

Center of plantar pressure during gait in pregnancy-related pelvic girdle pain and the effect of pelvic belts

JEANNE BERTUIT^{1*}, CLARA LEYH², VÉRONIQUE FEIPEL²

¹ School of Health Sciences (HESAV), University of Applied Sciences and Arts Western Switzerland (HES-SO), Lausanne, Switzerland.

² Laboratory of Functional Anatomy, Faculty of Motor Sciences, Université Libre de Bruxelles (ULB), Brussels, Belgium.

Purpose: Many pregnant women suffer from pelvic girdle pain (PGP) during pregnancy. Etiologies are multifactorial and affect the joint stability of the sacroiliac joint. Pelvic belts could restore stability and reduce pain during gait. The center of pressure (COP) is a reliable parameter to assess gait and balance. The objectives of this study were to analyze the COP during gait in pregnant women with PGP, to evaluate the effect of pelvic belts and to compare two types of belts on COP parameters. *Materials and Methods:* 46 pregnant women with PGP, 58 healthy pregnant women and 23 non-pregnant women participated in the study. The motor task consisted of three gait trials at different velocities on an electronic walkway. Two pelvic belts for pregnant women were used. An analysis of variance was performed to determine the effects of the progression of the pregnancy, gait speed, presence of pregnancy and occurrence of pain on the COP parameters. *Results:* Compared to the control group, pregnant women with PGP had a higher stance time, but COP displacement and velocity were lower. The COP parameters varied between pregnant women with and without pelvic girdle pain, the use of a belt during pregnancy decreased the walking velocity. No difference was found according to the type of belt. *Conclusions:* Differences in COP parameters during gait between pregnant women with or without PGP were minimal. Pelvic girdle pain did not affect the center of pressure. Wearing a belt during pregnancy modified the center of pressure velocity during gait in pregnant women with PGP.

Key words: pregnant women, gait, pelvic girdle pain, belt, center of pressure

1. Introduction

About 50% of pregnant women suffer from pelvic girdle pain (PGP) [20]. PGP is reported as the most common cause of sick leave, with up to 32% of women having to take leave during pregnancy. The condition also carries a high risk of injury as the risk of falling increases by 27% during the third trimester [11], [14]. The pain is significant and localized in the posterior region of the pelvis, between the posterior iliac crest and the gluteal fold, particularly in the vicinity of the sacroiliac joint (SIJ). It may include the pubic symphysis [7], [25]. Etiologies of PGP are multifactorial and affect the joint stability of the SIJ. The “self-locking” mechanism explains how shear in the

SIJ is prevented by the combination of the anatomical features (form closure) and the compression generated by muscles and ligaments which can be accommodated to the specific loading situation by a self-bracing mechanism (force closure) [26]. PGP appears to be related to hormonal and mechanical factors which have an impact on force closure leading to instability, by a slightly larger range of movement in the pelvic joints [2], [17]. Women with PGP suffer from significant impairments during daily activities. Pain manifests mainly in the evening, indicating that pain starts or increases after activities. Standing or sitting, walking and daily activities become limited [7].

A method to restore pelvic stability is the use of a pelvic belt. It is hypothesized that a belt applied with even a small force should have the capacity to gener-

* Corresponding author: Jeanne Bertuit, School of Health Sciences (HESAV), University of Applied Sciences and Arts Western Switzerland (HES-SO), Avenue de Beaumont 21, 1011 Lausanne, Switzerland. Phone: +41 21 316 81 33, e-mail: jeanne.bertuit@hesav.ch

Received: May 8th, 2018

Accepted for publication: August 10th, 2018

ate a “self-locking” mechanism, although this remains controversial [17], [22], [23]. A number of studies found that the use of pelvic belts decreased pain and made daily activities, such as walking, easier [7], [9].

The center of pressure (COP) refers to the point at which the pressure of the body over the soles of the feet would be if it were concentrated in one spot. The position of the COP is influenced by gait speed, cadence, cycle length and the distribution of the mass of the subject [24]. The mass gain during pregnancy is around 12 kg and the abdominal mass increases by at least 31% [27]. It is, therefore, relevant to examine if the position of the COP changes during pregnancy.

