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Pregnancy Is Characterized by Widespread Deep-Tissue Hypersensitivity Independent of Lumbopelvic Pain Intensity, a Facilitated Response to Manual Orthopedic Tests, and Poorer Self-Reported Health

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Abstract: **Lumbopelvic pain is common in pregnancy but the sensitization factors underlying the condition are largely unknown. This study characterized the somatosensory profile of pregnant and nonpregnant women and the relationship between pain, hypersensitivity, and commonly used manual clinical tests. Thirty-nine pregnant and 22 nonpregnant women were included. Although lumbopelvic pain was not an inclusion criterion, the pregnant women were divided into low- and high-pain groups following data collection. The sensitivity to light brush, pin-prick, and pressure pain was assessed bilaterally at 3 sites in the lumbopelvic region, at the shoulder, and in the lower leg. Responses to the active straight leg raise test and pain provocation tests of the sacroiliac joint were recorded. Participants completed questionnaires addressing emotional and physical well-being and rated disability using the Pelvic Girdle Questionnaire. Compared with controls, the high-pain group rated the active straight leg raise test as more difficult ($P < .05$), and both pain groups had more positive pain provocation tests ($P < .05$). The pregnant groups demonstrated significantly lower pressure pain thresholds at most assessment sites compared with controls ($P < .05$), but self-reported disability and pain were not correlated with pressure pain thresholds within pregnant participants. The high-pain group reported worse emotional health and poorer sleep quality than controls ($P < .05$).**

***Perspective:** This article presents the somatosensory profile of a healthy pregnant cohort. The results indicate that pain sensitivity increases during pregnancy possibly owing to the physical changes the body undergoes during pregnancy but also owing to changes in emotional health. This should be accounted for in clinical management of pregnant women with lumbopelvic pain.*

Key words: *Pelvic girdle pain, pregnancy, hyperalgesia, clinical tests.*

During pregnancy, between 72 and 84% of women develop pain to some extent in the lumbopelvic region.[10,61] Disability due to lumbopelvic pain (LPP) in pregnancy may have been underestimated previously because of the lack of adequate disability measures.[33] This is to some extent reflected in the fact that the ability to perform daily activities becomes so challenging that up to 60% of women go on sick leave before delivery.[22,88]

Despite the high prevalence of LPP during pregnancy, a majority of women perceive pain as being a normal part of pregnancy and receive no treatment for their condition.[73] It is uncertain what factors cause disabling pain among some women during pregnancy, but it may be related to a previous history of LPP and emotional health challenges (eg, depression, anxiety, poor coping strategies) as well as factors commonly associated with LPP during pregnancy,[3,49] accounting for the disability

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reported during daily life activities.[12,47] Additionally, sleep quality has been shown to be significantly affected[21,85,101] among pregnant women with LPP,[21,86,100] and early identification of these factors has proven useful in predicting the development of pain postpartum.[34,66,67]

During pregnancy, quantitative sensory testing (QST) has revealed that widespread deep-tissue hypersensitivity is associated with LPP.[8] Multiple individual factors related to LPP in pregnancy, such as poor sleep quality, depression, anxiety, perceived stress, and pain catastrophizing, are known to directly increase pain sensitivity.[17,46,83] In patients with low back pain, an association has been demonstrated between pain sensitivity as assessed by QST, physical functioning, and depression.[15] However, a similar relationship has not been examined in pregnancy-related LPP.

As part of clinical assessment of LPP including that associated with pregnancy, differentiating sources of tissue sensitivity is important from a pain management perspective, and in this regard clinical diagnostic tests have gained favor. Manual clinical tests are typically interpreted within the context of pain and hyperalgesia. The most common tests involve pain provocation of the sacroiliac joint (SIJ)[50] and low back[72] with manual pressure. Also, the active straight leg raise (ASLR) test[60] is a common assessment during pregnancy, considered valuable to assess the ability to transfer load across the pelvic girdle.[38,60] Recent data from experimental pain studies has demonstrated that induced SIJ-related pain and hypersensitivity in asymptomatic subjects reproduced positive SIJ provocation and ASLR tests similar to what is seen in the clinical presentation of LPP.[70,71] Hypermobility of the SIJ may potentially cause a painful overload of the joint structures in the pelvic girdle,[23] and adding mechanical stability in the pelvic girdle can significantly reduce the difficulty of performing the ASLR.[59] However, this only accounts for 32% of the variability during the test.[59] This indicates other potential contributing factors such as pain intensity and somatosensory sensitivity, but the relationship between these factors and the outcome of these clinical tests has not been investigated in pregnant women and may be important to informing appropriate clinical pathways.

The aim of this study was to investigate the clinical profile (related to pain sensitivity, psychometric measures, health-related findings, and clinical tests) in a group of pregnant women suffering from different pain intensity levels of LPP and to compare this group's profile with healthy nonpregnant controls. The relationship between the outcomes of clinical tests for the lumbopelvic region, disability, pain intensity, and pain sensitivity was also investigated in the pregnant group. Lastly, a relationship between disability, pain sensitivity, and psychometric variables was assessed. It was hypothesized that the outcome of manual clinical tests would be related to pain and hypersensitivity in pregnant women.

