measured described in Fig. 2A for conditions described in Fig. 1.

4. Measurements

From each radiograph, pelvic incidence, sacral slope, and lumbar lordosis were measured by use of the Keops sagittal balance analyzer (SMAIO, Lyon, France). The following markers were digitized: one point on each of the femoral heads, 2 corners of the sacrum, 4 corners of L5 and the top corners of L1. Data obtained in the sitting position were referenced to data obtained in the standing position (sitting value – standing value) to reduce inter-subject variability and analysed as absolute change and percentage change from standing values. Four sets of 100 blinded and randomized radiographs (20 subjects $\times$ 5 conditions) were created and analyzed twice (on 2 separate days) by 2 independent experienced physicians (MV, AD). Before unblinding, a preliminary analysis of intra- and interrater reliability was performed, then one of the 4 series was chosen at random for statistical analysis.

5. Statistical analysis

Statistical analysis involved use of SAS 9.3 (SAS Inst., Cary, NC) and R 2.9.2 (http://www.R-project.org, the R Foundation for Statistical Computing, Vienna, Austria). Inter- and intrarater reliability was measured by the intraclass correlation coefficient (ICC) with the individual effect considered as a random effect. The ICC was considered good at > 0.9 and acceptable at > 0.8. Under the condition that inter- and intrarater reliability was acceptable, a global ICC combining inter- and intrarater variability was computed by a mixed model including an individual random effect, a rater fixed effect and an order of measure fixed effect. Absolute and relative changes from standing to sitting in lumbar lordosis and sacral slope were analysed by a linear mixed-effects model with 2 repetition factors (posture and chair) and a group factor (CLBP versus controls). Interactions between factors were also tested. $P < 0.05$ was considered statistically significant.

6. Results

CLBP patients and controls were well-matched (Table 1): mean age 42.5 ± 9 and 43 ± 9 years, body mass index 26 ± 5.4 and 25.6 ± 5 kg/m^2. The ICCs (2 measures and 2 raters) for pelvis variables during standing and sitting in 2 types of chairs and with 2 positions were > 0.9 for all conditions (Table 2). Therefore, we randomly selected one measure for further analysis before ICCs were computed, and only the first measurement of rater 2 was analysed.

The type of chair (flat vs sloping) significantly affected lumbar lordosis and sacral slope changes ($P < 0.0001$ for all) (Table 3). As expected, as compared with the flat chair, the sloping chair was associated with a smaller decrease of lordosis and sacral slope relative to the standing position. For CLBP patients, the decrease in lumbar lordosis and sacral slope with the upright position was 36% and 32%, respectively, for the flat chair and 15% and 17% for the kneeling chair (Fig. 3). For controls, the decrease was 51% and 39%, respectively, for the flat chair and 20% and 11% for the kneeling chair (Fig. 3). An interaction of chair and posture on lumbar lordosis ($P = 0.02$) indicated a more pronounced difference between chairs in the slumped posture.

As expected, all dependent variables were affected by posture (Table 3; $P < 0.0001$). For lumbar lordosis, the interaction with chair ($P = 0.02$) indicated that these effects were less pronounced

Table 1
Characteristics and lumbopelvic values during standing for patients with chronic low back pain (CLBP) and matched healthy controls.

Characteristics	Total $n = 20$	CLBP patients $n = 10$	Controls $n = 10$
Age (year)	42.8 ± 8.8	42.5 ± 9	43 ± 9.1
BMI (kg/m^2)	25.8 ± 5.2	26 ± 5.4	25.6 ± 5.3
Pain duration (month)	–	24.8 ± 18.2	–
Pelvic incidence (°)	54 ± 13.1	59.4 ± 13.5	48.6 ± 10.6
Sacral slope (°)	40.2 ± 12.5	42.5 ± 15.2	38 ± 9.5
Lumbar lordosis (°)	56.8 ± 13	57 ± 14.5	56.7 ± 12.1

Data are mean $\pm$ SD. BMI: body mass index.

Please cite this article in press as: Vaucher M, et al. Effect of a kneeling chair on lumbar curvature in patients with low back pain and healthy controls: A pilot study. Ann Phys Rehabil Med (2015), http://dx.doi.org/10.1016/j.rehab.2015.01.003

Table 2
Intra- and interrater intraclass confidence intervals (ICCs) for pelvis variables during standing and sitting in 2 types of chairs and with 2 positions.

Lumbopelvic variables	Standing	Sitting			
		Flat chair		Sloping chair	
		Upright	Slumped	Upright	Slumped
Lordosis	0.96 (0.92–0.98)	0.94 (0.87–0.97)	0.94 (0.89–0.97)	0.97 (0.95–0.99)	0.97 (0.95–0.99)
Sacral slope	0.98 (0.96–0.99)	0.97 (0.93–0.98)	0.96 (0.93–0.98)	0.97 (0.94–0.98)	0.98 (0.97–0.99)
Pelvic tilt	0.94 (0.88–0.97)	0.95 (0.91–0.98)	0.97 (0.94–0.99)	0.97 (0.94–0.99)	0.97 (0.94–0.99)
Pelvic incidence	0.95 (0.90–0.98)	0.94 (0.88–0.97)	0.93 (0.87–0.97)	0.95 (0.90–0.98)	0.95 (0.90–0.98)

Data are ICCs and 95% confidence intervals.

with the sloping than flat chair (Table 3). For example, the decrease in lumbar lordosis ranged from 51% to 76% when controls adopted the slumped posture from the upright one on the flat chair but from 20% to 39% on the kneeling chair (Fig. 3).

