Motor Control Patterns During an Active Straight Leg Raise in Chronic Pelvic Girdle Pain Subjects

Darren John Beales, MManipTher, Peter Bruce O’Sullivan, PhD, and N. Kathryn Briffa, PhD

Study Design. Repeated measures.
Objective. To investigate motor control (MC) patterns in chronic pelvic girdle pain (PGP) subjects during an active straight leg raise (ASLR).
Summary of Background Data. The ASLR is a test used to assess load transference through the pelvis. Altered MC patterns have been reported in subjects with chronic PGP during this test. These patterns may impede efficient load transfer, while having the potential to impinge on respiratory function and/or to adversely affect the control of continence.
Methods. Twelve female subjects with chronic PGP were examined. Electromyography of the anterior abdominal wall, right chest wall and the scalene, intra-abdominal pressure, intrathoracic pressure, respiratory rate, pelvic floor kinematics, and downward leg pressure of the nonlifted leg were compared between an ASLR lifting the leg on the affected side of the body versus the nonaffected side.
Results. Performing an ASLR lifting the leg on the affected side of the body resulted in a predominant MC pattern of bracing through the abdominal wall and the chest wall. This was associated with increased baseline shift in intraabdominal pressure and depression of the pelvic floor when compared with an ASLR lifting the leg on the nonaffected side.
Conclusion. This MC pattern, identified during an ASLR on the affected side of the body, has the potential to be a primary mechanism driving ongoing pain and disability in chronic PGP subjects.
Key words: pelvic girdle pain, active straight leg raise, motor control, intra-abdominal pressure. Spine 2009;34: 861–870

Pelvic girdle pain (PGP) has been adopted as an umbrella term describing disorders where symptoms arise from musculoskeletal pelvic structures.¹ During pregnancy 72% to 84% of women report pain in the lumbopelvic region,²–⁴ with the point prevalence for PGP during this time being 16% to 20%.⁵–⁷ Although for most this is a self-limiting occurrence, in 7% to 10% of cases symptoms become chronic.⁸–¹⁰ Furthermore, chronic PGP may result from other aetiologies like trauma.¹¹,¹² In some presentations of PGP a specific diagnosis can be made from imaging studies and blood work, for example, ankylosing spondylitis and stress fractures.¹³,¹⁴ However, in many cases of chronic PGP no specific underlying pain mechanism can be identified. The pathogenesis in these cases may include varying contributions of biomechanical, pathoanatomic, psychosocial, neurophysiological, genetic, and hormonal factors potentially driving ongoing PGP.¹⁵

The active straight leg raise (ASLR) test is a clinical procedure used in assessing PGP subjects (Figure 1). There is increasing evidence conferring the validity and reliability of this test to assess load transfer through the pelvis.¹²,¹⁶–¹⁹ It is widely accepted as an integral component in physical evaluation of PGP.¹ During testing, assessment of the primary subjective feature of heaviness of the leg (± pain) is complimented by observation of motor control (MC) adaptations such as respiratory disruption and abdominal bracing¹² (Figure 1).

Studies specifically investigating MC patterns during an ASLR¹²,²⁰–²² and other aspects of MC in PGP subjects²³–²⁵ are summarized in Table 1. These studies support biomechanical models²⁶ championing MC contribution to lumbopelvic stability, and support the hypothesis of aberrant MC patterns providing a mechanism for ongoing pain in specific PGP presentations.¹⁵,²⁷ MC contributes to stability in the pelvic via force closure, a complex interaction of muscles and ligaments which may, when acting in symphony, actively add compression to the pelvic ring and thereby stabilize the sacroiliac joints (SJs).²⁶,²⁸ As there is a synergistic relationship between muscles which control lumbopelvic stability/force closure, respiration, intra-abdominal pressure (IAP) and continence, aberrant MC may also affect respiration and continence control.¹²,²⁵ At present, no study has investigated these systems in detail in nonpregnant PGP subjects during the ASLR.

This study aimed to investigate MC patterns exhibited by chronic PGP subjects during the ASLR. Improved understanding of MC strategies exhibited by chronic PGP subjects could assist in understanding this factor as a mechanism for the chronic pain state, and thereby aid classification and management of these subjects. It was hypothesized that PGP subjects would demonstrate (1) altered muscle patterning lifting the affected leg, (2) altered patterning would equate to a bracing strategy, and (3) these changes would be associated with the generation of higher levels of IAP and pelvic floor (PF) depression.

