Leo L. van Deursen
Jaap Patijn
John R. Durinck
Ruud Brouwer
Jeanne R. van Erven-Sommers
Bernard J. Vortman

Sitting and low back pain: the positive effect of rotatory dynamic stimuli during prolonged sitting

Received: 8 May 1998
Revised: 23 November 1998
Accepted: 28 December 1998

L. L. van Deursen (✉) · R. Brouwer
Institute for Manual Medicine,
Stratumsedijk 26,
5611 ND Eindhoven, The Netherlands

J. Patijn
Department of Neurology,
Institute for Manual Medicine,
Eindhoven, The Netherlands

J. R. Durinck
Department of Epidemiology
and Medical Informatics
of the Occupational Health Service,
Philips Electronics,
Eindhoven, The Netherlands

J. R. van Erven-Sommers
Department of Neuropsychology,
Institute for Manual Medicine,
Eindhoven, The Netherlands

B. J. Vortman
Department of Rehabilitation,
Institute for Manual Medicine,
Eindhoven, The Netherlands

Abstract In this study the effect of dynamic stimuli on low back pain during prolonged sitting was investigated. The pain experience of two groups of 60 subjects with aspecific low back pain was recorded. All subjects were investigated on pain behaviour by the Multidimensional Pain Inventory (MPI) and pain was measured on an open visual analogue scale (VAS). During sitting, one group received dynamic stimuli that were generated by alternating rota-

tions in the horizontal plane of the seat of the chair, with back and arm rests in fixed position. Two different frequencies of rotation were applied in subgroups. The authors concluded that such stimuli, especially of the lower frequency, reduced pain in prolonged sitting.

Key words Low back pain, sitting · Low back pain, rotatory dynamic stimuli · Low back pain, chair

Introduction

Sitting, especially prolonged sitting, is generally accepted as a risk factor in developing low back pain (LBP) [4, 8, 15, 16]. Although much attention has been paid to the best ergonomic sitting posture, the problem has never really been resolved [2, 3, 20, 26]. According to Jensen, one of the three factors responsible for the development of LBP in sitting is insufficient nutrition of the intervertebral discs due to lack of spinal motion [14]. Lack of spinal motion as a provocative factor seems to correspond with what we found in an analysis of patients with LBP: 85% found

pain was brought on by prolonged sitting, 73% by standing, but only 23% by walking and 15% by cycling [6].

For that reason we speculated that the introduction of a dynamic stimulus during prolonged sitting could reduce pain symptoms, especially in subjects with LBP. The simple introduction of the possibility for active movement, like on rocking chairs, balance chairs or chairs with tiltable seats, was proven to be insufficient [14]. We expected that a constant passive forced motion would be necessary. We decided to use a strictly rotatory dynamic stimulus, because rotation of the spine is independent of age, intervertebral disc degeneration and facet joint sclerosis [21]. Disc degeneration has an effect on flexion and

extension, but not on lateral flexion and rotation [21]. Unless a rotation is combined with lateral flexion and/or flexion, a rotatory range of 1° – 2° does not endanger the disc [1, 5, 9, 22]. For this reason we chose an angle of rotation of 1.25° to either side.

Our aim was to study the effect of strictly rotatory dynamic stimuli on LBP during prolonged sitting.

Material and methods

Population

120 LBP patients (72 female, 48 male) were included in this study. Neurological examination and X-rays of the lumbar spine were performed in all patients. All patients signed an informed consent.

The inclusion criteria were: (a) aspecific LBP longer than 6 weeks, and (b) lumbar pain and discomfort elicited by prolonged sitting. Patients with signs of lumbar radicular syndrome, systemic diseases, lysis and olisthesis and vertebral fractures or malignancy were excluded.

