The influence of different unloading positions upon stature recovery and paraspinal muscle activity

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Abstract

Objective. To determine whether stature recovery and paraspinal muscle activity can be altered in individuals with and without chronic low-back pain by assuming different unloading positions.

Design. A case-control study considering the effects of unloading position on stature recovery in individuals with and without chronic low-back pain.

Background. Stature recovery has been documented to be lower in individuals with chronic low-back pain. Elevated paraspinal muscle activity subjects the spine to increased compression, which may delay stature recovery. However, the mechanism(s) causing prolonged stature recovery are yet to be explored.

Methods. Eleven chronic low-back pain participants (age 33 yr (SD 12.2), height 1.72 m (SD 0.08), body mass 75.9 kg (SD 10.7)) and eleven asymptomatic participants (age 30.5 yr (SD 9.7), height 1.75 m (SD 0.10), body mass 73.3 kg (SD 11.7)) performed a loaded walking task (10% body mass) and adopted four unloading positions on separate occasions. Measurements of stature and muscle activity were recorded during each position.

Findings. Individuals with chronic low-back pain exhibited higher paraspinal EMG and delayed stature recovery in all positions (P < 0.05). Both groups experienced greatest stature recovery and least muscle activity during gravity inversion (P < 0.05).

Interpretation. Elevated muscle activity was found in the chronic low-back pain group supporting the existence of this explanation for delayed stature recovery. The gravity inverted position resulted in the lowest EMG and the greatest stature recovery. Further research is required to determine whether improving stature recovery has clinical implications by reducing pain/disability.

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1. Introduction

Numerous investigations have measured stature change to determine spinal loading in a range of positions, such as, sitting, prone lying and standing (van Diessen and Toussaint, 1993). Such investigations have generally been performed on healthy individuals and the findings generalized to clinical populations (Beynon and Reilly, 2001; Magnusson and Hansson, 1994). Conversely, Michel and Helander (1994) investigated the influence of chair type in individuals both with and without a back disorder. The back disorder group exhibited greater reductions in stature when a seated task was performed (once using a conventional chair and once using a sit-stand chair), and thus was believed to experience greater levels of spinal loading compared to the healthy group. This finding supports the use of individuals with back problems within such investigations, and demon-
strated that results obtained from healthy individuals should not always be generalized to clinical populations.

Previous research has demonstrated how individuals with chronic low-back pain (LBP) experience increased paraspinal muscle activity compared to asymptomatic participants (Ambroz et al., 2000; Shirado et al., 1995). van Dieen et al. (2003) proposed that increased activation reflects a trunk muscle recruitment strategy the serves to increase spinal stability. This proposal is in line with Panjabi (2003) who stated that paraspinal muscle activity is necessary to compensate for this reduced stability. However, such increases in paraspinal muscle activity have also been demonstrated to increase spinal compression by up to 26% (Marras et al., 2001). Rodacki et al. (2003) proposed that the persistent contraction of the erector spinae muscles may produce greater compression loading, which may, in turn, limit the ability to regain stature. They demonstrated that stature recovery was significantly less post-exercise in individuals with LBP (57.49% (SD 25.1)) compared to asymptomatic participants (111.24% (SD 13.6)), and as a consequence, individuals with LBP are exposed to the detrimental effects of spinal compression for longer. For example, spinal compression results in reductions in disc height, which lead to the transfer of load to other spinal structures, whereby a reduction of 1 mm in disc height increases the compressive load on the apophyseal joints from 4–16% (Adams et al., 2002). Reductions in disc height also lead to radial disc bulging, which reduces the space available for the spinal nerve roots (Adams et al., 2002). Improving stature recovery through assuming different unloading positions may reduce the time that the spinal structures endure such compressive loads and its associated effects, which may diminish the possibility of damage to the spinal column and the likelihood of pain.

The aim of this investigation was to determine if the paraspinal muscle activity of individuals with and without chronic LBP can be altered by assuming different unloading positions and whether this has any impact upon stature recovery. Hence, the two hypotheses tested within this investigation were (a) stature recovery is consistently lower in individuals with chronic LBP than in asymptomatic participants, independent of the unloading position assumed, and (b) the unloading positions that result in the lowest paraspinal muscle activity generate the greatest stature recovery.