The group effect ($P = 0.046$) confirmed that CLBP patients modulated the lumbar curvature less between standing and sitting than healthy controls but not the sacral slope ($P = 0.82$) (Table 4).

7. Discussion

We designed a cross-sectional, comparative, matched study to determine the effects of chair and posture on lumbar curvature in 10 patients with CLBP and 10 healthy matched controls. Lumbar lordosis was preserved more on the sloping chair than the flat chair in CLBP patients and healthy subjects alike. Previous studies had shown similar results in healthy subjects [8,9]. Although we found an interaction between the chair effect and posture, our conclusion holds for both upright and slumped sitting and hence most likely across the range of postures encountered in daily life. CLBP patients showed smaller changes in lumbar curvature and pelvic tilt between standing and sitting than controls, across chairs and postures.

Most studies have compared lumbar and pelvic adaptations in various sitting positions without considering standing values [2]. However, lumbar lordosis was found nearly 50% greater when standing than sitting [10]. Our results showed a similar modulation in healthy subjects in an upright posture on a usual chair (51%) but greater changes when subjects adopted a slumped posture (65% to 76% for CLBP and controls, respectively) and smaller changes in an upright posture on the kneeling chair (15% to 20% for CLBP and controls, respectively). Overall, this reduction in lordosis was reduced on the kneeling chair regardless of group. The kneeling chair may preserve more lumbar and pelvic angles (relative to standing) even with a slumped posture. This effect may result in less soft-tissue strain because the lumbar lordosis is closer to the neutral posture [11]. Moreover, Keegan hypothesized that a 135° trunk-thigh angle (close to that on the kneeling chair) was a neutral position for tension in thigh muscles [6]. Increased tension in the posterior thigh muscles appears to cause the pelvis to rotate posteriorly and thus decrease lumbar lordosis. In end-range positions of the spine, the reactive forces induced by the passive structures increase strain and thus the risk of lesion of soft tissues [11]. Our results confirm these effects of seat design and expand it to the CLBP population.

When people are sitting relaxed without lumbar support, they commonly adopt a slumped posture. Our results showed greater variations (such as loss of lordosis) in a slumped posture for both CLPB patients and controls. As expected, the upright posture limited the loss of lordosis. However, maintaining an upright sitting posture requires muscle activation that may cause muscle fatigue [12] and increases loading on the spine. Even with training, subjects cannot maintain an upright posture for extended periods of time [13]. Therefore, seat design is likely to be more effective in preserving lordosis in sitting than is instruction and training.

Table 3
Absolute changes relative to standing values for lumbar lordosis and sacral slope by chair type and posture for CLBP patients and healthy controls.

Lumbopelvic variables	CLBP patients				Controls			
	Flat chair		Sloping chair		Flat chair		Sloping chair	
	Upright	Slumped	Upright	Slumped	Upright	Slumped	Upright	Slumped
Lumbar lordosis (°)	−20 ± 7.7	−35.4 ± 8.7	−8.4 ± 3.8	−12.6 ± 8	−27.9 ± 9.7	−44.1 ± 18.9	−11 ± 7.6	−21.5 ± 11
Sacral slope (°)	−13.4 ± 7.7	−26.3 ± 7.8	−7.4 ± 5.5	−14.3 ± 4.2	14.4 ± 7.9	−25.2 ± 13.5	−4.4 ± 6.8	−14.9 ± 9.1

Data are mean ± SD.

Table 4
Absolute change in lumbar lordosis and sacral slope by chair, posture and group (CLBP patients and healthy controls): results of linear mixed-effects model.

Effect	Lumbar lordosis			Sacral slope		
	Effect estimation	SD	*P*-value	Effect estimation	SD	*P*-value
Intercept	−21.35	3.0		−14.85	2.2	
Upright vs relaxed posture	10.4	2.7	< 0.0001	10.50	2.6	< 0.0001
Flat vs sloping chair	−22.74	4.7	< 0.0001	−10.39	3.5	< 0.0001
CLBP patient vs healthy subject	8.81	4.3	0.0458	0.56	3.2	0.8203
Erect posture × flat chair	5.82	4.7	0.0181	0.32	3.1	0.1699
CLBP group × flat chair	−0.11	6.6	0.5265	−1.60	4.9	0.7080
CLBP group × erect posture	−6.29	3.8	0.3626	−3.63	3.7	0.7981
CLBP group × erect posture × flat chair	5.51	6.6	0.4146	5.71	4.4	0.2146

SD: standard deviation.