Methods

Subjects

Controls were healthy, nulliparous, nonpregnant women completely pain free with no current or previous history of ongoing pain (musculoskeletal, visceral), either generally or specifically, of the low back and pelvis. Days since the start of their last menstruation (day 0) was used to determine the phase of the menstrual cycle (days 2–6, menstrual days; days 7–16, periovulatory phase; days 17–22, luteal phase; and days 25–28, premenstrual phase) similar to Giamberardino et al,[29] as pain sensitivity has been shown to vary among the different phases in normally menstruating women.[44] Habitual use of hormonal contraceptives was registered but not used for data analysis. Pregnant subjects were included on the premise that they were healthy in the second or third trimester and had no signs of neurologic disorder, rheumatologic diseases, or any other systemic diseases that could affect the outcome of the experimental procedure. Previous history of LPP was not an exclusion criterion. Based on the findings from Bastiaanssen et al[10] and Mogren and Pohjanen,[61] a prediction was made that a significant proportion of the pregnant subjects would have pain to some degree. For data analysis, the subjects were then divided into low- and high-pain groups depending on the average pain intensity related to the lumbopelvic region in the previous week as indicated on the numeric rating scale (NRS). A cut-off score of 4 of 10 on an NRS was used to determine clinically significant pain as suggested in other studies,[16,28,48] and this score was used to allocate the subjects into the low- or high-pain group. The pregnant subjects were recruited from pregnancy water aerobics classes and through newspapers and radio advertisements. The nonpregnant controls were recruited from a population of university students. All subjects were recruited from metropolitan Perth, Western Australia. Subjects were given a detailed written and verbal explanation of the experimental procedure prior to providing informed consent. All testing was conducted in 1 session by the same investigator (T.S.P.), who was blinded to the potential pain status of the pregnant subjects. The study was conducted in accordance with the Helsinki Declaration and was approved by the Curtin University Human Research Ethics Committee (PT210/2012).

QST

Standardized QST was performed with subjects positioned on a bench in supine and side-lying positions, in a clinical setting with a constant room temperature. All QST measurements were taken at 10 different sites on the body, that is, 5 bilaterally matched sites (Fig 1). All sites were located by manual palpation and marked before measurements started: 1) the musculus gastrocnemius, midway between calcaneus and the popliteal line; 2) long posterior sacroiliac ligament (long dorsal ligament [LDL]), immediately below the attachment to the posterior superior iliac spine); 3) 1 cm lateral to the

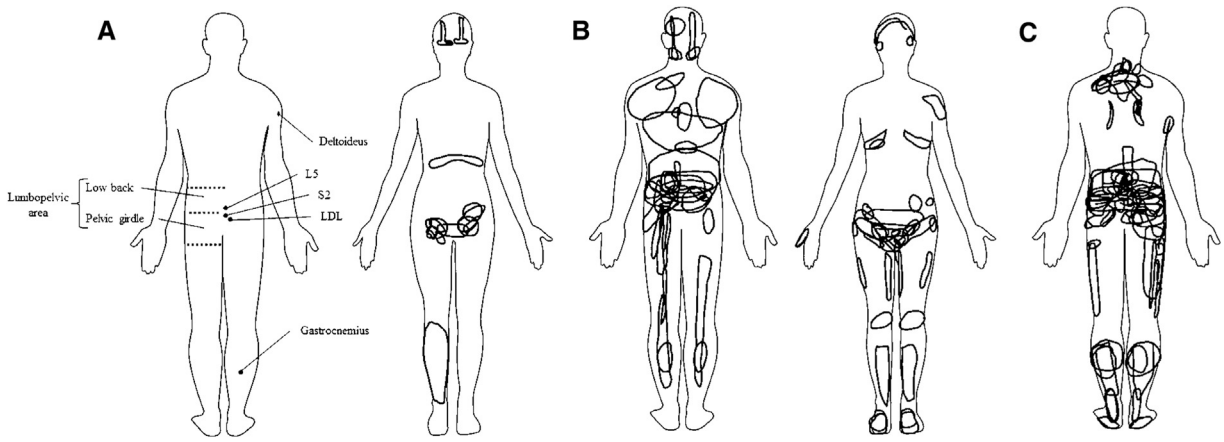

Figure 1. **(A)** Outlines of the area defined as the lumbopelvic area used for quantification of pain area (left) and location of assessment sites for quantitative sensory assessment (right). The assessment sites are only illustrated unilaterally but were assessed bilaterally. The assessment sites are the gastrocnemius muscle, long posterior sacroiliac ligament (LDL), lateral to S2, lateral to L5, and at the deltoideus muscle. Superimposed body chart pain drawings from the pregnant groups (**B**, low-pain group n = 20; **C**, high-pain group n = 19) showing both pregnancy-related pain areas as well as preexisting pain areas.

spinous process of S2; 4) over the muscle bulk of the paraspinal muscles lateral to L5, 3 to 5 cm lateral to the spinous process; and 5) over the bulky medial part of the musculus deltoideus, midway between acromion and the deltoid tuberosity. The order of the QST testing was randomized in terms of side and site, but the order of modalities assessed was always the same, starting with the light brush and ending with pressure algometry. This order was chosen to avoid potential soreness caused by the algometer affecting the results of other QST measurements. Each measure with all modalities was repeated 3 times and the averages of the measurements were used for further analysis.

Brush Movements

A soft standardized brush (SENSELab Brush 05; Somedic, Hörby, Sweden) exerting a force of ~200 to 400 mN was applied with a single stroke of 2 cm in length on the skin at a pace of approximately 3 to 5 cm/s in a constant direction to assess the response to dynamic tactile stimulation.[78,82] The subject was asked whether the brushing movement caused any pain or discomfort, and if so was asked to indicate the pain intensity by marking it on a visual analog scale (VAS). The VAS was anchored with "no pain" and "maximum pain" at 0 and 10 cm, respectively.