The COP moves as the subject walks, and displacement of speed is an indicator used to analyze the performance and quality of gait and balance [19]. However, only a small number of studies have used the COP to carry out such analysis. The displacement is measured at between 0.22 and 0.27 m/s in middle-aged adults and is about 0.38 m/s in young adults [10]. Pregnancy influences the COP parameters [4], [15]. Gait velocity is by 22% lower (pregnant women: 0.99 ± 0.16 m/s, control group: 1.26 ± 0.13 m/s – $p < 0.001$) [4]. Consequently, the stance time is higher during pregnancy [4, 15]. These results were explained by the fact that pregnant women, because of a disturbed proprioception and a sensation of imbalance are more cautious when walking [15]. The COP velocity is lower (pregnant women: 0.28 ± 0.03 m/s, control group: 0.33 ± 0.04 m/s – $p < 0.001$) [4], [15]. This, again, illustrates the caution pregnant women take when they move. The COP displacement is by 5% lower compared to the control group (pregnant women: 0.19 ± 0.01 m/s, control group: 0.20 ± 0.01 m/s – $p = 0.003$) although this remains controversial [4], [15], [19]. These results could reflect the fact that pregnant women displace their body mass less toward the forefoot [15]. All the results suggest that pregnant women adapt their gait to maximize their stability during the support phase and to control the displacements [4], [6], [15]. To date, only one study analysed the COP in pregnant women with PGP [15]. The COP during gait was similar to that found in healthy pregnant women. Hence, in this study, pelvic girdle pain did not influence COP parameters.

Considering the limited amount of literature on the subject, it is essential to improve our knowledge about changes of the center of pressure during gait for pregnant women with PGP. If the COP is different in pregnant women with pelvic pain, it would be interesting for clinical practice to be able to assess whether the COP parameters could be modified with the use of a pelvic belt. Gait could be facilitated, making the belt

a useful and valid tool for treatment and prevention of pain. Belts are easy to use and without side effects, and could be well-suited for pregnant women with PGP [13], [16]. However, there are many types of belts which have not been assessed, making it difficult to use them as part of an evidence-based practice.

The first objective of this study was to analyse the center of pressure during gait in pregnant women with PGP. The second objective was to evaluate the effect of pelvic belts on the center of pressure. The last objective was to compare two types of belts (narrow and flexible or broad and rigid).

2. Materials and methods

Participants

The characteristics of the three groups are presented in Table 1. The first group (PGP-PW) consisted of forty-six pregnant women with PGP aged 25 to 35. The inclusion criteria were: women from the 18th week of pregnancy, with pain in the sacroiliac joints and/or pubic region – verified by a set of tests during clinical examination (posterior pelvic pain provocation test, Patrick Faber’s test, modified Trendelenburg test and active straight leg raise test) [1]. The exclusion criteria were the presence of lumbopelvic pain before pregnancy as well as other pathologies that could involve gait problems: surgery of the lumbar spine, pelvis, hips or knees, fractures, pain radiating below the knee, tumors or active inflammation in the lumbopelvic region, the presence of known anomalies of the spine, and rheumatic diseases. Twin pregnancies and pregnancies with complications were also exclusion criteria. The women included were randomized into two groups (A and B): Group A included thirty-eight women who had worn a belt during pregnancy. Belts were used during 9 (+/-5) weeks of pregnancy. Group A was randomized into sub-groups (A1/A2) in order to assess the type of belts: A1 used belt 1 (seventeen women) and A2 belt 2 (twenty-one women). Group B included twenty women who did not wear a belt. There were twelve drop-outs, which reduced the number of women in this group to eight.

The second group (H-PW) consisted of fifty-eight healthy pregnant women aged between 24 and 31 from the 18th week of pregnancy. The exclusion criteria were the same as for PGP-PW, with the addition of the presence of lumbopelvic pain during pregnancy, and pain in the sacroiliac joints and/or pubic area.

