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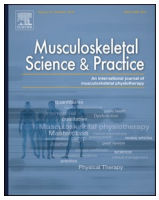

Original article

Differences in balance control despite self-reported resolution of pregnancy-related pelvic girdle pain. A cross-sectional study

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ABSTRACT

Background: Motor control patterns are altered when women with pregnancy-related pelvic girdle pain (PGP) experience pain. In low back pain, these adaptations can persist after recovery.
Objectives: This study aimed to assess balance control in postpartum women with and without a history of PGP during pregnancy.
Design: Cross-sectional study.
Method: Eighteen postpartum women who reported to be recovered from PGP, and twelve postpartum women without a history of PGP during pregnancy performed two clinical tests: the single leg stance and active straight leg raise test. Primary outcomes were ground reaction forces measured with a force platform.
Results: Multiple linear regression analyses showed smaller lateral displacement ($\beta = -11$cm; 95%CI: 19 to −3; $p = 0.008$) and lower displacement velocity of the Centre of Pressure (COP) (Ratio of Geometric Means (RGM) 0.76; 95%CI: 0.59 to 0.99; $p = 0.043$) during single leg stance in the participants with a history of PGP compared to participants without a history of PGP. Push-off force ($\beta = -4.8$ N; 95%CI: 22.0 to 12.5; $p = 0.57$) and asymmetry of push-off force (RGM 1.77; 95%CI: 0.62 to 5.04; $p = 0.27$) did not differ between groups. During the active straight leg raise test, no differences in lateral displacement ($\beta = 3$ cm; 95%CI: 3 to 8; $p = 0.30$) and COP displacement velocity (RGM 1.03; 95%CI: 0.70 to 1.52; $p = 0.87$) were observed.
Conclusions: Although the women with a history of PGP considered themselves recovered, their balance control during single leg stance was poorer compared to those without a history of PGP. No differences were found during the active straight leg raise test.

1. Introduction

Pelvic Girdle Pain (PGP) is a common musculoskeletal disorder during and after pregnancy. The underlying pathophysiology of PGP remains poorly understood (Wuytack et al., 2018; Meijer et al., 2020b). The reported prevalence of PGP varies widely (from 1 to 43%) between the postpartum stage and three years after childbirth (Albert et al., 2002; Norén et al., 2002; Mogren, 2006; Röst et al., 2006). At eleven years after childbirth, the prevalence is 10.7% (Elden et al., 2016). According to the European Guidelines for PGP (Vleeming et al., 2008), PGP is experienced deep in the sacral, sacroiliac, gluteal and/or pubic region. The pain may refer to the thighs, but not with the typical distribution of sciatica, and is often accompanied by low back pain. Pain typically increases during weight-bearing activities (Mens et al., 1996). The endurance capacity for standing, walking and sitting is often diminished (Vleeming et al., 2008).

Approximately 80–90% of women report recovery of PGP within six to twelve weeks after delivery (Elden et al., 2016; Gausel et al., 2020). However, in clinical practice, we often encounter women with a history of PGP who may be satisfied with their functional status despite lingering pain. This is in line with the classification of Gausel et al. (2020) who consider 'bothersome PGP up to two days per week' as

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'substantial recovery'. Similar findings are reported for people with low back pain (Verkerk et al., 2013, 2015). Hence, self-reported recovery may not be the equivalent of full recovery or being free of PGP.

We hypothesise that lingering pain and disability in women who consider themselves recovered from PGP may be associated with differences in motor performance. Several studies report aberrant motor control in postpartum women with PGP (Beales et al., 2009, 2010a) compared to non-symptomatic control participants (Beales et al., 2010a; Sjödahl et al., 2016; Mens and Pool-Goudzwaard, 2017). Aberrant motor control of the pelvic floor muscles is present in women with sacroiliac joint pain (O'Sullivan et al., 2002) and in women with PGP, which is associated with urinary incontinence (Pool-Goudzwaard et al., 2005). Studies on motor control after recovery of PGP are lacking. Therefore, the aim of this study was to examine and compare motor performance in postpartum women who consider themselves recovered from PGP and postpartum women without a history of PGP. We hypothesised that motor performance would be poorer in women with self-reported recovery of PGP in comparison to women who never experienced PGP.