Von Frey Filaments

A von Frey filament (Optihari2-Set; Marstock Nervtest, Marburg, Germany) with a bending force of 512 mN was used to examine the response to pin-prick. The subjects were asked to rate the pain from the stimulation by filling out a VAS scale.

Mechanical Pressure

A handheld pressure algometer (Somedic) with a 1-cm^2 probe (covered by a disposable latex sheath) was used to assess the mechanical sensitivity of deep tissues.[79] Pressure was increased gradually at a rate of 30 kPa/s until the pressure pain threshold (PPT) was reached, at which stage the subject pressed a button to stop the test. The PPT was defined to the subject as "the point at which the pressure sensation becomes *just* painful." An interval of at least 30 seconds was kept between each PPT assessment.

Clinical Tests

Lumbar Spine Pain Provocation Tests

The test is traditionally performed in the prone position but was adapted to suit the pregnant participants and was therefore performed with the participant in a side-lying position. The hips and knees were placed in a comfortably flexed position and the lordosis of the lumbar spine as close as possible to what was seen in standing position. The examiner (T.S.P.) placed his thumb over the tissues lying posterior to the facet joints of the uppermost L5/S1 segment and applied an anteriorly directed force. The examiner observed for a painful response (muscle guarding, apprehension) while applying the pressure, and the subject was asked whether any pain was detected at the stimulation site and/or at sites adjacent or distal to the stimulation site. This was repeated for the L4/L5 segment and then for the consecutive segments above, running the length of the lumbar spine up to the T12/L1 segment. The subject was asked to roll over, and the same procedure was then repeated on the other side. The first instance the stimulation was reported as painful, the pressure was relieved and the test registered as being positive. This was done to avoid unnecessary discomfort for the participants during and/or after the test. Pain provocation tests for the low back have been shown to have excellent sensitivity and specificity when a verbal response is given.[72] For data analysis, the values from both sides (left and right) were added.

SIJ Pain Provocation Tests

The pain provocation tests have been shown to have good sensitivity and specificity (94% and 78%,

respectively) for diagnosing SIJ pain and differentiating it from other potential sources when used together as a group of tests.[51] The battery of tests consisted of the following:

1. A modified version of the sacral thrust was performed with the subject in a side-lying position. A force was applied in a posterior-anterior direction on the center of the sacrum, causing an anterior shearing force of the sacrum against both ilia.
2. The compression test was performed during which the subject lay on the side with hips and knees in a comfortable, flexed position. The examiner applied a force vertically downward on the anterior tip of the iliac crest causing bilateral compression on the SIJ.
3. The thigh thrust test was performed with the subject lying supine with the hip and knee flexed at 90° and slightly adducted. With one hand on the sacrum, the examiner used the other hand to apply pressure on the knee, along the line of the femur, resulting in a unilateral posterior shearing force to the SIJ.
4. The distraction test was performed during which the subject lay in supine position. The examiner applied a posteriorly directed force to both the anterior superior iliac spines, causing bilateral distraction of the anterior aspects of the SIJ.
5. Gaenslen's test was performed with the subject in supine position with one leg hanging over the edge of the bench and the other flexed toward the chest. Firm pressure was applied to the flexed knee with counterpressure applied to the hanging leg toward the floor. This was repeated on both sides sequentially, causing a posterior rotation force to the SIJ on the side of the flexed knee while causing an anterior rotation force on the extension side.
6. Additionally, the Patrick–Faber test was performed with the subject lying supine on the bench and the examiner standing next to the subject on the side being tested. The examiner brought the subject's ipsilateral hip and knee into flexion and positioned the heel slightly above the knee on the opposite limb and then fixated the contralateral anterior superior iliac spine to ensure that no rotation occurred in the lower back. The ipsilateral knee was then lowered toward the table and light overpressure applied to the subject's knee at the end of range. With each test, the subject was asked if any pain was experienced in the lumbopelvic region and/or if any of the tests reproduced familiar symptoms.

Four of the tests (sacral thrust, compression test, distraction test, and the Gaenslen's test) stress both SIJs simultaneously, whereas the other 2 are mostly unilateral.[52] To account for a possible unilateral positive response, it was recorded whether the subject had a positive test on one side or both. Therefore, the maximum amount of positive tests was 9. The first instance any pain was reported, the procedure was stopped and the test registered as positive.

The pain provocation tests were deemed positive or negative as per usual clinical best practice based on whether they provoked familiar "clinical" pain in the participant.

ASLR Test

The ASLR test is considered a valid and reliable tool to assess the ability to transfer weight between the upper body and lower extremities[60] and is commonly used in studies involving patients suffering from LPP.[11,57] When performing the test, the subject was instructed to lift 1 leg at a time approximately 20 cm above the bench[19] and hold it steady for 5 seconds. When the leg returned to the bench, the subject was asked to rate the difficulty of the task using a 6-point Likert-type scale (0 = not difficult at all, 1 = minimally difficult, 2 = somewhat difficult, 3 = fairly difficult, 4 = very difficult, 5 = unable to perform).[58] The order for which leg was lifted first was randomized, and the subject was asked to perform the task 3 times consecutively on each side, with a 30-second interval between rounds.

