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Effects of mattress support on sleeping position and low-back pain

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Abstract

Purpose: To determine the efficacy of decreasing spinal curvature – when sleeping laterally – in reducing low-back pain (LBP) and improving sleep quality in people with chronic LBP. Secondly, to investigate whether sleeping positions, nocturnal movements, and skin temperature are related to pain in people with chronic LBP.

Methods: Sixteen subjects with chronic LBP (50% female, mean age 45.6 ± 13.1 years) slept for one night on their own mattress, followed by three nights on an experimental mattress – designed to reduce spinal curvature in lateral sleeping positions – and then a final night again on their own mattress. Sleep positions, nocturnal movements, skin temperature, and room temperature were measured throughout the five nights. Numerical pain ratings for pain while lying, pain on rising, stiffness on rising, sleep quality, and mattress comfort were recorded for both mattresses.

Results: The experimental mattress was associated with 18% (*p*<.05) lower pain scores while lying and a 25% (*p*<.01) higher comfort rating. Pain on rising, stiffness on rising, and sleep quality were not different between own and experimental mattress. The relationship between sleep positions and pain scores was non-significant, but pain when rising was positively correlated with nocturnal movement (*p*<.05) and skin temperature was negatively correlated with pain while lying (*p*<0.05).

Conclusion: Pain while lying in bed decreased and comfort was higher for the experimental mattress compared to the participants' own mattresses.

Keywords: Low-back pain, Mattress, Sleep quality, Spine

Introduction

The lifetime prevalence of non-specific low-back pain (LBP) is between 60% and 70% of the population in industrialised countries (Kaplan et al. 2013). This is likely to increase in the coming years as the population gets older. While most cases of LBP go undiagnosed, the UKs National Health Service identifies muscle strains, sprains, ruptured discs, and sciatica as some of the main sources of LBP (National Health Service 2020). LBP is the number one cause of days with disability worldwide and comes with a significant economic burden (James et al. 2018; Dieleman et al. 2020). For instance, in 2007, the total direct and indirect costs of LBP in the Netherlands accounted for 0.6% of the country's gross national product (Lambeek et al. 2011). Direct costs can come from hospitalisation, medical equipment, and medications. Indirect costs can come from reduced productivity or lost days at work.

LBP can have a detrimental effect on a person's psychophysiological wellbeing; with increased risks of depression, disability, and sleep disturbances (Yilmaz and Kaya 2009; Kelly et al. 2011). Patients with chronic LBP experience higher rates of sleep disturbance than their healthy counterparts and improving sleep quality has been suggested to be important for quality of life in LBP patients (Kelly et al. 2011). Physiological and biomechanical

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markers during sleep are indicative of sleep quality. These include skin temperature, nocturnal movements, and sleep positions. Thermoregulation is critical to sleep as a drop in core body temperature triggers sleep onset and a rise in temperature promotes wakefulness (Murphy and Campbell 1997). The rate of body movements during sleep is related to different sleep stages (Wilde-Frenz and Schulz 1983) and increased body movements (position changes) are a characteristic of poor sleep quality (Kaartinen et al. 2003). The primary sleeping positions are supine, prone, and lateral; with the latter being the most adopted position (Skarpsno et al. 2017). The freedom to bend the knees and hips in lateral positions allows a neutral spine posture – which is when the joints of the vertebrae are in their neutral zone (McGill 2007) – to be easy to achieve and maintain (Haex 2004). Lateral positions are also associated with superior sleep quality and thermoregulation (Gordon et al. 2007; Miyazawa 1976).

Several studies have found that sleeping on a medium to firm mattress can help alleviate back pain and improve sleep quality (Kovacs et al. 2003; Jacobson et al. 2008). Sleeping surfaces that promote a neutral spine can reduce LBP possibly by decreasing tensile stresses in spinal structures (Haex 2004). One example is a zonal mattress – a mattress with stiffness varying along its length to optimally support different parts of the body – which is designed to promote a neutral posture. However, evidence in the literature to corroborate this is scarce. This study investigated the efficacy of decreasing spinal curvature – using a zonal mattress – in reducing LBP and improving sleep quality. The second aim was to investigate whether sleeping positions, nocturnal movements, and skin temperature are related to pain.