2. Materials and methods

2.1. Participants

Thirty women participated in this cross-sectional study. Participants were eligible to participate if they were between 20 and 45 years of age and minimally 12 weeks to maximally 24 months postpartum of their youngest child. Convenient sampling was used to recruit participants from the general population, using announcements on community notice boards and social media. Also, referral sampling was used, as participating women were asked to share the study among their acquaintances. If inclusion criteria were met, participants were enrolled into one of two groups, based on self-reported recovery from PGP. For the remainder of the paper, 'women with self-reported recovery from PGP' will be referred to as 'participants with a history of PGP' and 'women without a history of PGP' as 'healthy controls'. Women in the 'history of PGP-group' had to have actively sought medical or allied health treatment for PGP during pregnancy, and had to consider themselves recovered from PGP. Exclusion criteria included: receiving or having received treatment in the past two months for any musculoskeletal condition (including PGP), a history of surgery to the spine, pelvis, or lower limb, given birth via caesarean section or insufficient command of the Dutch language to understand and complete the questionnaires. The participants' characteristics are listed in Table 1.

Written informed consent was obtained from all participants prior to the commencement of the study. Ethical approval was received from the Scientific and Ethical Review Board of VU University Amsterdam (VCWE-2019-007). The study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and is reported in accordance with the STROBE checklist (von Elm et al., 2008).

Table 1
Demographic data and clinical characteristics.

	History of PGP (n = 18)	Healthy controls (n = 12)	p-value
Age (years)	32.6 (2.6)	31.9 (4.7)	0.63 [a]
Weight (kg)	68.0 (61.3–85.0)	65.5 (57.8–69.0)	0.29 [b]
Height (m)	1.72 (0.07)	1.74 (0.05)	0.50 [a]
BMI (kg/m^2)	22.5 (21.1–26.5)	21.3 (20.0–23.7)	0.087 [b]
Parity (primipara)	11	10	0.25 [c]
Age at last delivery (years)	31.7 (2.7)	30.9 (4.5)	0.59 [a]
Time since last delivery (months)	11.1 (5.3)	11.8 (4.7)	0.74 [a]
Urinary incontinence (Yes)	8	6	0.77 [d]
Disability (QBPDS score)	10 (3–20.5)	0 (0–0)	<0.001 [b]
Mean pain intensity over past week (NPRS score)	0.5 (0–3.3)	0 (0–0)	0.039 [b]

Values are mean (SD) or median (IQR). PGP: Pelvic Girdle Pain; BMI: Body Mass Index; QBPDS: Quebec Back Pain Disability Scale; NPRS: Numeric Pain Rating Scale; a: independent sample *t*-test; b: Mann-Whitney *U* test; c: Fisher's exact test; d: Pearson Chi-Square test.

2.2. Tasks

Two asymmetrical leg lifting tasks that are frequently part of the physical examination of women with PGP were evaluated: the Single Leg Stance (SLS) and the Active Straight Leg Raise (ASLR) test. Both tasks were performed six times, three times on both legs. To control for order effects and fatigue, left and right leg and the order of the tasks were randomised.

The SLS was evaluated because weight bearing often provokes symptoms in people with PGP (Vleeming et al., 2008; Fagevik Olsén et al., 2021). For this task, women stood upright on a force plate, with their feet parallel and hip-width apart. They were looking forward during the task and their arms hung relaxed by their side. Participants were instructed to lift their leg towards approximately 90° of hip and knee flexion, and to maintain this position for 5 s. The position of the feet on the force plate was marked with tape, enabling participants to return to the same starting position after each trial. The tape was also used to measure stance width for correction of the data on SLS.

The ASLR is a recommended functional test for PGP (Mens et al., 2001; Vleeming et al., 2008; Fagevik Olsén et al., 2021). Women were asked to lie supine on a platform with an integrated force plate, with their feet hip width apart and their pelvis centred on the force plate. They were asked to lift their foot approximately 20 cm above the platform, at their own comfortable speed and without bending their knee. The participant rated the difficulty of the task on a six-point scale ranging from 0 (not difficult at all) to 5 (unable to do) (Mens et al., 2001).