Table. 1. Characteristics of the study samples

Groups		Number	Age [years]	Height [cm]	Week of pregnancy			Mass gain [kg]	
					T1	T2	T1 – T2		
PGP-PW	A	A1	17	29 (5)	161 (4)	28 (4)	36 (1)	8 (4)	13 (5)
		A2	21	30 (5)	162 (5)	26 (5)	35 (1)	9 (5)	12 (4)
		A1 + A2	38	30 (5)	162 (5)	27 (5)	36 (2)	9 (5)	12 (5)
	B	8	29 (5)	163 (6)	27 (6)	36 (2)	10 (7)	12 (2)	
	A+B	46	30 (5)	162 (5)	27 (5)	36 (2)	9 (5)	12 (4)	
H-PW		58	29 (5)	166 (6)	33 (4)	/			10 (4)
CG		23	27 (5)	168 (6)	/	/			/

PGP-PW: pregnant women with pelvic girdle pain, H-PW: healthy pregnant women, CG: control group.
 A: women with belt during pregnancy (A1: women with belt 1, A2: women with belt 2).
 B: women without belt during pregnancy.

The third group, corresponding to the control group (CG), included twenty-three non-pregnant women of the same age range, free from pelvic pain, and without any previous surgeries.

All subjects gave written informed consent prior to participation in the study, which was approved by the Ethics Committee of the University and Hospital Erasme (Be) (number P2011/017).

Equipment used

The COP parameters during gait were measured using an electronic walkway (GAITRite Gold, CIR Systems, PA, USA, length: 6.1 m, width: 61 cm). Embedded pressure sensors formed a horizontal grid. Data was sampled at a frequency of 100 Hz. The walkway was connected to a personal computer by a serial in-

terface cable. The COP coordinates during gait were sampled using GAITRite GOLD, version 3.2b software, and processed using Excel 2007 software.

Two pelvic belts for pregnant women were used:

Belt 1 (Ortel-P, Thuasne) (Fig.1a) which is narrow and flexible and can be placed in two positions: high position (at the level of the anterior superior iliac spine) or low position (at the level of the pubic joint). Women first had the belt adjusted to their body and then modified the belt pressure themselves with the help of elastic Velcro systems on each side.

Belt 2 (LombaMum, Thuasne) (Fig. 1b) which is broad and rigid with metal reinforcements in the lumbar area, and is designed to be worn in only one position, but a sophisticated Velcro system makes it possible to adjust tension to a number of different levels.



(a)

(b)

Fig. 1. Pelvic belts (www.thuasne.com): (a) belt 1, (b) belt 2

Data collection

Each participant was asked to walk barefoot on the walkway. The motor task consisted in nine gait trials (three at each velocity). Gait speeds were self-selected, but standardized instructions were used. First, the subject was invited to walk at her preferred velocity. Then, the subjects walked at fast and slow velocity. The order of these velocities was randomised by dice throwing. Each participant was invited to walk barefoot on the GAITRite walkway. The instructions for fast velocity were “walk as fast as possible. As if you need to catch a bus” and the instructions for slow velocity were “walk slowly. As if you were shopping”. A rest periods were allowed between trials. To counter the methodological bias of acceleration and deceleration in gait, participants started walking 2 m ahead of the walkway and finished the trial 2 m after the end of the walkway.

CG, H-PW and PGP-PW walked without belt. For PGP-PW, women were evaluated at two points in time (T1/T2) for a longitudinal evaluation: at the 18th week of pregnancy (T1) and between the 34th and 38th week (T2).

Data processing

The following parameters were calculated:

- Stance time (ST) was defined as $ST = T_{\max} - T_{\min}$, where T_{\min} and T_{\max} corresponded to the first and last instants of stance phase.
- COP excursion (EXC) was defined as the sum of absolute displacements between two successive COP values in anteroposterior (AP) or medio-lateral (ML) direction. Also, the distance between two successive COP values in the plane formed by AP and ML axes was computed. It is expressed in m.

- COP velocity (V) corresponded to the velocity of COP displacement in anteroposterior (AP axis), medio-lateral (ML axis) direction and was defined as $V_i = EXC_i / (T_{n+1} - T_n)$ where “ i ” indicates the direction (AP or ML) and T is the time between two successive positions of the COP. It is expressed in m/s.

The following dependent variables were analyzed: stance time (sec), COP excursion (m) and COP velocity (m/sec).