Materials and methods

Subjects

Table 1 shows demographics of the sixteen participants along with reported frequency of night-time LBP in nights per week. Participation was voluntary, and a questionnaire was used to determine the eligibility of all potential participants. The questionnaire also collected relevant information regarding participant characteristics, LBP history, sleeping disorders, and sleeping habits. Only adults aged between 18 and 70 years with a history of chronic (≥3 months) LBP were included in the study. The exclusion criteria were systemic disease, inflammatory disease, cancer, scoliosis, fibromyalgia or habitual prostration. Participants who either had a previous spinal injury, used anti-inflammatory medication, used medication that affects sleep, routinely slept in more than one bed, or were pregnant were also excluded. Eighteen participants were initially recruited, of whom, one participant subsequently withdrew and one was excluded due to a procedural error.

Procedure

The study was conducted over five nights. Sleep positions, nocturnal movements, skin temperature, and room temperature were recorded during all five nights. All participants slept on their own mattress for the first night and completed a pain assessment the following morning. For the next three nights, participants slept on a provided experimental mattress before completing another pain assessment (i.e. after night four of the study). This was a zonal support mattress which was tailored to the participant's body measurements – with the aim to reduce spinal curvature. On night five, participants slept again on their personal mattress and completed a final pain assessment the following morning. The study employed a withdrawal design (A-B-A) as it provides a high level of experimental control and can reduce order effects (Byiers et al. 2012). A control group was not feasible for the study because of the logistical difficulties. Instead, the study used a single group design where subjects acted as their own controls. A control mattress was avoided because research indicates that introducing a control mattress for this type of study would serve as an additional experimental intervention and not a standard of measurement (Jacobson et al. 2002). The study design followed a methodology similar to previous studies where comparisons were made between the experimental mattress and the subjects' personal beds (Jacobson et al. 2002).

Table 1 Subject demographics

Variable	Males (*n=8*) Mean ± SD (range)	Females (*n=8*) Mean ± SD (range)	Total (*N=16*) Mean ± SD (range)
Age (yrs)	42.4 ± 8.6 (33-55)	48.9 ± 16.4 (22-65)	45.6 ± 13.1 (22-65)
Weight (kg)	97.5 ± 17.0 (75-130)	75.4 ± 12.3 (66-95)	86.5 ± 18.3 (66-130)
Height (m)	1.87 ± 0.04 (1.80-1.95)	1.69 ± 0.05 (1.59-1.76)	1.78 ± 0.10 (1.59-1.95)
Body Mass Index (kg/m^2)	27.9 ± 4.2 (23.2-36.8)	26.6 ± 4.8 (21.3-34.5)	27.3 ± 4.4 (21.3-36.8)
LBP frequency (nights/week)	5.4 ± 2.1 (1-7)	4.9 ± 2.3 (2-7)	5.1 ± 2.2 (1-7)

Experimental mattress

A zonal support mattress (Blocks BM500, Sleeptrade B.V., Hoevelaken, The Netherlands) containing customisable blocks was used as the experimental mattress. The mattress thickness is 25cm with a 7cm cover layer composed of perforated natural latex and an upper sheet filled with virgin wool. The blocks contain conical pocket springs made from thermally hardened steel. The blocks are interchangeable and come in five different firmness levels: extra soft, soft, medium, firm, and extra firm. They are configured to promote a straight spinal alignment in the frontal plane. Softer blocks allow for contouring around heavier regions of the body (e.g. the hips and shoulders). Firmer blocks provide support for the lumbar region and the head (Fig. 1). To configure the experimental mattress, subjects first laid laterally on their personal mattress and a spinal deviation angle – which represents frontal plane spinal curvature – was recorded with a smartphone camera. This was then repeated on the experimental mattress. The purpose was to identify differences and to then rearrange the blocks (in the experimental mattress) to reduce the angle. This process was done through trial and error – for each participant – until the maximum spinal angle reduction was considered to have been reached. A qualified physiotherapist was present for the measurements to ensure the participant didn't have any existing spinal deformities.

Subjects used a latex neck support pillow (Sleeptrade B.V., Hoevelaken, The Netherlands) for all five nights. The pillow came in 3 sizes: 7cm, 9cm, and 11cm. Pillow selection was also based on optimising spinal neutrality and therefore was done in conjunction with the configuration of the experimental mattress. Linen and sleeping attire were not controlled.