2.3. Equipment and outcome measures

Ground reaction forces during the two tasks were measured with a force plate (Type 9281E, Kistler Instruments Corp., Amherst, NY). The output of the four load cells of the force plate was used to calculate three primary outcome measures: 1) lateral displacement of the Centre of Pressure (COP) (in mm) during SLS and ASLR, 2) COP displacement velocity (in m/s) during SLS and ASLR and 3) push-off force of the leg (in N) during SLS. The COP parameters reflect an individual's ability to maintain balance control during single leg movement tasks, such as the SLS (Liebenson et al., 2009; Aldabe et al., 2016) and ASLR (Crasto et al., 2020).

2.4. Questionnaires

Prior to performing the SLS and ASLR, participants completed questions regarding their sociodemographic and clinical background. In addition, they completed three questionnaires on secondary outcome measures: 1) Disability was assessed with the Quebec Back Pain Disability Scale (QBPDS) (Schoppink et al., 1996). The QBPDS is a 20-item self-administered questionnaire evaluating the difficulty of twenty activities of daily life (ranging from 0 (not difficult at all) to 5 (unable to do)). The scores range from 0 to 100, with higher numbers representing greater levels of disability. The QBPDS was originally developed to assess pain-related disability in people with low back pain (Kopec et al., 1995) and is valid and reliable (Schoppink et al., 1996; Smeets et al., 2011). As suggested in clinical guidelines (Vleeming et al., 2008; Bastiaenen et al., 2017), the QBPDS can be used in an adapted form for patients with PGP, replacing the words 'back pain' with 'pelvic pain' (Damen et al., 2001; Mens et al., 2002; de Groot et al., 2008; Ronchetti et al., 2008). Measurement properties for this adapted form of the QBPDS are unavailable. 2) Participants rated their average pain

intensity during the last week on a Numeric Pain Rating Scale (NPRS), ranging from 0 (no pain) to 10 (worst imaginable pain). The NPRS is a reliable and valid measurement of pain intensity (Ferreira-Valente et al., 2011) and is widely used in PGP research (Sakamoto and Gamada, 2019). 3) The 3 Incontinence Questions questionnaire (3IQ) was used to assess the presence of urinary incontinence. The 3IQ is a valid instrument to assess the presence of incontinence and to differentiate between stress, urge and mixed urinary incontinence (Brown et al., 2006).

2.5. Sample size

To the best of our knowledge, no previous study has reported differences between postpartum women with and without a history of PGP for our primary outcome measures. Hence, the sample size could not be calculated a priori in a meaningful way. Therefore, we based our sample size on the median sample size of studies included in a relevant systematic review (Ruhe et al., 2011). This method to estimate the sample size in the absence of specific data has been applied before (Tompra et al., 2021). The systematic review by Ruhe et al. (2011) summarises differences in COP parameters between people with low back pain and healthy participants during normal stance. The mode and mean sample size were 10 and 17 participants, respectively, for both the study and control groups. These numbers have been used to determine the sample size of our study, so the aim was to include 10 to 17 participants for each group.

2.6. Data analysis

To assess differences in clinical characteristics between groups, independent t-tests were used. In case of violation of normality assumptions, we used Mann-Whitney and Chi-square tests for continuous and dichotomous or categorical variables. When assumptions for Chi-square tests were violated, Fishers' exact tests were used.

Multiple linear regression was used to analyse the association between women with and without a history of PGP on three continuous outcomes: 1) lateral displacement of COP (in mm), 2) velocity of displacement of COP (in m/s), 3) difference in push-off force (in N). Outcomes 1 and 2 were calculated in two conditions: SLS and ASLR; outcome 3 was calculated only for SLS. This resulted in five linear regression models. The regression coefficient of a multiple linear regression model with a continuous outcome and a dichotomous variable indicates the difference between groups for the dichotomous outcome, corrected for the other variables in the model.

Since the total sample size was thirty, a rule of thumb to prevent optimism in the models should be to assess no more than (*n/10)* covariates. So, to prevent multiple testing effects and finding associations 'by chance', a selection of three variables was made: mean pain intensity over the past week (NPRS score), disability (QBPDS sum score), and presence of urinary incontinence (3IQ).