Experimental set-up

The subjects were selected by four physicians working at our clinic. Subjects who were willing to take part were asked to make an appointment with the secretary for the trial. This trial was conducted by another co-worker. Subjects were divided, by the order in which they enrolled, into an index group A ($n = 60$) with dynamic stimuli, and a control group B ($n = 60$) without stimuli. Subjects were unaware of the different test conditions. They were told that their LBP could benefit from a “newly developed chair”, but were given no further information about the technical characteristics of the chair. All test subjects were seated uninterrupted for 1 h on the experimental chair. In index group A the male/female ratio was 23/37 with a mean age of 41.4 years (SD 8.0 years) and a mean duration of LBP of 68.3 months (SD 71.6 months). In control group B the male/female ratio was 25/35 with a mean age of 40.5 years (SD 8.2 years) and a mean duration of LBP of 72.5 months (SD 74.7 months).

As it was also not clear to us whether the frequency of the seat rotation influenced the extent of pain response, two different frequencies were applied in index group A. Two subgroups were formed by order of enrollment in index group A: subgroup A-high, with a high frequency of 0.2 Hz ($n = 30$), and subgroup A-low, with a low frequency of 0.08 Hz ($n = 30$). Frequencies were related to the technical properties of the frequency adaptor. In subgroup A-high the male/female ratio was 12/18 with a mean age of 40.9 years (SD 8.0 years) and a mean duration of LBP of 70.4 months (SD 72.9 months). In subgroup A-low the male/female ratio was 11/19 with a mean age of 41.9 years (SD 7.6 years) and a duration of LBP of 63.2 months (SD 79.3 months).

Experimental chair

In the index group A, dynamic rotatory stimuli were produced by a “revolving seat” of a conventional office chair. The seat rotated horizontally and independently of the backrest and arm supports. A compact, small, worm-gear motor provided an alternating movement, which was set on an angle of 1.25° to either side. The centre of rotation was placed 10 cm from the back of the seat near to the axis of the spine. An adaptor was used for changing rotatory frequency. The height and inclination of the backrest were adapted to the individual needs of the subject. The same chair was used in all tests.

Pain

Subjects were initially tested, and classified into five types for their pain behaviour and burden of illness by the Multidimensional Pain Inventory – Dutch Language Version (MPI-DLV) [17, 19, 24], and the types were found to be equally distributed across all groups.

Although it is very difficult to measure pain, all subjects were asked to “score” their pain at the beginning of the test and then at intervals of 10 min. In this way, we obtained seven pain scores for each subject. Pain was recorded by an “open” visual analogue scale (VAS). The six successive time periods of 10 min seated were used as quantitative stimulus for the pain increment as applied to magnitude estimation procedures [25]. A quantitative analysis using the absolute length of the VAS scores was not applied, because it is unlikely that two subjects with the same pain in time will draw it the same on the VAS. The VAS score was considered as a position on an ordinal scale, which means that differences are only considered as “more” (pain) or “less” (pain), and do not refer to the absolute size of the VAS score. An arbitrary minimal difference of 0.5 cm in line-length between two successive VAS scores was considered as a real alteration in pain sensation. The subjects were able to compare their current VAS score with the previous scores so they did not draw their lines longer or shorter than they intended to by mistake.

A non-parametric analysis was made of the individual pain scores. We evaluated the number of VAS scores that had increased compared with the previous score. We distinguished six different pain increment scores, ranging from “no pain increment”, “one pain increment” up to “five or six pain increments”.

Secondly, in order to obtain a more quantitative approach, for every subject we divided each successive VAS score by the initial one (VAS-0), and defined it as the Relative Visual Analogue Scale (RVAS) score. The RVAS score indicates the multiplication factor that increased the initial pain score to the actual one, as a more or less objective “individual pain factor”.

Statistical analysis was performed using SPSS and the one-way Anova non-parametrical (Mann-Whitney) test.

Results

There are no statistical differences in age, sex or duration of LBP between the index group A and control group B or between subgroup A-low and subgroup A-high.