Statistical Analysis

All statistical procedures were conducted using Statistica 5.0 software for Windows (StatSoft Inc, Tulsa, Oklahoma). To investigate the normal distribution of the data, we used the Kolmogorov–Smirnov test. All of the scores were found to be normally distributed. A Student’s t -test for paired samples was not significantly different between sides; data from the left and right foot were, thus, averaged.

An analysis of variance for repeated measures (ANOVA) was performed to compare of all dependent variables between the different velocities and times (within-subject factor) and groups (between-groups factor). When a significant effect was found, the LSD post-hoc test was applied. The statistical level of significance was set at 0.05.

3. Results

Table 2 shows the results for the COP parameters according to the three groups. Speed influenced all parameters ($p < 0.001$) with the exception of COP

Table 2. Values of COP parameters for Pregnant Women with Pelvic Girdle Pain (PGP-PW), Healthy Pregnant Women (H-PW) and control group (CG)

	Slow speed			Preferred speed			Fast speed			ANOVA		LSD	
	PGP-PW	H-PW	CG	PGP-PW	H-PW	CG	PGP-PW	H-PW	CG	Speeds	Groups	1	2
Stance time [sec]	0.88 (0.13)	0.90 (0.15)	0.84 (0.12)	0.70 (0.07)	0.72 (0.10)	0.63 (0.06)	0.54 (0.08)	0.58 (0.07)	0.51 (0.05)	<0.001	0.002	0.172	0.015
Excursion [m]													
AP	0.17 (0.02)	0.18 (0.01)	0.18 (0.02)	0.17 (0.01)	0.18 (0.01)	0.18 (0.01)	0.17 (0.01)	0.18 (0.01)	0.18 (0.01)	0.108	0.010	0.131	0.003
ML	0.07 (0.01)	0.07 (0.01)	0.07 (0.01)	0.06 (0.01)	0.06 (0.01)	0.06 (0.01)	0.05 (0.01)	0.05 (0.01)	0.06 (0.01)	<0.001	0.115		
AP-ML	0.20 (0.02)	0.20 (0.02)	0.21 (0.02)	0.19 (0.01)	0.19 (0.01)	0.20 (0.01)	0.19 (0.01)	0.19 (0.01)	0.20 (0.02)	<0.001	0.002	0.289	0.001
Velocity [m/sec]													
AP	0.21 (0.03)	0.21 (0.03)	0.23 (0.03)	0.25 (0.03)	0.25 (0.03)	0.30 (0.03)	0.33 (0.05)	0.31 (0.04)	0.36 (0.04)	<0.001	<0.001	0.348	<0.001
ML	0.08 (0.01)	0.08 (0.01)	0.09 (0.01)	0.09 (0.01)	0.08 (0.01)	0.10 (0.02)	0.10 (0.02)	0.10 (0.02)	0.12 (0.03)	<0.001	<0.001	0.052	<0.001
AP-ML	0.24 (0.03)	0.23 (0.03)	0.26 (0.03)	0.28 (0.03)	0.28 (0.03)	0.33 (0.04)	0.36 (0.06)	0.34 (0.05)	0.40 (0.05)	<0.001	<0.001	0.256	<0.001

Note: data are given as mean (SD) – Abbreviations: AP, anteroposterior; ML, mediolateral – LSD 1: PGP-PW/H-PW, 2: PGP-PW/CG.

ML excursion. The parameters did not show any significant differences between PGP-PW and H-PW. The comparison between PGP-PW and CG revealed several differences: for PGP-PW, stance time was by 7% higher ($p = 0.015$), COP AP and AP-ML displacement was by 5% lower ($p = 0.003 - p = 0.001$) and COP ML and AP velocity were by 8 to 16% lower, depending on speeds (Fig. 2a-c).

Table 3 illustrates the COP parameters according to the groups with and without belt. Only COP AP-ML velocity ($p = 0.045$) was different between the groups. The values for group B were by 4 to 10% higher than those for group A. Between T1 and T2 the values for group A decreased by 8% for AP velocity ($p = 0.026$) and by 5% for AP-ML velocity ($p = 0.033$) (Fig. 3).