2. Methods

Eleven participants with chronic LBP (age 33 yr (SD 12.2), height 1.72 m (SD 0.08), body mass 75.9 kg (SD 10.7)) and eleven matched, asymptomatic participants (age 30.5 yr (SD 9.7), height 1.75 m (SD 0.10), body mass 73.3 kg (SD 11.7)) took part in the investigation. The chronic LBP group had suffered from chronic LBP for more than 6 months (mean pain duration, 6.8 [SD 5.2 yr]), and any chronic LBP volunteer showing evidence of a non-mechanical progressive spinal disease, or an organic pathology requiring surgical intervention was excluded from the investigation. Individuals were excluded from the asymptomatic group if they had experienced back pain within the preceding year, had ever endured back pain for longer than one week, if they had ever lost a working day due to back pain, or had ever consulted a General Practitioner for back pain. Approval was granted by the ethics committees of the Department of Exercise and Sports Science, MMU Cheshire and South Cheshire Hospital Trust. After having the protocol explained and any questions answered, all participants gave written, informed consent to participate in the investigation.

Changes in stature were measured using a standing stadiometer previously described by Rodacki et al. (2003). Five anatomical points were identified and then supported by the frame to maintain the natural contours of the head and spine: (1) the most posterior distension of the head; (2) the deepest point of cervical lordosis; (3) the most prominent point of the thoracic kyphosis; (4) the deepest point of lumbar lordosis; (5) the apex of the buttocks (see Fig. 1). Each of these postural controls included an adjustable support, which enabled precise control of the head alignment and depth of each spinal contour. This ensured that the participants adopted the same posture whilst standing within the stadiometer.

Fig. 1. Lateral view of the stadiometer.
during repeated measurement sets (Beynon and Reilly, 2001).

A high-resolution linear variable displacement transducer (LVDT) (Solartron DC 50, model RS646-511) was used to detect any changes in stature by measuring vertical displacement with an accuracy of approximately 0.01 mm. The LVDT was fixed to the top of the stadiometer and positioned to lie directly above the apex of each participant’s head.

Raw EMG signals were recorded for 5 s at a sampling frequency of 1000 Hz, using a MT8 Radio Telemetry EMG system (MIE Medical Research Ltd., Leeds, UK). The electrical activity within the left and right lumbar erector spinae musculature was detected via four sets of bi-polar Ag/AgCl disc electrodes 1 cm in diameter, filled with conductive gel (Spectra 360 Parker Laboratories., Fairfield, NJ, USA) (see Fig. 2). The lumbar erector spinae was selected as it plays a critical role in the dynamic stability of the lumbar spine (Macintosh and Bogduk, 1991). Importantly, the erector spinae muscle, in particular, has been demonstrated to be associated with the incidence of LBP (Plowman, 1992). Each electrode pair was attached to a pre-amplifier (gain × 4000, input impedance >10 MΩ, common mode rejection ratio >110 dB, input referred noise <4 μV), which were connected to a main amplifier that had a band-pass filter between 12 Hz and 1000 Hz.

Subjective measures of pain were obtained using four visual analogue pain scales (VAS) (Price et al., 1983). The Roland and Morris Disability Questionnaire (Roland and Morris, 1983) and Baecke’s Physical Activity Questionnaire (Baecke et al., 1982) were also administered.

All participants attended the laboratory at Manchester Metropolitan University, Cheshire on five occasions. On the first visit each participant attended a screening session with a Chartered Physiotherapist to assess his/her current health status and to check that the inclusion criteria were met. Following this, a familiarization session was conducted to allow the participants to practice the adoption of a repeatable and comfortable posture on the stadiometer. Familiarisation was deemed complete when a criterion of 10 consecutive measurements of stature with a standard deviation of ≤0.5 mm was met (Kanlayanaphotporn et al., 2003; Reilly et al., 1988). At the end of this session participants completed the scales and questionnaires and had their height and mass recorded.

Participants were requested to sleep for approximately 8 h on the nights prior to the four sessions of testing and to refrain from stressful physical activity for 24 h. Compliance to these pre-test conditions was assessed via self-report. Each session began approximately 1 h after rising from bed and generally took place between 08.00 and 12.00 h. Time was strictly controlled as it is recognised that spinal height is subject to diurnal variation and individuals lose most of their height within the first 3 h after rising (Tyrrell et al., 1985). At the beginning of each session the participants were asked to assume a 20 min unloading position, used previously by Rodacki et al. (2003), to eliminate any abnormal spinal loading that may have preceded arrival at the laboratory (Reilly et al., 1988; Tyrrell et al., 1985). To attach the electrodes correctly to the paraspinal muscles, the skin was dry shaved and cleaned with an alcohol wipe to reduce the impedance to less than 5 KΩ (Ng et al., 2002). The electrodes were placed over the erector spinae muscle at the L1–L2 and L4–L5 interspaces approximately 3 cm from the midline (inter-electrode distance of 1.5 cm), with the reference electrodes placed over the spinous processes of L1, L3 and on the left and right iliac crest. Following this the participants assumed a standing posture for 90 s while a baseline EMG recording was taken. This period also allowed soft tissue deformation to stabilize, which reduced the likelihood of it influencing the ensuing measurements of stature (Foreman and Linge, 1989). Participants then stood in the stadiometer and a baseline stature measurement set was recorded. During each measurement of stature participants were asked to place the arms to the front of the body with hands held together. Each measurement set was taken at end tidal volume and consisted of five consecutive recordings, which took approximately two minutes in total.