X-rays were performed to exclude abnormalities and also to score possible differences in the frequencies of disc degeneration in both groups. No statistical differences between the two groups or the two subgroups were found. Index group A and control group B are also comparable regarding pain behaviour and burden of illness expressed by the MPI-DLV classification.

Table 1 shows the distribution of the five MPI-DLV-pain behaviour types across the total population ($n = 120$), index group A, subgroups A-high and A-low and control group B. The five MPI-DLV types corresponded to:

1. Dysfunctional type
2. Interpersonally distressed type
3. Adaptive copier type
4. Average type
5. Anomalous type

Seven subjects are classified as MPI-DLV 5, because they could not fill in answers to questions about partner-related data.

Table 1 Distribution of the five types as classified by the Multidimensional Pain Inventory-Dutch Language Version (MPI-DLV)

		MPI-DLV pain behaviour types				
		1	2	3	4	5
Total Population	(n=120)	19	14	32	37	18
Index group A	(n= 60)	7	8	16	17	12
Subgroup A-high	(n= 30)	3	4	8	9	6
Subgroup A-low	(n= 30)	4	4	8	8	6
Control group B	(n= 60)	12	6	16	20	6
Median VAS-0 ^a		15.0 cm	7.5 cm	3.0 cm	6.0 cm	4.0 cm

^aMedian value of the initial pain level on the visual analogue scale

No differences exist between the MPI-DLV types with respect to sex, age and the duration of the LBP.

The median VAS-0 is high in the MPI-DLV type 1 “dysfunctional type”, at 15.0 cm, compared with the median VAS-0 values of the other types, which range from 3.0 cm to 7.5 cm. No relation is found between the VAS-0 and the characteristics of sex, age, duration of LBP and radiological diagnosis.

Although, strictly speaking, pain as a phenomenon cannot be considered as measurable, there are indications that the amount of pain experienced is similar among individuals. Evidence for this point of view can be found by correlating the initial VAS scores of the subjects with the expression of pain as measured by the two pain intensity questions of the MPI-DLV questionnaire. In 118 subjects, correlations of 0.21 ($P < 0.02$) and 0.39 ($P < 0.001$) respectively were found between initial VAS score and the questions of the MPI-DLV concerning actual pain and average pain experience during the preceding week.

Using a minimal difference of 0.5 cm between two successive VAS scores to define a real alteration in pain sensation resulted in 33.8% of the measurements showing no alteration and 66.2% showing an alteration, which indicates an acceptable sensitivity. Two subjects in control group B could not sustain the sitting procedure because of intolerable pain increase.

In the control group B, 47 of the remaining 58 subjects did have an increment of pain in the last VAS score compared to the initial one. There was “no progress” in 11 subjects, with 3 of these subjects showing “almost full relief”, comparing the first with the last VAS score. In index group A, 30 out of 60 subjects showed “no progress” (13 of these showed “almost full relief”).

The number of increased VAS scores is significantly lower ($P < 0.01$, Chi-square and Kruskal & Wallis) in the index group A. The average number of increases in VAS score per subject is 3.3 in the control group B, 2.3 in subgroup A-high and 1.5 in subgroup A-low, reflecting a possible frequency effect in the index group A.

Table 2 shows the distribution of the pain increment scores of all subjects. As already mentioned, subjects can show one of six patterns, ranging from a pattern with no pain increment (0+) to a pattern with five or more pain increments (5+/6+). A declining number of subjects with high scores is shown in the index group A, while the con-

Table 2 Distribution of the six different pain increment scores of all subjects

		Pain increment scores					
		0+	1+	2+	3+	4+	5/6+
Group A	(n = 60)	13	18	9	8	7	5
Group A-high	(n = 30)	5	9	3	4	5	4
Group A-low	(n = 30)	8	9	6	4	2	1
Control group B	(n = 60)	1	8	8	13	12	16

Fig. 1 The Relative Visual Analogue Scale (RVAS) scores of control group B ($n = 60$) and the subdivision into the five types of the Multidimensional Pain Inventory-Dutch Language Version (MPI-DLV)

trol group B shows an increasing number of subjects with high scores.