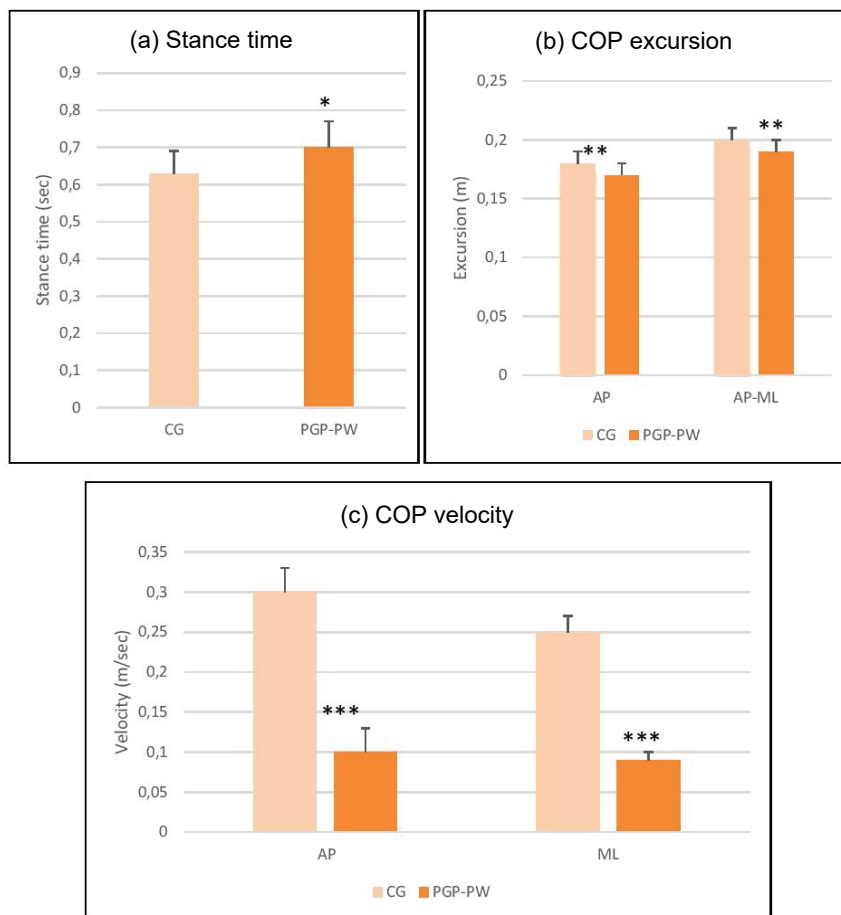


Fig. 2. Comparison between PGP-PW and CG for: (a) Stance time, (b) COP excursion, (c) COP velocity. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Values of COP parameters for Pregnant Women with Pelvic Girdle Pain with (A) and without belt (B) during pregnancy at preferred speed

	Pregnant women with belt			Pregnant women without belt			ANOVA
	T1	T2	ANOVA	T1	T2	ANOVA	Groups
Stance time [sec]	0.70 (0.07)	0.73 (0.08)	0.097	0.70 (0.09)	0.69 (0.08)	0.747	0.765
Excursion [m]							
AP	0.17 (0.01)	0.17 (0.01)	0.737	0.17 (0.01)	0.17 (0.01)	0.937	0.261
ML	0.06 (0.01)	0.06 (0.01)	0.406	0.06 (0.01)	0.06 (0.01)	0.569	0.397
AP-ML	0.19 (0.01)	0.19 (0.01)	0.512	0.20 (0.02)	0.19 (0.01)	0.810	0.157
Velocity (m/sec)							
AP	0.25 (0.03)	0.23 (0.03)	0.026	0.26 (0.02)	0.26 (0.02)	0.901	0.083
ML	0.09 (0.01)	0.09 (0.01)	0.228	0.09 (0.01)	0.09 (0.01)	0.646	0.067
AP-ML	0.27 (0.03)	0.26 (0.03)	0.033	0.29 (0.02)	0.29 (0.02)	0.832	0.045

Note: data are given as mean (SD) – Abbreviations: AP – anteroposterior; ML – mediolateral; T1 – first evaluation; T2 – second evaluation.