Questionnaires

Prior to the clinical assessment and QST session, all subjects were asked to complete a set of self-report questionnaires addressing pain intensity, disability, and emotional, physical, and mental health. The questionnaires were kept concealed and the assessor (T.S.P.) was blinded to their outcome (ie, participant's pain status). After the physical tests had been performed, demographic information was registered along with a short standardized interview adapted from Scholz et al[82] with questions regarding preexisting pain conditions, menstrual pain, the temporal characteristics of pain, aggravating factors, and painful and nonpainful sensations.

In the questionnaires, the subjects were asked to report their average pain related to the lumbopelvic region over the previous week using an NRS (0 = no pain, 10 = worst imaginable pain). The Pelvic Girdle Questionnaire (PGQ) was included as a validated tool to assess the symptoms and disability of subjects in pregnant and postpregnancy populations,[89] and subjects answered questions regarding both problems with functional activities and perceived symptoms. The results of the questionnaire are given in percentages, where higher numbers indicate higher levels of disability. The Short Form–36 Health Survey (SF-36) was used to measure health-related quality of life,[102] and it is one of the most widely used tools to assess different patient populations across several health domains.[26] The outcome of the questionnaire in this study was used to indicate the overall physical and emotional health. Lower scores in each category represent a poorer health status. All subjects filled out the short form of the Depression Anxiety Stress Scales (DASS-21), a valid and reliable tool to measure emotional functioning,[36,69] in which higher scores in each dimension indicate higher levels of depression, anxiety, and stress. Sleep quality was assessed using the Pittsburgh Sleep Quality Index, which has been shown to be a valid and reliable tool to assess sleep disturbance,[6,13] and higher numbers indicate poorer overall quality of sleep. The Tampa Scale of

Kinesiophobia was used to quantify the fear of movement and injury; it has been validated and is considered reliable for use in low back pain populations.[77,96,103] Here, the lower the score, the less fear of movement. Finally, all subjects filled out the Pain Catastrophizing Scale, which has been shown to be a valid and reliable tool to quantify the extent of catastrophic cognitions in relation to past painful experiences.[68,90] Higher scores indicate a greater tendency toward catastrophic cognitions.

After the clinical tests and QST measurements, the main researcher (T.S.P.) was no longer blinded to the participant's pain condition and, when relevant, the subjects were asked to fill out a body chart indicating their pain areas. On the body chart, the subjects were asked to indicate both the area where they had pain related directly to their pregnancy and also pain areas unrelated to their condition (eg, preexisting pain areas). For the purpose of differentiating between LPP and other pain areas, all pain areas below the thoracolumbar junction and above the gluteal lines as well as pain overlying the pubic symphysis and groin were defined as LPP (Fig 1A). Based on previous studies where higher disability levels are linked with pain in multiple areas of the pelvic girdle,[35,74] pain in the anterior and pain in the posterior pelvic girdle were analyzed separately. Specific attention was paid to whether participants had pelvic girdle pain only (pain below the level of the posterior iliac crest and above the gluteal fold[97]) or a combination of pelvic girdle pain and low back pain (pain located between the thoracolumbar junction above and the gluteal lines below).

Statistics

To analyze psychometric and psychophysical data to investigate differences between control and pregnancy groups, parametric or nonparametric methods were used based on normality assessment. Parametric data are presented as mean and standard error of the mean (SEM), and nonparametric data as median and interquartile range (.25–.75). Parametric data were analyzed with an analysis of variance (ANOVA), with the Bonferroni test used for post hoc comparisons incorporating correction for the multiple comparisons on parametric data. For nonparametric data, the Mann-Whitney U (MWU) test and Kruskal-Wallis test were used, where the MWU test was used for post hoc comparisons.

All the PPT data passed the Kolmogorov-Smirnov test for normality and were analyzed with a mixed model ANOVA where side (left and right) and site (5 unilateral locations for PPT measurements) were set as repeated factors and group (control, low-pain, high-pain) was set as independent between-group factor. For the control subjects, an additional analysis was run with "phase of menstrual cycle" as an independent factor to account for the potential effect of the menstrual cycle on pain sensitivity. Other QST data as well as pain distribution, the response to pain provocation tests, and the ASLR (Likert-type scale) did not pass the normality test and were therefore analyzed with the MWU and Kruskal-Wallis ANOVA. The questionnaire data for pain intensity (NRS), the PGQ, and DASS-21 did not pass the normality test and were analyzed with MWU and the Kruskal-Wallis ANOVA. The remaining questionnaire data were normally distributed and were analyzed with relevant parametric tests.

To investigate possible associations between the measured variables among the pregnant subjects, a Spearman rank-order correlation analysis or a Pearson's product-moment correlation was performed (based on distribution of data). A Bonferroni correction (level of significance divided by factor 110 based on a 10 × 11 correlation; Table 2) was made to correct for multiple correlations. A statistical significance level of 5% for all analyses was accepted.

Results

The results from 3 subjects in the control group were excluded because of a preexisting pain condition not revealed at inclusion. Furthermore, 2 subjects from the pregnant group were excluded because of gestational diabetes. In total, data from 61 subjects were available for analysis. A detailed description of demographic data along with the results from questionnaires and body charts are presented in Table 1 and Fig 1B. In short, all the groups were of similar size (control group, n = 22; low-pain group, n = 20; and high-pain group, n = 19). Apart from a significant difference in pain intensity, the 2 pregnant groups were similar with regard to age, height, weight, and stage of pregnancy (weeks).