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Ethical approval for this study was granted by the Human Research Ethics Committee of Curtin University of Technology.
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Materials and Methods

Subjects

Twelve women with chronic unilateral PGP diagnosed according to well established criteria identifying the SIJ as a source of symptoms (Table 2) were recruited from the Perth metropolitan region. Exclusion criteria were as follows: any other musculoskeletal pain disorder in the last 6 months; surgery in the last year; neurologic or inflammatory disorders; significant respiratory disorder; and pregnancy or less than 6 months postpartum.

The Human Research Ethics Committee of Curtin University of Technology granted ethical approval and all subjects provided written informed consent. Table 3 displays demographic data.

Equipment and Set-Up

Respiratory, electromyographic (EMG), pressure and kinematic data were collected simultaneously using a custom designed LabVIEW v6.1 (National Instruments, Austin, TX) data acquisition program. The pneumotach of a Benchmark Pulmonary Exercise System (P.K. Morgan Instruments Inc., Andover, MA) was coupled to the human subject’s oropharynx and connected through a Tubing Duct (Vaculog Display, Kenwood, TX) to the pneumotach before the pressure transducer was calibrated.

Table 1. Findings From Investigations of Motor Control: A, During an ASLR; and B, in PGP Subjects During Other Tasks

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Motor Control Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased activation of IO and EO on the side of the ASLR</td>
<td>Predominant pattern of increased chest wall activation on the side of the ASLR</td>
</tr>
<tr>
<td>Minimal influence on IAP and ITP</td>
<td>Delayed onset of transversus abdominis during ASLR in the groin pain subjects</td>
</tr>
<tr>
<td>Increased bilateral EO activity in PGP subjects</td>
<td>Less hip flexor force production in PGP subjects</td>
</tr>
<tr>
<td>Decreased diaphragmatic excursion/diaphragmatic splinting in pain subjects</td>
<td>Altered respiratory patterns in pain subjects</td>
</tr>
<tr>
<td>Altered respiratory patterns in pain subjects</td>
<td>Descent of the PF in pain subjects</td>
</tr>
</tbody>
</table>

Other PGP studies

Hungerford et al25 SIJ pain vs. pain-free controls

O’Sullivan and Beales24 Chronic SIJ pain vs. pain-free controls

Pool-Goudzevaard et al25 Pregnancy relate PGP vs. pain-free controls

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A custom-made silicone rubber nasogastric catheter (Dentsleeve International Ltd., Mississauga, Canada) with 2 small lumens was used to record IAP and intrathoracic pressure (ITP). Once situated in the esophagus, saline solution was passed through the lumen at high pressure. Changes in flow rate of the saline which occur in response to pressure change were monitored by a custom-built pressure transducer and output to the data collection program. One lumen was located in the abdomen and the other in the thorax by observing opposite pressure changes in both channels during respiration.49

Downward pressure exerted by the leg not being lifted was monitored with an inflated pad, placed under the heel, linked to another pressure transducer. Kinematics of the PF were monitored with a Capesee SSA-220A ultrasound unit (Toshiba Corp., Tochigi, Japan) and recorded to digital video. The bladder was viewed by positioning the probe transabdominally, angled inferiorly. This has been established as a reliable, non-invasive method of investigating PF movement.12,50–52

### Data Collection and Processing

Average root mean square (RMS) for 3 seconds trials of a crook lying double leg raise with cervical flexion was calculated for submaximal EMG normalization.40,53–55 Data were then collected for 60 seconds in resting supine. An ASLR trial was then performed for each leg. A cough at the start of each trial, producing movement of the PF on ultrasound, was used to synchronize PF data with the other variables. After coughing the leg was lifted for approximately 45 seconds. A further trial was performed on each leg for repeatability analyses.

Data were prepared for analyses with a custom LabVIEW processing program. Initially EMG was inspected for contamination by heartbeat and other artifacts and manually eliminated if necessary. Data were then demeaned, band pass filtered from 4 to 400 Hz with a fourth order zero lag Butterworth filter and normalized. The RMS of the EMG was obtained for 500 milliseconds during the middle of inspiration and expiration each of 3 breath cycles. This was to allow for an impression of phasic EMG changes in relation to respiration versus tonic changes in response to the ASLR.

Respiratory fluctuation of IAP and ITP were found by calculating the difference between the maximum and minimum value for each variable respectively over a breath cycle. Pressure change related to the physical load of the ASLR was assessed via a baseline shift, obtained by subtracting the minimum IAP or ITP value of relaxed supine breathing from the corresponding minimum value during the ASLR.