The number of subjects with no pain increment in their pattern is significantly ($P = 0.01$) higher in the subgroup A-low than in the control group B. A weak indication for the same phenomenon also exists ($0.15 < P < 0.20$) between subgroup A-high and the control group B.

Semi-quantitative analysis using the mean RVAS scores is shown in Fig. 1. There is a clear relation between the increase in the mean RVAS scores of the entire control group B, the MPI-DLV subtypes and the duration of sitting. Only type 5 shows a more pronounced increase in mean RVAS scores.

In the index group A the mean RVAS scores at the different measurement points are almost the same for MPI-DLV types 2–5. Only MPI-DLV type 1 shows a marked rise in the mean RVAS, at $t = 10$ min (Fig. 2). This suggests an MPI-DLV type effect on the mean RVAS scores in the index group A. Further analysis revealed that this effect was entirely due to the pain scores at $t = 10$ min of one single subject (number 003). This subject had an ini-

tial open VAS score at ($t = 0$ min) of 5 cm and at $t = 10$ min an open VAS score of 171 cm, resulting in a RVAS of 34.2. Such an extravagant pain increment was observed only once in the entire population. Analysis of the mean RVAS scores in the different MPI-DLV types without the data of subject 003, illustrated by the curve marked MPI-1 Corr (Fig. 2), shows the same slope as the curves of MPI-DLV types 2–5.

Figure 3 shows the mean RVAS scores of the index group A and the control group B in relation to the duration of sitting. The P -values of the difference for the mean RVAS scores between index group A and the control group B on the different measurement moments ($t = 10 - t = 60$) are added. Significant differences in mean RVAS score between index group A and control group B become clear after $t = 30$ min. From $t = 40$ min the mean RVAS increases slightly, but the difference with control group B remains significant till the end. Despite the dynamic stimulus in the first 10 min the mean RVAS at $t = 10$ min shows the same elevation as in the control group B, suggesting a lack of stimulus effect. This observation, again,

Fig. 2 RVAS scores of index group A (Corrected) and subdivision into MPI-DLV types

Fig. 3 RVAS scores of index group A, index group A Corrected and control group B, showing P -values for significance

Fig. 4 RVAS scores of index group A-high and A-low versus control group B. *P*-values for significance are shown

was solely due to the pain scores of abovementioned subject 003. It is illustrated by the curve marked "Index A Corr", in which subject 003 was excluded from analysis. This curve shows considerable significant differences between groups A and B in the mean RVAS scores at all measurement moments. *P*-values for significance are indicated in the Figure.

Figure 4 shows the mean RVAS scores of the subgroups A-high and A-low. *P*-values for differences with the control group B are also shown. No significant difference in mean RVAS scores exists between subgroup A-high and A-low. The first rise in the curve of subgroup A-high vanishes by excluding subject 003 from analysis (curve marked subgroup A-high Corr).

A probable frequency effect is illustrated by the observation that all *P*-values of subgroup A-low are smaller than those of subgroup A-high and A-high Corr.

Discussion

The clinical experience that "static load", such as during prolonged sitting, acts as a provocative factor for LPB [6] in patients with aspecific low back problems was confirmed by the findings of pain increment in our control group of patients who were sitting uninterrupted for 1 h. We know of no previous study regarding the relation between prolonged sitting and increment of pain in a population of aspecific LBP patients. Because of the multidimensional aspects of pain, such as sensoric, emotional and cognitive components, a pain questionnaire (MPI-DLV), classifying respondents into five types, was used to retrospectively ensure an equal distribution of burden of illness and pain behaviour in index group A and control group B.