QST

No pain was registered by any of the participants at any of the sites after the light brush (VAS = 0). No significant difference was found between controls and the pregnant groups in response to pin-prick at any of the sites (gastrocnemius: VAS 0 [0–0] (control), low-pain 0 [0–3], and high-pain (pregnant) 0 [0–2]; LDL: 0 [0–3], 0 [0–3], and 0 [0–3]; S2: 0 [0–1], 0 [0–2], and 0 [0–3]; L5: 0 [0–1], 0 [0–3], and 0 [0–1]; and deltoid: 0 [0–0], 0 [0–1], and 0 [0–0]). A significant interaction between group and sites was evident for PPTs (ANOVA: $F[5, 34] = 2.144$, $P < .01$), with both pregnant groups demonstrating increased sensitivity at S2, L5, and deltoideus compared with controls (Bonferroni: $P < .03$; Fig 2). Furthermore, the high-pain group demonstrated more sensitivity to pressure at gastrocnemius and the LDL compared with controls (Bonferroni: $P < .002$). Within the control group, no interaction was found between pain sensitivity and phase of menstrual cycle.

Clinical Tests

A significant interaction between groups and number of positive pain provocation tests for the lumbar spine was found when comparing the groups (Kruskal-Wallis $H[2, 61] = 18.6$, $P < .0001$), where both pregnant groups had a significantly greater number of positive pain

Table 1. Demographics of Participants Included in the Study and Results From Questionnaire Data (n = 61)

Characteristics	Control Group (n = 22)	Low-Pain Group (n = 20)	High-Pain Group (n = 19)
Age, y (range)	28 (20–39)	31 (26–45)	32 (25–40)
Height, cm (range)	167 (154–183)	169 (158–179)	168 (152–179)
Weight, kg (range)	61.3 (50–77)	78.9 (62–111)	77.6 (57–89)
Previous pregnancies (n)			
None	0	13	16
One	0	7	1
Two	0	0	2
Primary dysmenorrhea (% of subjects)	40.9	60	95**
Weeks into pregnancy (range)	N/A	28 (15–40)	31 (15–39)
Low back and pelvic girdle pain (n)			
No pain	N/A	7	0
Low back pain only	N/A	3	3
Pelvic girdle pain only	N/A	3	3
Low back and pelvic girdle pain	N/A	7	13
Previous history of LPP (n)	N/A	8	12
Average pain (0–10 NRS) (IQR)	N/A	1.3 [1.0–2.3]*	4.0 [3.5–5.5]**
DASS-21 (IQR)			
Depression (0–21)	0 [0–2]	2 [0–3]	2 [0–5]*
Anxiety (0–21)	0 [0–2]	4 [2–6]*	4 [2–6]*
Stress (0–21)	4 [0–8]	6 [2–10]	8 [6–18]*
Tampa (±SEM) (11–44)	24.9 ± 1.3	30.4 ± 1.3*	34.4 ± 1.2*
Pain Catastrophizing Scale (±SEM) (0–52)	6.0 ± 1.4	6.0 ± 1.3	10.0 ± 2.2
SF-36 (±SEM)			
Physical health (100–0)	94.6 ± 1.5	68.1 ± 3.3*	53.1 ± 3.2**
Emotional health (100–0)	85.1 ± 2.9	80.2 ± 1.3	65.1 ± 4.2**
Sleep quality (±SEM) (0–21)	3.9 ± .5	6.2 ± .8	8.4 ± 1.4*
PGQ disability (IQR) (0–100)	0 [0–0]	17 [6–29]*	48 [24–61]*

Abbreviation: IQR, interquartile range.
NOTE: Data are presented as either mean (standard error of the mean, SEM) or median (IQR).
*$P < .05$, significant difference compared with controls.
**$P < .05$, significant difference compared with control and low-pain groups.

provocation tests compared with controls (low-pain group, MWU: $P < .001$; and high-pain group, MWU: $P < .001$; Fig 3A). For the SIJ pain provocation tests, a significant group difference was also found (Kruskal-Wallis H[2, 61] = 35.1, $P < .0001$), where both pregnant groups had a significantly greater number of positive pain

Table 2. Correlations in Pregnant Subjects Between Clinical Orthopedic Tests and Psychophysical and Psychometric Variables

			Pain provocation tests			PPTs				
Variables	Average pain	PGQ	SIJ	Lumbar spine	ASLR	Gastrocnemius	LDL	S2	L5	Deltoid
Average pain	–	.61*	.52	−.01	.36	−.23	−.30	−.14	−.04	−.29
PGQ	.61*	–	.67*	−.02	.45	−.16	−.23	.03	−.01	−.32
Stage	.18	.39	.32	.18	.29	−.26	−.22	−.04	−.10	−.26
Depression	.19	.36	.40	.12	.22	−.05	−.03	.13	−.17	−.23
Anxiety	.15	.14	.22	.10	.09	−.06	−.18	−.12	−.10	−.33
Stress	−.03	.01	−.01	−.09	−.06	.17	.07	.06	.01	−.01
Sleep quality	.39	.37	.46	.27	.22	−.13	−.30	−.11	−.20	−.19
PCS	.30	.39	.32	−.29	.06	−.06	−.09	−.04	−.03	−.14
Tampa	.33	.34	.08	−.19	.11	−.17	−.27	−.25	−.05	−.19
Physical health	−.52	−.67*	−.56*	−.05	−.63*	.17	.18	.03	−.08	.37
Emotional health	−.42	−.56*	−.44	.01	−.25	.003	.12	−.10	−.04	.17

Abbreviation: PCS, Pain Catastrophizing Scale.
NOTE. The variables analyzed were disability (PGQ), average pain intensity (NRS scores), ASLR (response to the ASLR test), pain provocation tests (SIJ), PPTs (LDL: long posterior sacroiliac ligament; S2: lateral to S2; L5: lateral to L5; deltoid: musculus deltoideus), and the outcome of questionnaire data (depression, anxiety, and stress from DASS-21, sleep quality from the Pittsburgh Sleep Quality Index, Tampa Scale of Kinesiophobia, PCS, and physical and emotional health from the SF-36 health survey). Spearman or Pearson correlations were investigated based on normality of data. Significant correlations are indicated (*$P < .05$, Bonferroni corrected).