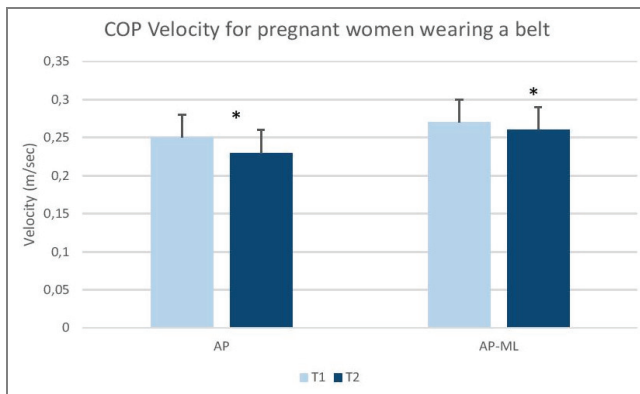


Fig. 3. Values of COP velocity (m/sec) for pregnant women wearing a belt during pregnancy (between T1 and T2). * $p < 0.05$

Table 4. Values of COP parameters for Pregnant Women with Pelvic Girdle Pain with belt 1 (A1) and belt 2 (A2) during pregnancy

	Pregnant women with belt 1			Pregnant women with belt 2			ANOVA
	T1	T2	ANOVA	T1	T2	ANOVA	Groups
Stance time [sec]	0.70 (0.08)	0.72 (0.06)	0.265	0.71 (0.07)	0.74 (0.09)	0.227	
Excursion [m]							
AP	0.17 (0.01)	0.17 (0.01)	0.680	0.17 (0.01)	0.17 (0.01)	0.960	0.981
ML	0.06 (0.01)	0.06 (0.01)	0.196	0.06 (0.01)	0.06 (0.01)	0.875	0.469
AP-ML	0.19 (0.01)	0.19 (0.01)	0.916	0.19 (0.01)	0.19 (0.02)	0.424	0.783
Velocity [m/sec]							
AP	0.25 (0.04)	0.24 (0.03)	0.304	0.24 (0.03)	0.23 (0.03)	0.065	0.950
ML	0.09 (0.01)	0.09 (0.01)	0.600	0.09 (0.01)	0.08 (0.01)	0.049	1.456
AP-ML	0.28 (0.04)	0.26 (0.03)	0.380	0.27 (0.03)	0.26 (0.03)	0.063	0.956

Note: data are given as mean (SD); Abbreviations: AP – anterop.

Table 4 shows the COP parameters according to the type of belt worn (belt 1 and belt 2). For all parameters, we observed no difference between groups. For the group with belt 2, the COP ML velocity showed a decrease of 11% between T1 and T2 ($p = 0.049$).

4. Discussion

In this study, the center of pressure during gait in pregnant women with pelvic girdle pain was investigated. In addition, the effects of pelvic belts and various types of belts were assessed. The center of pressure during gait is one of the parameters that can be analyzed to understand the impact of PGP in pregnant women. It could be completed using data concerning foot morphology [3], [8], [18], [21], spatiotemporal [5] and pedobarographic [3], [6], [18] parameters, as well as pain [7].

The center of pressure in pregnant women with PGP

The stance time was by 7% higher and the COP velocity was by 8 to 16% lower for the pregnant

women with pelvic pain, compared to the control group. This increase is similar to the values between healthy pregnant women and the control group found in other studies, where the stance time for healthy pregnant women was by 5 to 12% higher [4], [15]. The extent of COP displacement was significantly smaller for pregnant women with pelvic pain: it was by 5% lower compared to the control group. The study found similar results for healthy women compared to the control group [4], [15]. These data corroborate findings of previous studies on gait parameters during pregnancy [5], [6], [15]. Pregnant women both with and without pelvic pain reduce their gait speed in order to increase their gait stability. The results showed no difference between pregnant women with pelvic pain and healthy pregnant women, suggesting that both groups had similar COP displacement patterns during gait. Other studies also found that the presence of pelvic pain did not alter the COP parameters analyzed in this study [15].

The effect of pelvic belts on plantar pressure

Between the groups who wore a belt and did not, we can observe a difference for the COP velocity: the group without belt had values that were by 4 to 10% higher. Furthermore, pregnant women who wore a belt dis-

played significant changes for several parameters between T1 and T2. The COP velocity showed a 5-to-8% decrease. One hypothesis could be put forward to explain these observations. The pelvic belt could compress soft tissues in the pelvic girdle area and, consequently, stimulate proprioceptive receptors. With more proprioceptive inputs, women wearing a belt walk more carefully and slowly to avoid pain or falling. On the contrary, women without a belt could tend to forget their pain because of lower proprioceptive inputs. This would lead them to be less cautious and inflict excessive biomechanical stress to their bodies. We did not see any significant changes in the group without belt.