Since our sample size was small, we chose to assess these variables for effect modification and confounding when significant differences between groups were present. This was the case for mean pain intensity and disability, but not for the presence of urinary incontinence (see Table 1). Confounders were identified using forward selection, using the change in estimate method with a cut-off value of 10%, commonly used in epidemiologic studies (Budtz-Jørgensen et al., 2007; Talbot et al., 2021). In this way, the linear regression models provide insight in balance control of women without a history of PGP, considering pain intensity over the last week and disability.

Linear regression requires normally distributed data. Hence, positively skewed data were log transformed. Accordingly, results of the regression analyses are presented as the ratio of geometric means (RGM) with 95%CI and p-values of the regression analyses on which the RGM and geometric mean difference (GMD) are based. The RGM is calculated as the ratio of the geometric mean of the PGP group to the control group. It can therefore be interpreted as the percentage difference in mean value between the participants with a history of PGP to the healthy controls. For example, a RGM of 1.50 indicates that the mean value of that variable is 50% higher in participants with a history of PGP than in healthy controls.

SLS data were corrected for stance width before further analysis. The transition from double leg stance to SLS involves an initial weight shift prior to the actual lifting of the leg (Hodges and Richardson, 1997; Dingenen et al., 2013). This shift of weight from two legs to one is heavily influenced by stance width. Accordingly, the regression models with measurements during SLS were corrected for stance width first (see Table 2 for uncorrected data on SLS and see crude models for SLS in Table 3, Table 4, and Table 5 for data on SLS that was corrected for stance width). These models were considered crude models for SLS and these were used for further analysis.

3. Results

Due to diligent data collection strategies, there were no missing data. Demographic data and clinical characteristics of the participants are shown in Table 1.

A comparison of the uncorrected mean values of the primary outcome measures between women with a history of PGP and healthy controls is provided in Table 2. Women with a history of PGP show a significant smaller lateral displacement of COP and a larger asymmetry of push-off force during SLS. During ASLR, there are no differences between both groups. No effect modification by mean pain intensity over the past week or disability was present in any of the associations in the analyses.

The crude models for lateral displacement of COP during SLS and ASLR were corrected for confounding by disability. The difference in lateral displacement of COP during SLS between groups in the corrected model was small and significant (see Table 3). The difference in lateral displacement of COP during ASLR between groups was small and not significant in the corrected model (see Table 3).

Both models for COP displacement velocity were corrected for disability. For SLS, the corrected difference between groups was significant (see Table 4). The difference between groups for COP displacement velocity during ASLR was negligible and not significant (see Table 4).

Table 2
Comparison of uncorrected mean values of primary outcome measures between participants with a history of PGP and healthy controls.

	History of PGP (n = 18)	Healthy controls (n = 12)	Mean difference (95%CI)	p-value
SLS				
Lateral displacement COP during SLS (mm)	137 (19)	152 (16)	- 15 (−30, −1)	0.037[a]
COP displacement velocity during SLS (m/s)	0.46 (0.39–0.53)	0.57 (0.44–0.69)	NA	0.059[b]
Push-off force during SLS (N)	50.2 (15.8)	52.1 (19.9)	−1.9 (−15.3, 11.4)	0.77[a]
Difference in push-off force between legs during SLS (N)	6.7 (3.9–14.4)	3.1 (1.3–12.6)	NA	0.048[b]
ASLR				
Lateral displacement COP during ASLR (mm)	27 (6)	25 (5)	2 (−3, 6)	0.37[a]
COP displacement velocity during ASLR (m/s)	0.07 (0.06–0.09)	0.08 (0.05–0.11)	NA	0.39[b]

Values are mean (SD) or median (IQR). PGP: Pelvic Girdle Pain; SLS: Single Leg Stance; COP: Centre Of Pressure; NA: Not Applicable; ASLR: Active Straight Leg Raise test; a: univariate linear regression analysis; b: Mann Whitney *U* test.