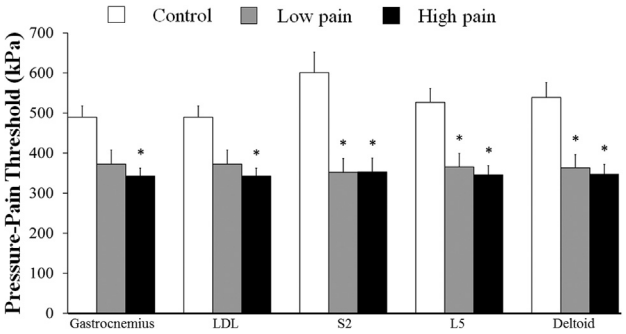

Figure 2. Mean (±SEM, n = 61) PPTs for side 1 and side 2 at the 5 assessment sites (gastrocnemius, long posterior sacroiliac ligament [LDL], lateral to S2, lateral to L5, and at the deltoideus muscle). PPT values are presented as an average between sides 1 and 2. The PPTs are shown for control subjects (open bars) and pregnant subjects with low (gray bars) and high pain intensity (black bars). Significant difference compared with controls (*Newman-Keuls: $P < .05$).

provocation tests compared with controls (low-pain group, MWU: $P < .001$; and high-pain group, MWU: $P < .0001$; Fig 3B). A significant interaction between groups and the Likert-type scale score was found for the ASLR test (Kruskal-Wallis H[2, 61] = 17.4, $P < .0002$), where the pregnant subjects from the high-pain group reported more difficulty when performing the ASLR than controls (MWU: $P < .0001$; Fig 3C). Despite being asymptomatic, 8 subjects from the control group (36%) rated the ASLR as 1 to 2 (minimally to somewhat difficult).

Questionnaire Data

A significant difference was found between groups for average pain (NRS) (Kruskal-Wallis H[2, 61] = 53.9, $P < .0001$) where both the low-pain and high-pain groups reported significantly more pain than controls (MWU: $P < .001$ and $P < .0001$, respectively). As expected, the high-pain group had significantly more pain than the low-pain group (MWU: $P < .001$; Table 1). For disability, a significant group difference was also found (Kruskal-Wallis H[2, 61] = 42.5, $P < .0001$), where both pain groups scored higher on the PGQ than controls (MWU: $P < .0002$).

For the SF-36 questionnaire, a significant group difference was found (ANOVA: F[2, 58] = 16.6, $P < .0001$) where both pain groups reported poorer physical health than controls (Bonferroni: $P < .0001$) and the high-pain group had poorer emotional health ratings than controls (Bonferroni: $P < .001$). Additionally, the high-pain group reported significantly poorer physical (Bonferroni: $P < .05$) and emotional health status (Bonferroni: $P < .05$) than the low-pain group (Table 1). The results from the DASS-21 showed a significant group difference for the subscales measuring depression (Kruskal-Wallis H [2, 61] = 10.5, $P < .01$), anxiety (Kruskal-Wallis H[2, 61] = 13.1, $P < .001$), and stress (Kruskal-Wallis H[2, 61] = 7.3, $P < .03$). Post hoc testing revealed that the high-pain group scored higher on depression than controls (MWU: $P < .01$), both pain groups scored higher in anxiety than controls (MWU: $P < .01$), and the high-pain group had more stress than controls (MWU: $P < .02$). For sleep quality, a significant group difference was found for the Pittsburgh Sleep Quality Index (ANOVA: F[2, 58] = 5.8, $P < .005$), where the high-pain group had significantly poorer sleep quality than controls (Bonferroni: $P < .004$). Significant group differences were found for the Tampa Scale of Kinesiophobia (ANOVA: F [2, 58] = 14.2, $P < .0001$), where both pain groups scored significantly higher than controls (Bonferroni: $P < .01$) but no significant group differences were found for the Pain Catastrophizing Scale (ANOVA: F[2, 58] = 1.7, $P < .2$).