Sleep positions

Participants were encouraged to sleep in their natural position and were advised against using additional support (e.g. sleeping with a pillow between the knees). Data on sleep positions were collected over the five nights using a sleep sensor (SlaapID sensor, Sleeptrade B.V., Hoevelaken, The Netherlands). The sensor is placed into a neoprene strap and worn around the chest for the duration of use. Using a three-dimensional accelerometer, the sensor can ascertain the subject's sleeping position. It measures orientation of the upper body (to a precision of 1.2°), from which a position determination system can distinguish the subject's body orientation. The sensor detects when the wearer is lying in one of four positions: lateral (left and right), supine, and prone. The sensor also registers the number of position changes (i.e. nocturnal movements) throughout the night. The sensor can detect body positions to an accuracy of 96.3% (Star et al. 2012). Chest strap sensors are reportedly comfortable, easy to use and preferred over other measurement tools (Berry et al. 2019).

Self-assessment forms

The Numerical Pain Rating Scale (a validated self-assessment tool) was used to determine pain scores. It contains a 100mm line with polar extreme labels and provides an accurate measure of subjective pain. It was selected as the pain scoring system because it was deemed the most responsive method when compared to other commonly used measures (Ferreira-Valente et al. 2011). Participants were asked to rate five dependent variables: pain while lying in bed, pain on rising, stiffness on rising, sleep quality, and mattress comfort. These items were scored on scales from zero (best for the first three items and worst for the last two items) to ten (worst for the first three items and best for the last two items). For instance, the scale for pain when rising went from 'no pain' (zero) to 'worst possible pain' (ten) while mattress comfort went from 'no comfort' (zero) to 'best possible comfort' (ten).

Temperature data

Skin temperature was measured during all five nights using iButtons. These are wireless semiconductor temperature sensors that gather data on time and temperature (range of -40°C to 85°C & accuracy of ±0.5°C). Two

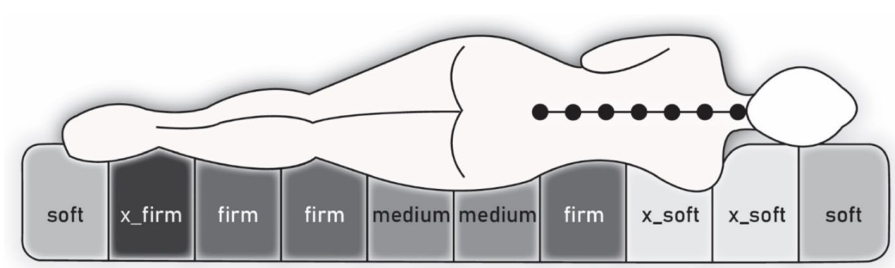

Fig. 1 Example of block configuration under the zonal support mattress

iButtons (Maxim DS1922L, San Jose, CA, USA) were used to record temperature data and were placed at the right infraclavicular area of the chest and on the medial metatarsal area at the plantar site of the non-dominant foot. The sampling interval was set at 10-minutes with a resolution of 0.0625°C. Data from the two sensors were averaged. Highly improbable readings: <28.2°C and >37.2°C (Aidlab.Measuring Skin Temperature 2020) were removed from the dataset.

A data logger (Voltcraft DL-210TH, Hirschau, Germany) was used to record room temperature (±1°C). The sampling interval was set at 10-minutes (range between -30°C and 60°C). The data logger recorded continuously throughout the 5 nights and was placed close to the subject's bed (e.g. on a bedside table).

Statistical analysis

Statistical analysis was carried out using SPSS (version 27.0) for Windows. A Friedman's ANOVA was used to compare Numerical Pain Rating Scale (NPRS) scores between the two mattresses and a Wilcoxon signed ranks test was used for post-hoc analyses. Sleep positions were recorded as a percentage of total time asleep, then averaged between the two mattresses and analysed using a paired sample t-test. Nocturnal movements were recorded as turns per hour, then averaged between the two mattresses and also compared using a paired sample t-test.

Each subject's NPRS scores were averaged between the three nights (i.e. nights one, four, five) and were used for all subsequent correlation analysis. Correlations between sleep positions and NPRS scores were analysed using a Pearson's correlation coefficient. Correlations between nocturnal movements and NPRS scores were tested using a Spearman's correlation coefficient. Only temperature data recorded between 23:00 and 08:00 were used for the analysis. The Pearson's correlation coefficient was used to examine correlations between skin temperature, room temperature, nocturnal movements, and sleep positions. Correlations between skin temperature and NPRS scores were analysed using a Spearman's correlation coefficient. Any technical or procedural errors (i.e. subject slept for less than six hours) were removed from the dataset. Significance level for all analyses was set at $p \leq .05$.