We did not use a calibrated VAS score with fixed scale values, because it is unlikely that two subjects with the same pain in time will show an equal and a standardized VAS score increment. We preferred an "open" VAS score, as used in magnitude estimation procedures [25] because we were interested in time- and subject-dependent pain changes during six successive periods of 10 min of sitting, with or without a slightly moving seat. In our pain evaluation procedures, subjects could always check their previous open VAS score to estimate the alteration of pain due to the preceding 10 min of sitting, in order to help ensure the most accurate recording.

We obtained a more quantitative approach by dividing for each subject the successive VAS scores by the initial one (VAS-0), resulting in the so-called relative visual analogue scale (RVAS).

Strictly speaking, pain cannot be considered as a measurable quantity. Nevertheless, we found significant correlations between the initial VAS-0 scores and the two different pain intensity scores of the MPI-DLV questionnaire. This supported the application of a semiquantitative analysis of pain by means of the RVAS score. The use of an RVAS score is restricted to pain evaluation procedures on an individual level and indicates the multiplication factor that increased the initial pain score to the actual one.

The qualitative non-parametric analysis of pain increment scores as well as the semi-quantitative analysis of the RVAS scores in the control group B confirmed the provocative effect of prolonged sitting on pain. In the control group, 47 out of 58 subjects had a final individual RVAS score of more than 1, which means a pain increase. Two subjects even had to give up because of intolerable pain increase.

The effect of dynamic stimuli during prolonged sitting in index group A was significant. No progress in pain levels was noted in 30 out of 60 subjects in the index group A versus 11 out of 60 subjects in control group B.

On ethical and practical grounds we limited the sitting period to 1 h; therefore, it is unknown whether the slight increment of pain at the end of this test procedure would

continue. A possible relation between frequency of the seat rotation (high/low) and pain remission was noted. The low frequency application seems the more favourable.

Our test conditions and stimuli are in a way comparable with the experiments of Reinecke and Hazard, who also emphasize and recommend continuous passive motion as beneficial in sitting, and who introduced the "BackCycler" as a dynamic stimulus during sitting. In a study of patients with chronic, stable LBP who routinely drive motor vehicles for more than 2 h per day, the continuous passive motion (CPM) device clearly reduced LBP, stiffness and fatigue [23]. It provides continuous lumbar spinal movement through greater and lesser degrees of lordosis, by inflating and deflating a lumbar support bladder in cycles of 2 min [12, 23]. We could not find any reports of other investigations into pain in relation to prolonged sitting.

Williams et al. investigated effects of sitting posture on subjects with LBP, and found a centralization and reduction of the pain when sitting with a lordotic posture [26]. Other investigations were only performed on small groups of healthy subjects with ratings of spinal shrinkage, lumbar curvature and comfort, but no pain measurements [7, 13, 18, 20]. We are not able to explain how the small alternating seat rotations in our study resulted in a beneficial effect on low back pain. We may refer to authors who suggest that lack of spinal motion causes insufficient nutrition of the disc [10–12, 14, 23]. On the other hand the

angle of only 1.25° axial rotation seems too small for significant motion in all lumbar spinal segments. The more pronounced effect of low frequency dynamic stimuli in our study could correspond with calculations that showed little fluid flow to the centre of the disc when disc load fluctuates rapidly [2].

The present experiment shows pain reduction, but does not help to explain why the rotatory stimuli reduce pain, and it does not support the disc nutrition hypothesis any more than many other possible explanations. For example, the rotatory movements may stimulate the back muscles and improve blood flow within them, or relax them.

From the observed pain reduction in LBP patients, we conclude that application of small, low-frequency seat rotation in the horizontal plane is promising. The slight movement can hardly be felt and will not disturb labour. While we also support the idea of Reinecke et al. of using continuous passive motion during sitting [23], we are suggesting another kind of stimulation. In this study only subjects with pre-existing LBP were involved. It would be interesting to investigate whether application of rotatory stimuli can prevent LBP in populations at risk from mainly sedentary working conditions. This needs further investigation.

Acknowledgements The authors thank Chris J. Snijders for his valuable advice.