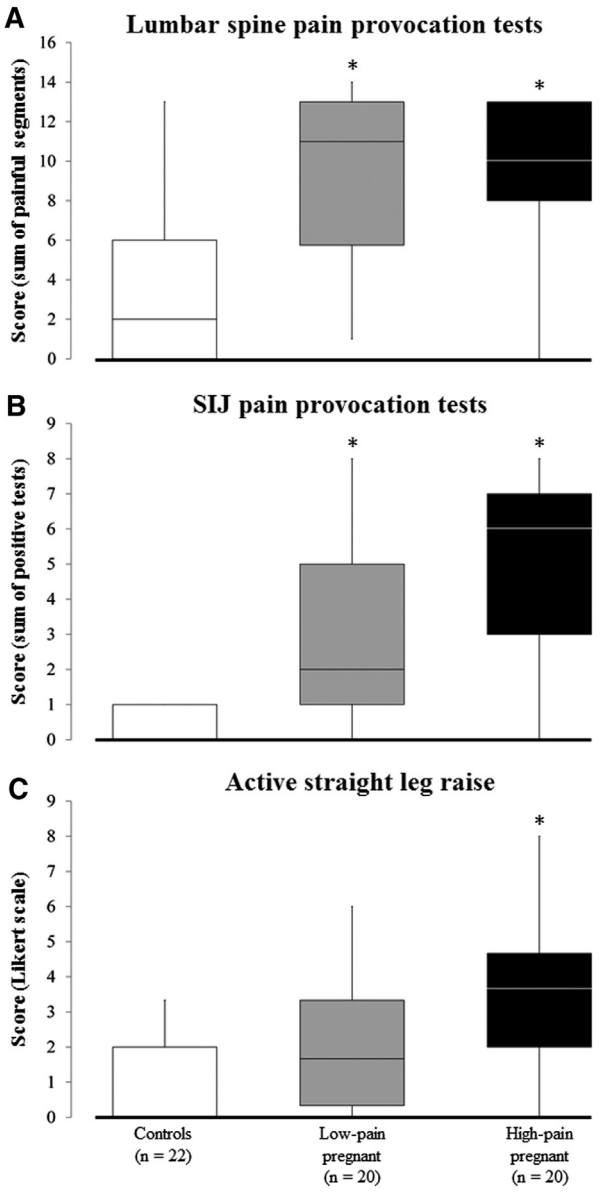

Figure 3. Median (±interquartile range, n = 61) for the number of painful segments in the low back **(A)**, the sum of positive SIJ pain provocation tests **(B)**, and Likert values after performing the ALSR test **(C)**. Values are presented as raw values, where higher values indicate a worse outcome in the respective test. The results from the 2 tests are shown for the control subjects (open bars), the low pain group (gray bars), and the high-pain pregnant subjects (black bars). Significant difference compared with controls (*MWU: $P < .001$).

Correlation Between Pain Intensity, Disability, and Provocation Tests

For pregnant subjects, a significant positive correlation was found between the outcome of the SIJ pain provocation tests and disability (Table 2). Although significant differences were found between the pregnant subjects and controls, the lumbar spine pain provocation tests did not correlate with any of the measured variables. There was a negative correlation between disability and physical and emotional health (SF-36) such that higher levels of disability were correlated with poorer health-related quality of life ratings. Disability also correlated positively with average pain intensity. PPTs did not significantly correlate with any of the measured variables.

No correlation was found between number of previous pregnancies, previous history of LPP, history of dysmenorrhea, and any of the measured variables.

Discussion

This is the first study to investigate the somatosensory profile in pregnancy and compare it with the outcomes of commonly used manual clinical tests, as well as self-reported physical and emotional health. The findings indicate that widespread deep-tissue pressure hypersensitivity is a general finding in this pregnant cohort with subtle differences in pain sensitivity and psychometric factors when comparing low-pain-intensity and high-pain-intensity pregnancy groups with controls. However, pressure hypersensitivity was not associated with disability and the outcome of manual clinical tests.

Widespread Deep-Tissue Hyperalgesia

The current data indicate that widespread mechanical hypersensitivity is a feature of pregnancy in this cohort regardless of levels of pain or disability. Similar findings have been reported in pregnancy-related LPP[8] as well as in chronic spinal pain,[30,84] but the underlying mechanisms are poorly understood.

In pregnancy, the female body undergoes postural, hormonal, and reproductive organ changes. Although the influence of the hormone relaxin on LPP has been negated,[2,4,100] the gonadal hormones, which are rapidly upregulated in pregnancy,[1,37] can directly increase pain sensitivity, potentially via modulation of responses in primary afferents, in dorsal horn neurons, and at supraspinal sites.[92] On the other hand, during pregnancy, gonadal hormones have also been reported to have an analgesic role,[18] potentially resulting in decreased pain sensitivity. As hormonal changes are fairly consistent for all pregnant women, they are unlikely to fully account for the pain and disability observed.

In a study by Bajaj et al,[8] it was shown that pregnant women suffering from LPP had pain hypersensitivity in superficial and deep tissue in the lumbopelvic region as well as distant to it, indicating widespread hypersensitivity. Interestingly, differences in deep tissue sensitivity were mostly maintained throughout all trimesters, indicating that group differences were not mediated through biomechanical or hormonal changes.[8] This is in line with the current study, where both pain groups were at a similar stage of pregnancy, distributed over the second and third trimesters, indicating that the women had undergone comparable physical changes at group level with similar variability within each group. Furthermore, the stage of pregnancy did not correlate with disability, pain, and hypersensitivity, indicating that increased pain sensitivity is likely related to several factors, including altered biomechanics (of somatic and visceral tissues) and changes in the hormonal status.

Manual Clinical Tests

The current findings show that pregnant women are more sensitive than nonpregnant controls to pain provocation tests of the SIJ and the lumbar spine, regardless of pain status. This may be clinically useful in planning management considering the relationship found between disability and positive SIJ pain provocation tests, as this may indicate that increased sensitivity of SIJ structures affects the individual's ability to function normally in pregnancy. The provocation tests traditionally used have been validated by using intra-articular blocking protocols,[50,72] but this neglects the potential contribution from extra-articular structures,[91] which may be sensitized as demonstrated here and elsewhere.[70] However, pressure algometry has the most impact on moderately deep structures,[24] potentially explaining the lack of association between hypersensitivity and the outcome of clinical tests, which also stress the structures not targeted by pressure algometry.