Respiratory rate (RR) was calculated from the respiratory traces. PF movement was assessed by capturing 2 frames of video: (a) slightly before and after the leg lift to ascertain bladder motion secondary to the ASLR, and (b) at the maximum and minimum points of excursion over each of the 3 breath cycles to observe motion in response to respiration. Movement was directly measured by overlaying the 2 captured frames. Average downward pressure exerted by the nonlifted leg during the ASLR was calculated for each breath cycle.

### Analyses

Values for analyses were obtained by averaging the 3 breath cycles. Patterns of activation (hypothesis 1) were investigated for each muscle by comparing RMS with a 2 (side) ANOVA with repeated measures. The presence of a bracing effect was assessed by comparing RMS with a 2 (side) ANOVA with repeated measures. The presence of a bracing effect for each muscle by comparing RMS with a 2 (side) ANOVA with repeated measures.
strategy (hypothesis 2) during an ASLR on the affected or non-affected side was investigated by looking at side-to-side muscle symmetry with a 2 (muscle: nonaffected side, affected side) by 2 (respiration: inspiration, expiration) repeated measure analysis of variance and post hoc Student t tests. Half the subjects had a symptomatic right SIJ, the other half on the left, so the EMG data were side corrected accordingly to be labeled as either the affected or noneffected side. As the CW was only collected on the right, for 6 subjects this represented the affected side and 6 the nonaffected side. Because of this low sample size (n = 6) and the number of factors in the statistical model this variable was not considered for statistical analyses. IAP, ITP, RR, PF movement, and downward leg pressure were compared lifting each leg with paired Student t tests (hypothesis 3). Visual inspection of all data were also used to investigate the MC patterns.

The intraclass correlation coefficient and corresponding 95% confidence intervals over 2 trials were calculated for all variables as an estimation of consistency. Statistical analysis was performed with SPSS 15.0 for Windows (SPSS Inc., Chicago, IL), with a critical P value of 0.05.

### Results

#### Electromyographic

Table 4 displays results from EMG analyses.

#### Obliquus Internus Abdominis

**Patterning.** The IO on the affected side showed greater activation lifting the leg on the affected side (side: P = 0.0254) (Figure 2). Activation of IO on the nonaffected side was the same lifting either leg (side: P = 0.378) (Figure 2). The activation pattern for either muscle was tonic in nature and as such not overtly influenced by respiration.

**Bracing.** During an ASLR on the affected side, there was symmetrical tonic activation of the IOs (muscle: P = 0.235) consistent with a bracing pattern, but asymmetrical tonic activation during a nonaffected side ASLR (muscle: P = 0.034) (Figure 2). Respiration had no influence.

**Visual Inspection.** This was consistent with greater ipsilateral activation of IO lifting the leg on the nonaffected side compared with bilateral activation in a bracing pattern for IO lifting the leg on the affected side (Figure 3: subject A). Although this was the predominant pattern, EMG traces demonstrated some variation. Three subjects displayed bilateral activation lifting either leg (Figure 3: subject B), whereas 3 tended to have greater ipsilateral activation during the affected ASLR. Interestingly 2 subjects appeared to have minimal IO activation during the ASLR (Figure 3: subject C).

#### Obliquus Externus Abdominis

**Patterning.** There was no difference in EO activation lifting either the leg on the affected or nonaffected side (affected EO: side, P = 0.150; nonaffected EO: side, P = 0.456) (Figure 2), and no effect for respiration.

**Bracing.** Activation of EO was symmetrical during ASLR on the affected side (muscle: P = 0.087) but asymmetrical during ASLR on the nonaffected side (muscle: P = 0.456) (Figure 2). There was no phasic respiratory effect.

**Visual Inspection.** This suggested a predominant pattern of bilateral tonic EO activation lifting the affected or nonaffected leg.