After all baseline measurements were taken participants walked at a self-selected pace on a treadmill for 20 min wearing a weighted vest (10% of body mass) to induce spinal loading. Towards the end of the walk participants were asked to rate their perceived exertion (Borg, 1970), and to score their low-back discomfort on a VAS. Following the walking task another set of EMG and stature measurements were taken to quantify both the change in paraspinal muscle activity and the

Fig. 2. Location of four bi-polar EMG surface electrodes and their corresponding reference electrodes and pre-amplifiers.
reduction in stature caused by the walking task. A post-exercise unloading period was then assumed for 20 min to allow the participants to recover. The unloading position differed during each of the four sessions and was randomly assigned to the participant. Each position assumed by the participants had previously been demonstrated to result in significant gains in stature (side lying (Rodacki et al., 2003), 50° gravity inversion (Boocock et al., 1988), spinal hyperextension (Magnusson and Pope, 1996) and 110° supported sitting (Magnusson and Hansson, 1994)) (see Fig. 3). A total of four electromyogram (EMG) and stature measurements were obtained at 5 min intervals during each unloading period.

To allow normalisation of the EMG data participants performed a reference voluntary contraction (RVC). This required each participant to remain in the stadiometer and hold a 4 kg mass at arms length for 15 s. Raw EMGs were rectified and integrated over a period of 5 s. All the integrated EMGs recorded during each session were expressed as a percentage of the RVC.

Participant characteristics (age, height, body mass and BMI) were compared between groups using independent *t*-tests. Levels of physical activity, pain, disability, exertion and low-back discomfort post-exercise were compared between groups with Mann–Whitney *U* tests. Differences in stature reduction, stature recovery, and paraspinal muscle activity were examined between groups and over time using two-way factorial ANOVAs. Finally, total stature recovery and paraspinal muscle activity were compared between unloading positions and groups using two-way factorial ANOVAs. For all statistical tests the threshold of significance was set at *α* ≤ 0.05. All analyses were performed on SPSS version 11.5 for windows.

3. Results

Statistical analysis of age, height, body mass and BMI demonstrated no significant differences between the two groups (*P* > 0.05). Each participant attained the required level of repeatability for the measurements of stature (SD ≤ 0.5 mm) during the familiarization session. The mean SD for the measurements at the end of the familiarization session for the asymptomatic and chronic LBP group was 0.48 mm (SD 0.08) and 0.44 mm (SD 0.06), respectively. Analysis of the physical activity questionnaire demonstrated no significant differences between the two groups for any of the three dimensions (sport, leisure, work). The chronic LBP group exhibited significantly higher levels of pain and disability than the asymptomatic group (*P* < 0.05). The levels of pain (3.8 cm (SD 1.0)) and disability (6.1 (SD 3.4)) demonstrated by the chronic LBP group represented relatively low to moderate levels. No significant differences were found between the two groups with regards to the self-selected walking speed chosen during the first session of testing (chronic LBP = 3.6 km h⁻¹ (SD 0.7); asymptomatic participants = 3.3 km h⁻¹ (SD 0.5) (*P* > 0.05). The levels of perceived exertion and discomfort in the low-back area obtained at the end of the walking task were not significantly different for any of the unloading positions.

Fig. 3. The four recovery positions used to unload the spine: (a) side lying; (b) 50° gravity inversion; (c) spinal hyperextension; (d) 110° supported sitting.
the four sessions of testing within the two groups (P > 0.05). Though, while the level of perceived discomfort was significantly higher in the chronic LBP group after each walking task (P < 0.05), the level of perceived exertion was not significantly different between groups.

No significant difference was found with regards to the reduction in stature caused by the loaded walking task between test sessions or groups (P > 0.05) (see Table 1). The chronic LBP group recovered significantly less stature compared to the asymptomatic group in all of the unloading positions (see Table 1). The differences in stature recovery between the two groups appear to be consistent and independent of which position was assumed, as the stature recovery of the chronic LBP equalled 61.4% (SD 2.9) of that experienced by the asymptomatic group.