The types of belt and the center of pressure

For clinical practice, pelvic belts can be recommended as it has been previously demonstrated that they decrease pelvic girdle pain and improve functional capacity, for activities such as walking during pregnancy [7], [12]. However, this study reveals no difference between the two types of belt used. Therefore, this study does not support the use of a particular type of pelvic belt during pregnancy if the aim is to modify the center of pressure during gait.

Limitations

This study has several limitations: our group of healthy pregnant women was recruited during sessions of pre-natal gymnastics. This suggests that these women were able to move freely and had a correct level of activity and knowledge of their body map. Therefore, our sample may not correctly represent the general population of pregnant women. This could bias our results by overestimating the capacities of this group. Furthermore, group B was a small group: there were 12 drop-outs, which reduced the number of women. The main reason was a lack of motivation of the participants.

5. Conclusions

Pregnant women with PGP displayed nearly the same changes to the values of the center of pressure during gait as healthy pregnant women, when compared to non-pregnant women. Pain did not induce relevant changes in the center of pressure parameters. We suggest that the belts have a proprioceptive effect leading to a decrease of the COP velocity in pregnant women with PGP. No difference could be detected with regards to the type of belt used (narrow and flexible or broad and rigid).

Conflict of Interests

The author(s) declare(s) that there is no conflict of interests regarding the publication of this article.

Acknowledgements

The authors are grateful to all the women who volunteered to participate in this study and Thuasne (Levallois-Perret, France) who supplied the pelvic belts used in this research.

References

- [1] ALBERT H., GODSKESEN M., WESTERGAARD J., *Prognosis in four syndromes of pregnancy-related pelvic pain*, Acta Obstet. Gynecol. Scand., 2001, 80(6), 505–510.
- [2] ALDABE D., MILOSAVLJEVIC S., BUSSEY M.D., *Is pregnancy related pelvic girdle pain associated with altered kinematic, kinetic and motor control of the pelvis? A systematic review*, Eur. Spine J., 2012, 21(9), 1777–1787.
- [3] ALVAREZ R., STOKES I.A., ASPRINIO D.E., TREVINO S., BRAUN T., *Dimensional changes of the feet in pregnancy*, J. Bone Joint Surg. Am., 1988, 70(2), 271–274.
- [4] BERTUIT J., LEYH C., ROOZE M., FEIPEL V., *Pregnancy-related changes in center of pressure during gait*, Acta Bioeng. Biomech., 2017, article in press.
- [5] BERTUIT J., FEIPEL V., ROOZE M., *Temporal and spatial parameters of gait during pregnancy*, Acta Bioeng. Biomech., 2015, 17(2), 93–101.
- [6] BERTUIT J., LEYH C., ROOZE M., FEIPEL V., *Plantar Pressure During Gait in Pregnant Women*, J. Am. Podiatr. Med. Assoc., 2016, 106(6), 398–405.
- [7] BERTUIT J., VAN LINT C.E., ROOZE M., FEIPEL V., *Pregnancy and pelvic girdle pain: analysis of pelvic belt on pain*, J. Clin. Nurs., 2017, 25.
- [8] BLOCK R.A., HESS L.A., TIMPANO E.V., SERLO C., *Physiologic changes in the foot during pregnancy*, J. Am. Podiatr. Med. Assoc., 1985, 75(6), 297–299.
- [9] CARR C.A., *Use of a maternity support binder for relief of pregnancy-related back pain*, J. Obstet. Gynecol. Neonatal. Nurs., 2003, 32(4), 495–502.
- [10] CHIU M.-C., WU H.-C., CHANG L.-Y., *Gait speed and gender effects on center of pressure progression during normal walking*, Gait Posture, 2013, 37(1), 43–48.
- [11] DØRHEIM S., BJØRVATN B., EBERHARD-GRAN M., *Sick leave during pregnancy: a longitudinal study of rates and risk factors in a Norwegian population*, BJOG Int. J. Obstet. Gynaecol., 2013, 120(5), 521–530.
- [12] FLACK N.A., HAY-SMITH E.J.C., STRINGER M.D., GRAY A.R., WOODLEY S.J., *Adherence, tolerance and effectiveness of two different pelvic support belts as a treatment for pregnancy-related symphyseal pain – a pilot randomized trial*, BMC Pregnancy Childbirth., 2015, 15, 36.
- [13] FORCZEK W., STASZKIEWICZ R., *Changes of kinematic gait parameters due to pregnancy*, Acta Bioeng. Biomech., 2012, 14(4), 113–119.
- [14] INANIR A., ÇAKMAK B., HISIM Y., DEMİRTURK F., *Evaluation of postural equilibrium and fall risk during pregnancy*, Gait Posture, 2014, 39(4), 1122–1125.