Results

Spinal angles

The spinal angles varied among participants as many factors contributed (e.g. body and mattress characteristics). Mattress configuration was done ad hoc with 81% (n=13) of subjects using firm support for the lower back and 19% (n=3) using extra firm support. Extra soft support at the shoulder region was used by 59% (n=10) of the subjects while 38% (n=6) received soft support. For the hip and pelvis region, subjects received a blend of firm and medium – depending on body composition. The lower half of the body received a combination of the remaining blocks, as this region has an insignificant impact on spine curvature. The average angle on the participants' own mattresses was 13.76°±5.79 and on the experimental mattress it was 9.99±6.83°. This difference of 3.78±4.55° was statistically significant (p<.01), implying that spinal curvature was more neutral on the experimental mattress.

Pain ratings

Pain scores while lying were significantly lower (18% difference) on the experimental mattress, and the comfort score was significantly higher (25% difference) for the experimental mattress (Table 2). However, pain on rising, stiffness on rising, and sleep quality were not different between mattresses. Post hoc analysis showed that the significant differences in pain while lying and in mattress comfort were found between the first and fourth night. Mattress comfort was also significantly different between the fourth and fifth night.

Pain scores and stiffness on rising scores were strongly correlated ($r(14)=0.912$, $p<.01$) for all nights. Relationships between sleep quality and the pain and stiffness variables were not significant, nor were the relationships between mattress comfort and the pain and stiffness variables.

Table 2 NPRS scores for each variable. Experimental mattress means are from night four and personal mattress means are an average of nights one and five

Variable (N=16)	Mean ± SD	X^2	df	p
Pain while lying in bed				
Personal mattress	4.59 ± 2.05	7.71	2	<0.05[a]
Experimental mattress	3.78 ± 2.24			
Pain on rising				
Personal mattress	4.61 ± 2.03	4.54	2	0.103
Experimental mattress	4.03 ± 2.19			
Stiffness on rising				
Personal mattress	5.17 ± 1.94	5.92	2	0.052
Experimental mattress	4.25 ± 2.12			
Sleep quality				
Personal mattress	5.56 ± 1.50	5.15	2	0.076
Experimental mattress	6.13 ± 1.20			
Mattress comfort				
Personal mattress	5.53 ± 1.39	16.63	2	<0.01[a]
Experimental mattress	7.38 ± 1.04			

[a] *Significant with Bonferroni adjustment*

Differences in mattress configuration between subjects did not affect the subjective scores. For example, when comparing participants with soft shoulder support to participants with extra soft shoulder support, there was no significant difference in pain while lying, pain on rising, stiffness on rising, sleep quality, and mattress comfort between the two groups.

Sleep positions and movements

Subjects spent 34.4% of time in the right position, 33.2% in the left position and 25.9% in the supine position. Only 4.1% of time was spent in the prone position (Fig. 2). The mean percentage of time in each sleep position was not significantly different between mattresses. The percentage of time spent in each position was not related to pain scores for any of the sleep positions.

Frequency of turns between sleeping positions was 2.2 per hour. Mean sleep time was 7 hours and 54 minutes. Hence, an average of 17 turns per night was observed. The number of turns was not significantly different between mattresses. The correlation between pain when rising and turns per hour (for both mattresses) was significant ($r(14)=.544, p<0.05$) (Fig. 3).

Temperature data

The average skin temperature for all nights was 34.2±1.0°C and room temperature was 22.63±2.08°C. Pain while lying and skin temperature were negatively correlated on both mattresses ($r(14)=-.601, p<0.05$) (Fig. 4). The relation between skin temperature and time spent in the sleep positions was not significant.

Discussion

The first aim of the study was to investigate the efficacy of an experimental mattress – designed to reduce spinal curvature in lateral sleeping positions – in reducing LBP and improving sleep quality. The study shows reduced pain while lying and better comfort with the experimental mattress. The other three variables approached significance, but more than 16 subjects may have been required here to gain sufficient statistical power. Overall, results indicate that a sleeping surface which promotes spinal neutrality may have favourable effects on pain and comfort.

The strong relationship between rising pain and stiffness scores may show an inability to differentiate between the two. Stiffness can be described as the sensation of the muscles feeling tight and heavy (Clinic et al. 2020) whereas lumbar pain is commonly expressed as a dull ache (Web 2020). So, despite differing definitions, they are correlated and possibly indistinguishable; especially if experiencing them simultaneously.