The women reporting higher pain levels had significantly more difficulty performing the ALSR than controls, a finding consistent with recent reports showing that ASLR difficulty correlates with pain intensity[71] and is related to reported physical health (Table 2). These findings support the role of the ASLR test, reflecting impaired motor control of the lumbopelvic region in the presence of clinically significant LPP.[11]

Clinical Profile in Pregnancy

In this study, disability and pain were significantly related whereas mechanical hypersensitivity did not correlate with either of these variables, in line with what has previously been concluded in spinal pain patients.[39]

The number of previous pregnancies and history of LPP episodes have been linked with pregnancy-related LPP.[3,80] However, although approximately half of the pregnant subjects in both pain groups had previously experienced LPP, more women in the low-pain group had previously given birth (n = 7) than in the high-pain group (n = 3). Moreover, more subjects from the high-pain group had pain in the low back and pelvic girdle (n = 13) than in the low-pain group (n = 3, Table 1), which is in contrast to previous findings,[75] where pelvic girdle pain alone caused similar disability as low-back and pelvic girdle pain combined. This discrepancy, however, may be related to differences in accuracy in filling out the body charts when comparing the 2 studies. Interestingly,

a history of primary dysmenorrhea was most common in the high-pain group (95%; Table 1). This condition has been previously related to a widespread increase in sensitivity of somatic structures,[7,31] probably because of changes in central pain processing,[43,93,95] which may also have contributed to the widespread mechanical hypersensitivity observed in this study. Nociceptive activity related to painful menstruation may therefore potentially prime the nociceptive system, rendering it more sensitive to a new noxious event as indicated recently.[43]

The pregnant subjects had significantly higher scores for anxiety than controls, with the high-pain group additionally reporting more depressed mood, more stress (DASS-21), and worse emotional health (SF-36) (Table 1). Despite group differences the values fall within the range of normal to moderate[36,54,55] and are similar to what has been demonstrated in a healthy pregnant population[81] for the DASS-21. For the SF-36, the values were somewhat lower than previously reported among healthy pregnant women[45,53] but slightly higher than among pregnant women with clinically diagnosed spinal pain.[25] Nevertheless, the significance of addressing these factors early may be important given the high rate of emotional distress postpartum among untreated subjects[5] as well as the increased risk of developing LPP in late pregnancy.[9,76] Although emotional factors such as low mood have been reported to account for a significant proportion of disability during everyday activities in pregnancy,[12,47] no relationship was found between these factors and other outcome measures in the present study. This discrepancy may be related to the relatively low levels of depression and anxiety measured here or a lack of power to determine such differences. Furthermore, sleep is known to be an independent predictor of depression and pain in pregnant[21,65] and nonpregnant[63] populations. Accordingly, only the high-pain group had poorer sleep quality than controls.

Possible Pain Mechanisms in Pregnancy-Related Lumbopelvic Pain

Recent experimental findings[70,71] have implicated the significant role of the LDL on the outcome of clinical tests, which is in line with clinical observations,[98] but pain from the structure may be induced by unfavorable biomechanical loading.[99] Ongoing pain from the area may, over time, lead to hypersensitivity of other remote regions of the body,[32] which may be facilitated further by systemic factors affecting the sensory system through similar pathways. Gonadal hormones can increase pain sensitivity directly (see above) but also indirectly through their ability to modulate emotional factors. This modulation mainly affects the dopamine, norepinephrine, and serotonin systems,[27] but increased sensitivity to estrogenic signaling has also been described.[56] Experimental and clinical studies have revealed an association between increased pain sensitivity and poor emotional functioning,[17,20,46,83] but emotional factors are also closely linked with sleep quality in nonpregnant populations.[41,42,83] Moreover, an upregulation of proinflammatory biomarkers seems to occur in sleep-deprived nonpregnant[14,40,87] and pregnant populations[64,66] and in populations with anxiety disorders[62] and depression,[94] which may contribute to the widespread hypersensitivity. Additionally, disturbed sleep can modulate the endogenous inhibitory pain control system, causing a shift toward nociceptive facilitation,[20,86] potentially explaining the increased sensitivity to innocuous stimuli as well as spontaneous pain.

In summary, LPP, disability, and widespread hypersensitivity observed in pregnancy may relate to various biophysical and psychosocial factors that may, through shared neurophysiological mechanisms, contribute to hypersensitivity of the nociceptive system.

Limitations

The pregnant women were recruited regardless of pain and disability levels in order to gain a representation of a normal pregnant population. However, although the assessor was blinded to the pain and disability levels of the participants, it must be acknowledged that this may be difficult given the clinical presentation of pregnant women in pain. A majority of the pregnant participants participated in water aerobics classes at physiotherapy clinics possibly because of an underlying pain condition. This may reflect a recruitment bias in which women with pain but without high levels of disability volunteered for the study. As the sample size was relatively small, future studies should aim at including a larger cohort and following the cohort through the different stages of pregnancy.

Conclusion

The clinical profile of pregnant women in this study was characterized by widespread deep-tissue hypersensitivity, positive manual clinical tests, sleep disturbance, and lower levels of self-reported physical and emotional health. In addition to accounting for potential hypermobility of the SIJ, future studies should focus on these factors in early pregnancy in a larger cohort to study causality and predictive value for the development of LPP. The lack of correlation between the main outcome variables indicates that several factors, biophysical and psychometric, contribute to the condition, and this should be accounted for when implementing clinical management of pregnant women with LPP.

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