### Table 4. Repeated Analyses of Variance P Values for EMG Comparisons

<table>
<thead>
<tr>
<th>Side by Respiration</th>
<th>Side</th>
<th>Respiration</th>
<th>Side by Respiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterning (affected vs. non-affected ASLR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO-Aff. side</td>
<td>0.024*</td>
<td>0.854</td>
<td>0.728</td>
</tr>
<tr>
<td>IO-N-A side</td>
<td>0.378</td>
<td>0.559</td>
<td>0.625</td>
</tr>
<tr>
<td>EO-Aff. side</td>
<td>0.015</td>
<td>0.097</td>
<td>0.187</td>
</tr>
<tr>
<td>EO-N-A side</td>
<td>0.456</td>
<td>0.268</td>
<td>0.212</td>
</tr>
<tr>
<td>RA-Aff. side</td>
<td>0.064</td>
<td>0.820</td>
<td>0.033*</td>
</tr>
<tr>
<td>RA-N-A side</td>
<td>0.197</td>
<td>0.604</td>
<td>0.743</td>
</tr>
<tr>
<td>Sc-Aff. side</td>
<td>0.624</td>
<td>0.261</td>
<td>0.306</td>
</tr>
<tr>
<td>Sc-N-A side</td>
<td>0.119</td>
<td>0.215</td>
<td>0.072</td>
</tr>
</tbody>
</table>

Muscle Respiration

<table>
<thead>
<tr>
<th>Muscle by Respiration</th>
<th>Muscle</th>
<th>Respiration</th>
<th>Muscle by Respiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracing (muscle of affected vs. non-affected body side)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aff. ASLR-IOs</td>
<td>0.235</td>
<td>0.887</td>
<td>0.730</td>
</tr>
<tr>
<td>Aff. ASLR-EOs</td>
<td>0.087</td>
<td>0.980</td>
<td>0.912</td>
</tr>
<tr>
<td>Aff. ASLR-RAs</td>
<td>0.111</td>
<td>0.143</td>
<td>0.195</td>
</tr>
<tr>
<td>Aff. ASLR-Scs</td>
<td>0.247</td>
<td>0.252</td>
<td>0.693</td>
</tr>
<tr>
<td>N-A ASLR-IOs</td>
<td>0.034*</td>
<td>0.605</td>
<td>0.568</td>
</tr>
<tr>
<td>N-A ASLR-EOs</td>
<td>0.002*</td>
<td>0.180</td>
<td>0.710</td>
</tr>
<tr>
<td>N-A ASLR-RAs</td>
<td>0.235</td>
<td>0.762</td>
<td>0.145</td>
</tr>
<tr>
<td>N-A ASLR-Scs</td>
<td>0.917</td>
<td>0.227</td>
<td>0.955</td>
</tr>
</tbody>
</table>

*Significant difference. N-A indicates nonaffected; Aff., affected.
Rectus Abdominis

Patterning and Bracing. No differences were found for either side or muscle. Side by respiration was significant for the affected RA (affected RA: side by respiration, $P = 0.033$), but there was no other effect for respiration.

Visual Inspection. There was no indication of a respiratory effect with visual inspection, with all subjects displaying bilateral tonic activation.

Right CW

Visual Inspection. The predominant pattern of CW activation was phasic when lifting the leg on the nonaffected side, but increased tonic when lifting the leg on the affected side (Figure 4, Figure 5: subject D-affected CW; subject E-nonaffected CW). There were some variants such as phasic activity lifting either leg in one case and tonic activity lifting either leg in another (Figure 5: subjects B and C).

Scalene

Patterning and Bracing. No differences were found for either side or muscle, nor any change related to respiration (Figure 4).

Visual Inspection. On visual inspection the Sc revealed variant patterns with a penchant for either tonic or phasic Sc activation, which within individuals tended to be consistent between lifting the affected or nonaffected leg.

Other Variables

Data are presented as mean (standard error of the mean).

Intra-Abdominal Pressure and Intrathoracic Pressure

Respiratory fluctuation of IAP and ITP did not vary lifting either leg (IAP: $P = 0.185$, ITP = 0.571) (Figure 6).
The baseline shift in IAP was greater during an ASLR on the affected side ($P = 0.044$), but did not change for ITP ($P = 0.892$) (Figure 6).

**Respiratory Rate**
The RR did not differ lifting either leg (affected ASLR: 16.8 [1.4] breaths/min; nonaffected ASLR: 16.5 [1.5] breaths/min; $P = 0.748$).

**PF Movement**
There was greater PF downward movement in response to an ASLR on the affected side (affected ASLR: 9.0 [1.8] mm; nonaffected ASLR: 4.0 [0.6] mm; $P = 0.012$). There was no difference for PF motion with respiration (affected ASLR: 3.1 [0.6] mm; nonaffected ASLR: 3.0 [0.5] mm; $P = 0.887$).

**Contralateral Leg Downward Pressure**
Downward leg pressure with the nonlifted leg did not differ during either ASLR (affected ASLR: 58.85 [6.75] N; nonaffected ASLR: 65.04 [7.79] N; $P = 0.326$).