The second aim was to investigate how sleeping positions, nocturnal movements, and skin temperature were related to pain. Nocturnal movements showed no differences between the two mattresses. Haex (Haex 2004) discussed nocturnal movements from an energy perspective: softer mattresses surround the user more, making it harder to move when sleeping.

Increased pain when rising was related to increased turns per hour (Fig. 3). A position change may help mitigate pain and/or pain may lead to restlessness and more movements. In line with this finding, Kaartinen (Kaartinen et al. 2003) showed an inverse relationship

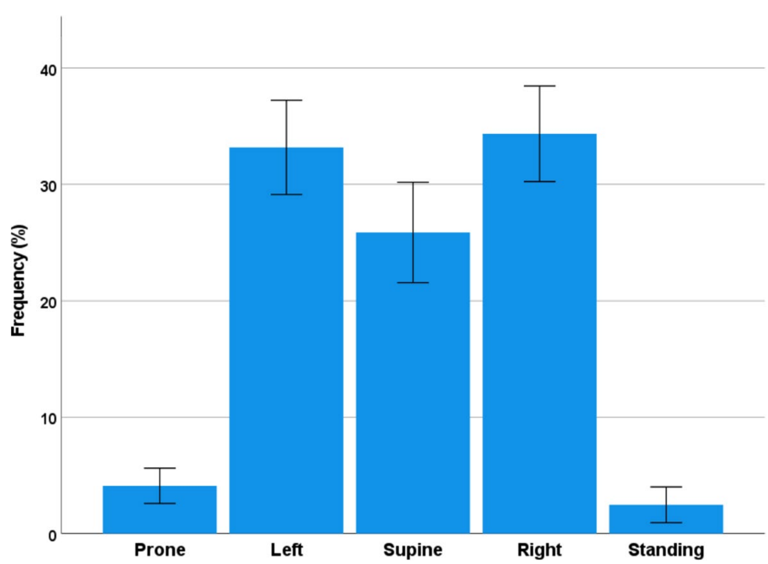

Fig. 2 Percentage of time spent (in %) related to body positions

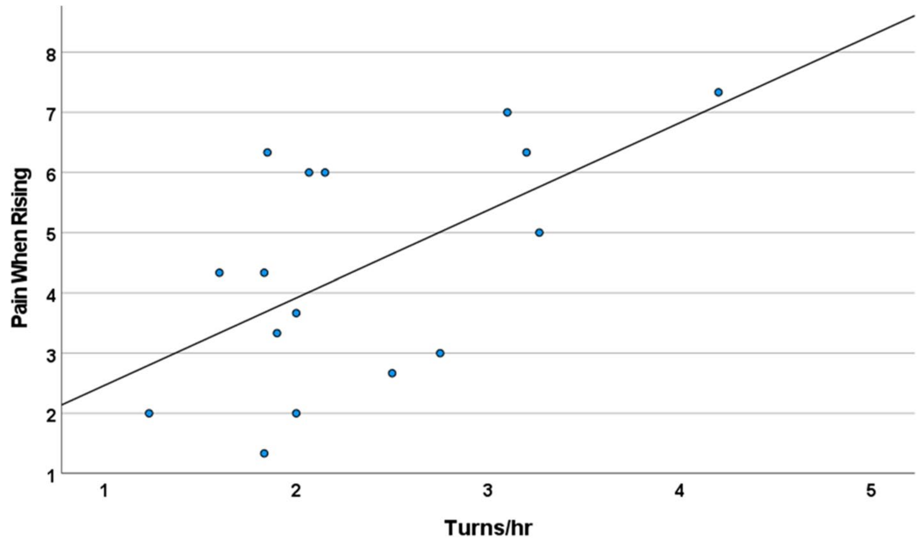

Fig. 3 Relation between number of turns per hour and pain when rising

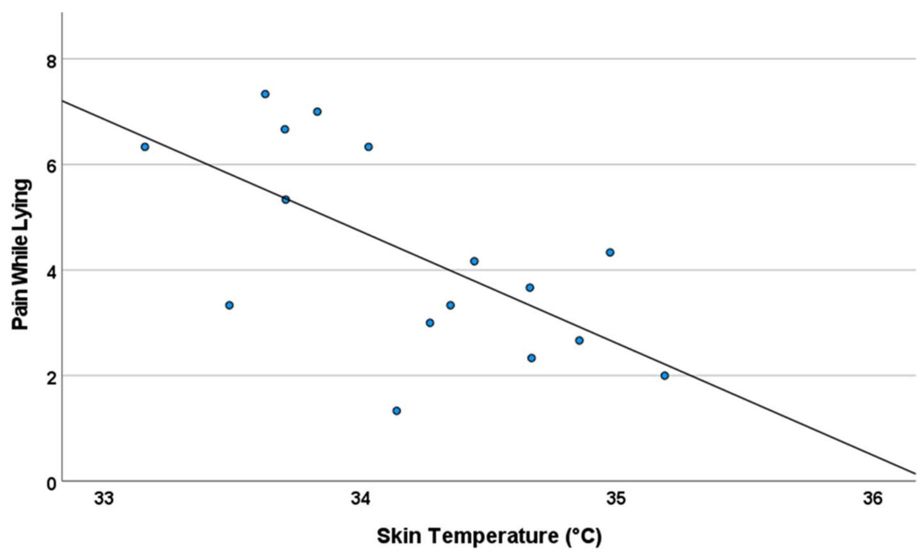

Fig. 4 Relation between skin temperature (°C) and pain while lying

between sleep quality and the number of nocturnal movements per hour. This strengthens the notion that a high rate of nocturnal turns per hour is a detrimental component of sleep. On the other hand, there are indications that movements during sleep are required to prevent bedsores (Liu et al. 2014). In summary, it is likely that nightly movements during sleep show a U-shaped relation with health complaints.

The recommended room temperature for sleeping ranges from 19-21°C (Harding et al. 2019). Average room temperature in this study was 22.63±2.08°C. This higher value was possibly because data were collected in the summer. There was no relation between skin temperature and room temperature in this small ambient temperature range. Several sleeping components would explain why these two variables did not relate. For instance, duvets and sleeping attire create a microclimate which likely differed between subjects. Humidity was also not controlled. Since data were collected throughout June and July, the humidity level varied both between and within subject readings.

An inverse relationship between skin temperature and pain while lying was observed for both mattresses (Fig. 4). Increased skin temperature is related to higher perfusion rates in the underlying tissue (González-Alonso 2012). This improved circulation may be having a pain reducing effect since muscle metabolites are more easily removed (Gerdle et al. 2014) .

Participants predominantly slept in lateral positions, regardless of the mattress. Literature indicates that lateral positions are both common and conducive to back health (Skarpsno et al. 2017; Haex 2004). So, these results would suggest that adverse sleeping positions were not a contributor to back complaints in this population.