Table 3
Comparison of lateral displacement of COP during SLS and ALSR between participants with a history of PGP and healthy controls.

		Crude model		Corrected model*	
		Mean Difference (95%CI)	p-value	Mean Difference (95% CI)	p-value
Lateral displacement of COP (mm)	SLS	−6 (−13, 2)	0.14	−11 (−19, −3)	0.008
	ASLR	2 (−3, 6)	0.37	3 (−3, 8)	0.30

COP: Centre Of Pressure; ASLR: Active Straight Leg Raise; SLS: Single Leg Stance; PGP: Pelvic Girdle Pain; Mean difference: between participants with a history of PGP and healthy controls.* Multivariate regression models corrected for disability.

The model for mean push-off force of both legs during SLS was corrected for disability and pain. The difference between groups in the adjusted model was small and not significant (see Table 5). The data on asymmetry of push-off forces of the right and left leg were positively skewed, so analyses were performed on log-transformed values (LNdiff). This model was corrected for disability and pain. No differences between groups were present (see Table 5).

4. Discussion

The results of this study partially support the hypothesis that motor control is poorer in participants with a history of PGP in comparison to healthy controls. The participants with a history of PGP had smaller lateral displacement and lower COP displacement velocity during SLS. During ASLR, lateral COP displacement and COP displacement velocity did not differ between groups.

The mean lateral COP displacement during ASLR was larger than the values found in the study by Crasto et al. (2020) (e.g., 27 vs 19 mm in asymptomatic people with a positive ASLR test). Differences in results might be because it concerned people with low back pain, rather than PGP. Moreover, the authors did not correct their findings for confounding factors, such as disability or pain intensity. No previous studies have been conducted in women with a history of PGP, or in women with PGP, to compare results.

A reduction in velocity of movement during hip and spine flexion in people with low back pain of sacroiliac origin has been presented before (Bussey and Milosavljevic, 2015). Increased muscle contraction, causing smaller and slower movement, has been observed in patients with PGP (O'Sullivan et al., 2002; O'Sullivan and Beales, 2007). This can be an indication for augmented constraint of movement, known as tight control patterns (Van Dieën et al., 2019). However, a significant reduction of COP amplitudes during a standing postural control task has also been associated with fear (Adkin et al., 2002) and a more conscious control of posture (Huffman et al., 2009). It is plausible that participants recovered from PGP recognised SLS as an activity of daily living that has often caused pain while experiencing PGP. This might, at least in part, explain the fact that no differences on our primary outcome measures were found during ASLR, as the ASLR might not be a recognisable movement for these women.

Notably, our results support the hypothesis that the concept of self-reported recovery can still imply presence of ongoing pain and disability, and that these lingering complaints are associated with differences in motor performance. Women with a history of PGP demonstrated significantly higher scores on mean pain intensity over the last week and disability (see Table 1). The mean difference between groups of lateral displacement of COP during SLS was larger in the model that was corrected for disability than in the crude model (see Table 3). Similarly, correcting for disability decreased the RGM on velocity of displacement during SLS (see Table 4). Motor control is influenced by the perception of the difficulty of the movement (Bialosky et al., 2010; Wertli et al., 2018), and perhaps by the perception of pain and recovery as well. Women in this population did not define recovery from PGP as the total absence of pain and disability. Women with long-term post--partum PGP have lower health-related quality of life, higher levels of anxiety and depression, lower self-efficacy, and are more prone to pain catastrophizing (Elden et al., 2016). A further insight in the patients' perception of PGP and recovery could contribute to our understanding of the role of cognitive function in PGP (Meijer et al., 2020a).

4.1. Strengths and limitations

To our knowledge, this is the first study that compares women with self-reported recovery of PGP to women who do not have a history of PGP, yielding important insights in their interpretation of recovery. Our data show that even though women consider themselves recovered, ongoing pain and disability remain present. Moreover, these lingering complaints significantly influence balance control during SLS. This is an important finding which should be taken into account in future studies and in daily clinical practice. Wu et al. (2004) reported that the prevalence of women suffering from peri and postpartum PGP diminishes by 20% when mild complaints are excluded. Our data show that the

Table 5
Comparison of push-off force in SLS between participants with a history of PGP and healthy controls.