**Consistency of Patterns**
Repeated trials were not available for 2 subjects as urgent need to void urine resulted in early cessation of data collection. Repeatability was good to very good, except for the baseline shift of IAP during a nonaffected ASLR and PF movement lifting either leg, which displayed more variability (Table 5).

**Discussion**
As hypothesized, subjects with unilateral chronic PGP of mild to moderate severity adopt bracing MC strat-
egies performing an affected side ASLR, with associated generation of higher levels of IAP and greater PF depression.

**Muscle Activation**

During an ASLR on the affected side a bracing strategy highlighted by bilateral tonic activation of IO and EO was observed. These findings contrast to the strategy of greater ipsilateral activation of these muscle groups, particularly IO, observed in nulliparous pain-free females. This bracing strategy concurs with the finding of greater EO activation during an ASLR in pregnant subjects with PGP compared with pain-free pregnant subjects.

Activation of the right CW during an ASLR in pain-free subjects has been reported as variable. In that study there was a tendency in 8 of 14 subjects for tonic activation lifting the ipsilateral leg, but phasic activation lifting the contralateral leg, suggesting a change in MC pattern dependant on the side of the leg lift. In this study,
CW activation in PGP subjects was not overtly influenced by lifting the contralateral or ipsilateral leg, but was influenced more by if the ASLR was on the affected or nonaffected side. Specifically, performing an ASLR on the affected side predominately resulted in tonic CW activation (i.e., bracing strategy) whether this was ipsilateral or contralateral to the CW. This concurs with ultrasound observation of diaphragmatic splinting during an affected ASLR in a similar group of subjects suggesting a shift in function of the CW from respiration to additional control of IAP. These observations on CW activation must be considered cautiously due to the small sample size in this study, but would be an interesting area for further research.

Over half the subjects demonstrated tonic activation of the Sc, whereas Sc activity was phasic in pain-free subjects. This might reflect a general increase in muscle tone, or tonic activation of accessory breathing muscles as a component of the bracing strategy in some subjects. This could provide a mechanism for the development of concurrent cervicothoracic symptoms, which clinical observations denote as a common comorbidity in subjects with chronic lumbopelvic pain.

It should be noted that even though a commonality in muscle activation patterns has been identified between subjects, examination of raw EMG traces demonstrates some individual variability (Figures 3, 5). This is an important consideration in the physical examination of PG subjects. Not all chronic PG subjects present in the same manner, nor respond to the same intervention. Clinical identification of individual variants in MC patterns may facilitate targeted intervention.

### Intra-Abdominal Pressure and Intrathoracic Pressure

Variability between tests with IAP baseline shift performing a nonaffected ASLR despite good repeatability of the EMG activation was noted, which is similar to what has been observed in pain-free individuals during an ASLR. It was suggested that this may be due to the fact that not all muscles (i.e., transversus abdominis, PF) which produce IAP were monitored, a limitation shared by this study, or that it might reflect flexibility in the control of IAP under low load conditions. In contrast the repeatability for IAP baseline shift during an affected ASLR was very good. This suggests that PGP subjects have reduced flexibility in their MC strategy with regard to the generation of IAP during an affected ASLR.

### PF Movement

Greater depression of the PF was noted during the affected ASLR, as previously reported in SJJ pain subjects. This is contrast to observations in pain-free subjects. It may result from an inability of PF musculature to resist downward force created by increased baseline IAP. However, these findings do not inform regarding the level of PF muscle activation. Further research into PF activation during the ASLR would be useful in enlightening the role of the PF in the production of force closure.

Recent research has demonstrated a strong positive correlation between lumbopelvic pain and continence dysfunction. Caution must be taken in implying “cause and effect” between the 2 disorders from these cross-sectional studies. However, depression of the PF during an ASLR, or with an attempt to voluntarily elevate the PF, has been linked to continence dysfunctions and there is growing evidence of other forms of MC dysfunction linking these 2 disorders. It is important to recognize that the presence of PF depression does not automatically mean that continence will be compromised as 5 subjects did not report continence issues despite demonstrating PF depression during an affected ASLR.