It is recommended that future research should focus on the importance of spinal alignment – on reducing LBP – when comparing zonal support mattresses to new conventional mattresses. Both mattresses would supposedly provide superior support (compared to a used mattress), but it would also better distinguish any discrepancies between targeted zonal support and conventional mattress support. This study should be augmented to include other zonal support mattresses such as adjustable airbeds.

Limitations

Ideally participants would have had to be blinded to sleep in either a neutral mattress or the zonal support mattress. However, this was not achievable in this field trial. Obviously, there was considerable variation in the firmness and thickness between the own mattresses of the patients. This is undesired from a standpoint of repeatability but is the most valid situation in a field trial.

Literature indicates that sleep adaptations to a new mattress take time. It has been reported that adaptation to mattress firmness may take about five nights (Bader and Engdal 2000). The measurement period of three days in our study is short, and it is recommended in future studies to extend the period for adaptation to at least five days.

Conclusion

In subjects with LBP, an experimental mattress – which promoted spinal neutrality in lateral sleeping positions – resulted in less pain during lying and a better comfort rating while pain on rising, stiffness on rising, and sleep quality approached significance. Evidence of sleep positions relating to pain scores was inconclusive, thus further research is needed to examine potential underlying mechanisms. Evidence of turns per hour relating to pain when rising was detected. This suggests that increased nocturnal movements are associated with LBP.

Abbreviations

ANOVA: Analysis of variance; LBP: Low-back pain; NPRS: Numerical Pain Rating Scale; SPSS: Statistical package for the social sciences.

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Authors' contributions

RB and HH performed the measurements. RB drafted the text of the manuscript and HH, JD and HD contributed to the final manuscript. The author(s) read and approved the final manuscript.

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Availability of data and material

The data and materials are available upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the local ethics commission of the Faculty of Behavioural and Movements Sciences under number VCWS-S-20-00040.

Consent to publication

Not applicable.

Competing interests

There are no financial and non-financial competing interests.

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