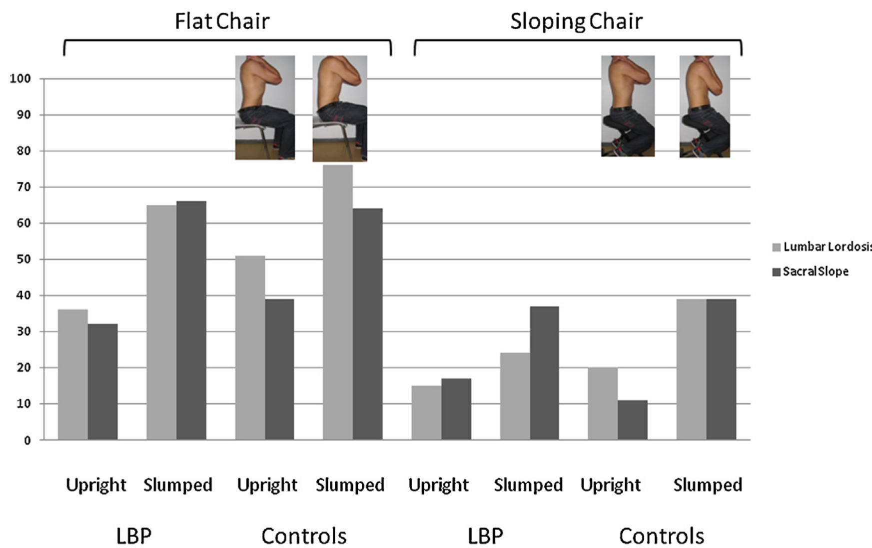

Fig. 3. Relative change (%) in lumbar lordosis and sacral slope by condition (the y-axis represents the % decrease). LBP: low back pain.

Patients with CLBP preserved lumbar lordosis more during sitting than did healthy controls. Of note, the baseline values for lumbar lordosis and sacral slope did not differ between the groups. This finding agrees with Dankaerts et al. [5], who found that CLBP patients showed smaller differences in lordosis between slumped and relaxed sitting. This finding could be an indication that patients are avoiding lumbar kyphosis. However, this suggestion would contrast with Dankaerts et al. [5], who found a more kyphotic curvature in relaxed sitting in a subgroup of patients than controls. Therefore, the reason for this decreased modulation of lumbar curvature across different postures remains unclear but may be related to unwillingness or inability to mobilize the lumbar spine by CLBP patients. Moreover, age-related disc degeneration and subsequent stiffening may affect lumbopelvic values and explain part of these differences.

The literature generally agrees that sitting with a lordotic lumbar spine is preferable. An association between decreased lumbar lordosis and degenerative disc disease at L5-S1 has been described [14]. Others have emphasized the relationship between kyphosis and pressure within the nucleus pulposus [15–17]. Moreover, decreased lordosis has been suggested to cause high stresses and strains on posterior structures [10] because lower intervertebral joints reach their maximal range of motion in slumped sitting [1]. In upright sitting, lumbopelvic muscle activation equilibrates the trunk mass over the pelvis, whereas in slumped sitting, posterior passive structures appear to do so [18,19], but the biomechanical consequences of these 2 conditions are incompletely understood. Finally, Williams et al. reported that enhancing lumbar lordosis through seat design (lumbar support) reduced back pain and leg pain [20].

The sloping chair may provide a means of preserving lordosis in CLBP patients and healthy subjects alike, even when they are sitting relaxed. Indeed, lumbar lordosis and sacral tilt are less reduced in a slumped posture on a sloping chair than in an upright posture on a flat chair as compared with standing. However, no clinical effect can be extrapolated from this finding without further clinical evaluation.

Our study has several limitations. First, the sample size was small, but nevertheless, all main effects studied were significant. Although demographic characteristics were similar between groups, the pelvic incidences differed, which may have caused some bias in our between-group comparison. Indeed, post-hoc analysis of the data showed that subjects with high pelvic incidence showed greater variations in curvature between standing and sitting than those with low pelvic incidence, which may have contributed to the group effect. However, according to the Roussouly classification [21], high pelvic incidence was equally distributed among the 2 groups (7 CLBP patients and 6 controls with grade III/IV). Previously, the height of the chair seat was suggested to modify lumbopelvic angles [8]. In the present study, all subjects were seated on the same chair with the same height, which probably affected individual variation and may limit generalization.

8. Conclusion

Lordosis is better maintained, relative to the standing posture, when sitting on a kneeling chair than on a usual flat chair, with upright as well as slumped posture and in CLBP patients and healthy subjects alike. CLBP patients showed less reduction in lumbar lordosis between standing and sitting than healthy controls on both chair types and with upright and slumped postures.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Funding

No funding was received for this work.

Acknowledgments

We thank Dr Dominique Blin for assistance in managing the radiography protocol and Drs Anthony Gélis, Vincent Grémeaux and Emmanuel Coudeyre for their 10 years of benevolent support.

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