	Crude models			Corrected models*		
	Mean Difference (95%CI)		p-value	Mean Difference (95%CI)		p-value
Mean push-off force both legs (N)	−1.6 (−15.9, 12.6)		0.82	−4.8 (−22.0, 12.5)		0.57
	GMD (95% CI)	RGM (95% CI)	p-value	GMD* (95% CI)	RGM (95% CI)	p-value
LN Difference in push-off force between both sides*	0.7 (−0.2, 1.5)	1.92 (0.81, 4.55)	0.13	0.6 (−0.5, 1.6)	1.77 (0.62, 5.04)	0.27

SLS: Single Leg Stance; PGP: Pelvic Girdle Pain; GMD: Geometric Mean Difference; RGM: Ratio of Geometric Means, calculated as the ratio of the geometric mean of the participants with a history of PGP to the geometric mean of healthy controls; LN: Natural Logarithm. * Multivariate models corrected for disability and pain.

Table 4
Comparison of COP displacement velocity during SLS and ASLR between participants with a history of PGP and healthy controls.

		Crude models			Corrected models*		
		GMD (95% CI)	RGM (95% CI)	p-value	GMD (95% CI)	RGM (95% CI)	p-value
LN COP displacement velocity	SLS	−0.15 (−0.38, 0.08)	0.86 (0.69, 1.08)	0.20	−0.27 (−0.53, −0.009)	0.76 (0.59, 0.99)	0.043
	ASLR	−0.075 (−0.40, 0.25)	0.93 (0.67, 1.28)	0.63	0.030 (−0.36, 0.42)	1.03 (0.70, 1.52)	0.87

COP: Centre Of Pressure; SLS: Single Leg Stance; ASLR: Active Straight Leg Raise; PGP: Pelvic Girdle Pain; GMD: Geometric Mean Difference; RGM: Ratio of Geometric Means, calculated as the ratio of the geometric mean of participants with a history of PGP to the geometric mean of healthy controls; LN: Natural Logarithm. *Multivariate models corrected for disability.

interpretation of statements like these should be taken with caution. It also raises the question whether self-reported recovery is a valid selection criterion or covariate when assessing PGP in future studies.

A limitation of the current study is that compensational movement during the ASLR, such as downward pressure of the non-lifted leg (Beales et al., 2010b; Hu et al., 2010) or shoulders was not measured. This might have introduced an underestimation of differences between groups for the ASLR. For future studies, we recommend the use of multiple force plates to assess compensation strategies.

The size of our sample yielded limitations in relation to secondary outcome measurements used for adjustment of estimates of differences between groups. First, the dichotomisation of the variable for urinary incontinence could have caused the groups to appear similar on this aspect and different forms of urinary incontinence could not be assessed in our models. We aimed to assess the presence of different forms of urinary incontinence with the 3IQ and to include this variable in our models. However, according to the questionnaire, urge incontinence was not present in the present population, and the mixed form only appeared once. However, our sample reflects the high prevalence of post-partum urinary incontinence (Thom and Rortveit, 2010). A recently published systematic review with meta-analysis showed that specifically stress and mixed forms of urinary incontinence are associated with mild back pain and PGP (Bertuit et al., 2021) We recommend further analysis of this aspect in larger studies. Second, a strong mediating effect of pain on disability has recently been revealed in people with low back pain (Mühlhauser et al., 2020). It is conceivable that this also applies for people with PGP. However, our sample size did not allow analysis of this phenomenon. Increasing the sample size in a future study would increase the power of the study and allow analysis of mediation by pain, without compromising the quality of the association models. However, recruitment of postpartum women is difficult. We contacted 101 potential participants of which 79% met the inclusion criteria and were only able to include thirty of them. The main reason was not being able to travel to the lab considering their busy work schedule and taking care of a baby.

5. Conclusions

Motor control during SLS was poorer in women with a history of PGP during pregnancy even though these women consider themselves recovered from PGP. Furthermore, participants who considered themselves recovered from PGP had significantly higher pain and disability scores than participants without a history of PGP, indicating lingering complaints.

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Declaration of competing interest

none.

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