References

- Adams MA, Hutton WC (1981) The relevance of torsion to the mechanical derangement of the lumbar spine. *Spine* 6: 241–248
- Adams MA, Hutton WC (1983) The effect of posture on the fluid content of lumbar intervertebral discs. *Spine* 8: 665–671
- Andersson BJG, Ortengren R, Nachemson AL, Elfstrom G (1974) Studies on car drivers seat. *Scand J Rehabil Med* 6: 128–133
- Andersson BJG (1981) Epidemiologic aspects on LBP in industry. *Spine* 6: 53–69
- Bogduk N (1992) Die Schmerzpathologie der Lumbalen Bandscheibe. *Manuelle Med* 30: 8–16
- Deursen LLJM van, Patijn J (1993) Aufwertung der "ligamentaren Kreuzschmerzen". *Manuelle Med* 31: 108–110
- Frey JK, Teklin JS (1986) Comparison of lumbar curves when sitting on the Westnofa Balans Multi Chair, sitting on a conventional chair and standing. *Phys Ther* 66: 1365–1369
- Frymoyer JW, Pope MH, Constanza MC, et al (1980) Epidemiological studies of low back pain. *Spine* 5: 419–423
- Gregersen G, Lucas DB (1967) An in vivo study of axial rotation of the human thoraco-lumbar spine. *J Bone Joint Surg [Am]* 49: 247
- Grieve GP (1981) Common vertebral joint problems. Churchill-Livingstone, Edinburgh
- Hansen HJ (1959) Comparative views on the pathology of disc degeneration in animals. *Lab Invest* 8: 1242
- Hazard RG, McKenzie RA, Mooney V (1994) Helping your back pain patients make the most of spinal motion. *J Musculoskeletal Med* 1: 24–35
- Helander MG, Quance LA (1990) Effects of work-rest schedules on spinal shrinkage in a sedentary worker. *Appl Ergonom* 21: 279–284
- Jensen CV, Bendix T (1992) Spontaneous movements with various seated-workplace adjustments. *Clin Biomech* 7: 87–90
- Kelsey JL, White AA (1980) Epidemiology and impact of low back pain. *Spine* 5: 133–142
- Kelsey JL (1975) An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. *Int J Epidemiol* 4: 197–204
- Kerns RD, Turk DC, Rudy TE (1985) The West Haven Yale Multidimensional Pain Inventory (WHYMPI). *Pain* 20: 345–356
- Lander C, Korbon GA, DeGood DE, Rowlingson JC (1987) The balance chair and its semi-kneeling position. An ergonomic comparison with conventional sitting position. *Spine* 12: 269–272
- Lousberg R (1994) Chronic pain: multi-axial diagnostics and behavioral mechanisms. Thesis, University Press, Maastricht
- Mandal AC (1980) The seated man, "Homo sedens". The seated workposition, theory and practice. *Appl Ergonom* 12: 1: 19–26

-
21. Nachemson AL, Schultz AB, Berkson MH (1979) Mechanical properties of human lumbar spine motion segments. Influence of age, sex, disc level and degeneration. *Spine* 4: 1–8
 22. Percy JM, Tibrewal SB (1984) Axial rotation and lateral bending in the normal lumbar spine measured by three dimensional radiography. *Spine* 9: 582–587
 23. Reinecke SM, Hazard RG, Coleman K (1994) Continuous passive motion in seating: a new strategy against low-back pain. *J Spinal Disord* 7: 1–6
 24. Rudy TE (1989) Multiaxial assessment of pain: multidimensional pain inventory. Computer Program Users Manual, version 2.0. University of Pittsburgh, Pittsburgh
 25. Stevens SS (1975) *Psychophysics: introduction to its perceptual, neural and social prospects*. John Wiley, New York
 26. Williams MM, et al (1991) A comparison of the effects of two sitting postures on back and referred pain. *Spine* 16: 1185–1191