### Implications

All subjects in this study had reduced heaviness of the leg with the addition of compression during the affected ASLR (Table 2), consistent with inefficient load transfer through the pelvis. This could result from impairments in passive pelvic stability (form closure), insufficient dynamic pelvic stability (reduced force closure), or a combination of these factors. The addition of manual pelvic compression to the ASLR has been shown to have a positive effect on MC in a similar group of subjects to those in this study. Altered breathing patterns, decreased diaphragmatic motion, and PF descent have been improved with compression during an ASLR. Presumably, compression improves load transference by enhancing both passive stability of the SIJs and MC patterns/force closure. As such, compression might well have a positive effect on the bracing strategy observed in the present study, and may facilitate a reduction in baseline IAP. This is the topic of an ongoing study by our research group.

### Table 5. Consistency of Motor Patterns Over 2 Trials for the N-A and Aff. ASLR, Expressed Via ICC (95% CI) Values

<table>
<thead>
<tr>
<th>Muscle activation</th>
<th>N-A ASLR: ICC (95% CI)</th>
<th>Aff. ASLR: ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest: 0.995 (0.980–0.999)</td>
<td>Lowest: 0.858 (0.472–0.965)</td>
<td></td>
</tr>
<tr>
<td>Median: 0.944</td>
<td>Median: 0.972</td>
<td></td>
</tr>
<tr>
<td>IAP-breath cycle</td>
<td>0.910 (0.926–0.978)</td>
<td>0.943 (0.978–0.985)</td>
</tr>
<tr>
<td>ITP-breath cycle</td>
<td>0.954 (0.945–0.968)</td>
<td>0.915 (0.938–0.947)</td>
</tr>
<tr>
<td>IAP-baseline shift</td>
<td>0.498 (0.875)</td>
<td>0.911 (0.644–0.978)</td>
</tr>
<tr>
<td>ITP-baseline shift</td>
<td>0.926 (0.704–0.982)</td>
<td>0.979 (0.916–0.995)</td>
</tr>
<tr>
<td>RR</td>
<td>0.970 (0.879–0.993)</td>
<td>0.953 (0.810–0.988)</td>
</tr>
<tr>
<td>PF movement-leg</td>
<td>0.383 (0.847)</td>
<td>0.538 (0.865)</td>
</tr>
<tr>
<td>lift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF movement-breathe cycle</td>
<td>0.698 (0.925)</td>
<td>0.813 (0.247–0.954)</td>
</tr>
<tr>
<td>Contralateral leg pressure</td>
<td>0.887 (0.341–0.981)</td>
<td>0.910 (0.473–0.984)</td>
</tr>
</tbody>
</table>

ICC indicate intra-class correlation coefficient.
Psychosocial factors such as fear avoidance can also effect load transfer through the pelvis, though this is unlikely to be a factor in the subjects in this study as the average score for the Tampa Scale for Kinesiophobia was within normal limits (Table 3). Further screening of other psychosocial factors, such as anxiety and depression, would be advantageous in future studies investigating MC strategies in chronic PGP.

The bracing strategies observed in this study could be a reaction of the neuromuscular system to impaired load transference and pain, consistent with a protective response. There is growing evidence though that bracing patterns may be provocative in nature, providing a mechanism for ongoing pain. In vivo examination has determined that bracing contraction of the abdominal wall is less effective at creating pelvic stiffness/force closure than local muscle activation. As such, the bracing patterns observed in this study may result in suboptimal force closure, compromising effective load transference through the pelvis. This potentially creates ongoing stimulation of sensitized peripheral nociceptors during loading, and consequently a mechanism for ongoing pain. Supporting this is the finding that exercise intervention re-enforcing bracing patterns tends to worsen symptoms in PGP. Conversely, interventions initially promoting local muscle control are effective at alleviating some presentations of chronic PGP. Furthermore, it has been postulated from a theoretical model that high levels of IAP could be sufficient to mechanically provoke painful pelvic structures, providing a peripheral nociceptive drive for ongoing PGP. The magnitude of IAP elicited by the ASLR in our study was below the pressure thresholds calculated for this biomechanical model. Nevertheless, the increased baseline IAP observed during the affected ASLR could potentially result in ongoing mechanically mediated peripheral pain generation in the manner described by this model. Further research investigating IAP production in chronic PGP subjects during functional activities and high load tasks is warranted.

- **Key Points**
  - The ASLR test is used to assess load transfer through the pelvis.
  - This study documents multiple facets of altered MC strategies in chronic PGP subjects during an ASLR.
  - During an ASLR, lifting the leg on the affected side of the body, PGP subjects demonstrated bracing through the abdominal wall and CW, increased generation of IAP, and depression of the PF.
  - Aberrant MC patterns adopted by subjects with chronic PGP may represent a mechanism for ongoing pain and disability.

**References**
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