- [15] KERBOURCH F., BERTUIT J., FEIPEL V., ROOZE M., *Pregnancy and Pelvic Girdle Pain Analysis of Center of Pressure During Gait*, J. Am. Podiatr. Med. Assoc., 2017, 107(4), 299–306.
- [16] MENS J.M.A., VLEEMING A., STOECKART R., STAM H.J., SNIJDERS C.J., *Understanding Peripartum Pelvic Pain*, Spine, 1996, 21, 1363–1370.
- [17] MENS J., POOL-GOUDZWAARD A., STAM H.J., *Mobility of the pelvic joints in pregnancy-related lumbopelvic pain: a systematic review*, Obstet. Gynecol. Surv., 2009, 64(3), 200.
- [18] NYSKA M., SOFER D., PORAT A., HOWARD C.B., LEVI A., MEIZNER I., *Planter foot pressures in pregnant women*, Isr. J. Med. Sci., 1997, 33(2), 139–146.
- [19] OLIVEIRA L.F., VIEIRA T.M.M., MACEDO A.R., SIMPSON D.M., NADAL J., *Postural sway changes during pregnancy: A descriptive study using stabilometry*, Eur. J. Obstet. Gynecol. Reprod. Biol., 2009, 147(1), 25–28.
- [20] ROBINSON H.S., MENGSHOEL A.M., VEIERØD M.B., VØLLESTAD N., *Pelvic girdle pain: potential risk factors in pregnancy in relation to disability and pain intensity three months postpartum*, Man. Ther., 2010, 15(6), 522–528.
- [21] SEGAL N.A., BOYER E.R., TERAN-YENGLE P., GLASS N.A., HILLSTROM H.J., YACK H.J., *Pregnancy leads to lasting changes in foot structure*, Am. J. Phys. Med. Rehabil. Assoc. Acad. Physiatr., 2013, 92(3), 232–240, DOI: 10.1097/PHM.0b013e31827443a9.
- [22] SNIJDERS C.J., VLEEMING A., STOECKART R., *Transfer of lumbosacral load to iliac bones and legs: Part I: Biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise*, Clin. Biomech., 1993, 8(6), 285–294.
- [23] SOISSON O., LUBE J., GERMANO A. et al., *Pelvic belt effects on pelvic morphometry, muscle activity and body balance in patients with sacroiliac joint dysfunction*, PloS One, 2015, 10(3), e0116739, DOI: 10.1371/journal.pone.0116739.
- [24] TITIANOVA E.B., MATEEV P.S., TARKKA I.M., *Footprint analysis of gait using a pressure sensor system*, J. Electromyogr. Kinesiol., 2004, 14(2), 275–281.
- [25] VLEEMING A., ALBERT H.B., ÖSTGAARD H.C., STURESSON B., STUGE B., *European guidelines for the diagnosis and treatment of pelvic girdle pain*, Eur. Spine J., 2008, 17(6), 794–819.
- [26] VLEEMING A., STOECKART R., VOLKERS A.C., SNIJDERS C.J., *Relation between form and function in the sacroiliac joint. Part I: Clinical anatomical aspects*, Spine, 1990, 15(2), 130.
- [27] WHITCOMB K., SHAPIRO L.J., LIEBERMAN D.E., *Fetal load and the evolution of lumbar lordosis in bipedal hominins*, Nature, 1997, 450.