Both groups experienced the greatest stature recovery in the gravity inversion position (P < 0.05), while the remaining unloading positions caused similar stature recovery within groups (P > 0.05). Each position was ranked with regards to the amount of stature recovery that was experienced. The order was different for each group (chronic LBP = (1) gravity inversion, (2) side lying, (3) sitting, (4) hyperextension; asymptomatic participants = (1) gravity inversion, (2) side lying, (3) hyperextension, (4) sitting), although there was no significant difference between the last three unloading positions for either group (P > 0.05).

No significant difference was found between left and right erector spinae muscle activity (normalised) in either group at baseline or during recovery, and thus these data were pooled for analysis. Paraspinal muscle activity was higher in the chronic LBP group at baseline and during all four recovery periods (P < 0.05). Both groups demonstrated significantly less paraspinal muscle activity in the gravity inversion position compared to the other unloading positions (see Fig. 4). No significant difference in muscle activity existed between the three remaining positions. These findings were evident in both the normalised and non-normalised data.

### 4. Discussion

The reductions in stature experienced by each group were not significantly different, which is supportive of previous research (Rodacki et al., 2003). In addition, the magnitude of stature reduction was consistent between test sessions, which is in agreement with Kanlayanaphotporn et al. (2002) who examined reduction in stature in asymptomatic and chronic LBP participants following a loaded activity, and demonstrated good repeatability of the change in stature between two days of testing in both groups.

The stature recovery of the chronic LBP group was significantly less than the asymptomatic participants in each unloading position, similar to Rodacki et al. (2003) who also demonstrated that individuals with LBP recover significantly less than asymptomatic participants. In addition, the current study demonstrated how this difference exists in various unloading positions not just side lying. The current investigation also established that stature recovery is consistently lower in individuals with chronic LBP than in asymptomatic participants, independent of the unloading position assumed, therefore hypothesis 1 was accepted. During each unloading position the chronic LBP group experienced only 61.4% (SD 2.9) of the stature recovery exhibited by the asymptomatic group.

The main aim of this investigation was to determine if different unloading positions altered paraspinal muscle activity and whether this resulted in improved stature recovery. The chronic LBP group experienced greater muscle activity compared to the asymptomatic participants during all of the unloading positions. Such clear and consistent paraspinal EMG patterns have previously been demonstrated to distinguish between different LBP groups and asymptomatic participants (Arena et al., 1989), however it is this by no means a consistent finding within the literature. The current investigation demonstrated poor stature recovery in the supported sitting condition. This may be because this is a stressful position for the spine (Nachemson, 1966), and hence it is reasonable to suspect that individuals would have raised levels of muscle tension in this position (Arena et al., 1989). The gravity inversion position resulted in the lowest paraspinal muscle activity of all the positions, which may suggest this was the least stressful of the positions for the spine. This position also resulted in the greatest stature recovery in both groups, therefore it is reasonable to conclude that gravity inversion decreased paraspinal muscle activity. It can be sug-

### Table 1
Stature reduction experienced by the chronic LBP and asymptomatic group following the loaded walking task (10% body mass) and percentage of stature recovery following each unloading position

<table>
<thead>
<tr>
<th>Position</th>
<th>Stature loss (mm)</th>
<th>Stature recovery (% of stature loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLBP</td>
<td>Controls</td>
</tr>
<tr>
<td>Side lying</td>
<td>-0.47 (0.20)</td>
<td>-0.51 (0.08)</td>
</tr>
<tr>
<td>Gravity inversion</td>
<td>-0.47 (0.10)</td>
<td>-0.47 (0.11)</td>
</tr>
<tr>
<td>Supported sitting</td>
<td>-0.47 (0.1)</td>
<td>-0.48 (0.10)</td>
</tr>
<tr>
<td>Hyperextension</td>
<td>-0.49 (0.09)</td>
<td>-0.51 (0.05)</td>
</tr>
</tbody>
</table>
gested that this reduction in paraspinal muscle activity lowered spinal compression and allowed disc height to be regained at an improved rate, however this requires further investigation. The remaining unloaded positions all had greater levels of paraspinal muscle activity compared to gravity inversion and resulted in less stature recovery. These other positions exhibited similar levels of paraspinal muscle activity to each other and also resulted in comparable stature recovery. These findings led to the acceptance of hypothesis 2.

5. Conclusion

The elevated paraspinal muscle activity exhibited by the chronic LBP group increased compression of the intervertebral discs and reduced their ability to regain height post-exercise, and was thereby causal to delayed stature recovery. This association between paraspinal muscle activity and stature recovery was particularly demonstrated by gravity inversion, which resulted in the greatest amount of recovery in the presence of the lowest muscle activity. Further research is required to determine the implications of improving stature recovery using gravity inversion for the treatment of chronic LBP and its impact upon levels of pain and disability.

References


