

## Research Paper

# Measuring the Association Between the Biomechanics of Plantar Pressure and Musculoskeletal Changes throughout Pregnancy and Postpartum

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## ABSTRACT

Hormonal and anatomical changes during pregnancy tend to disrupt balance, posture and locomotion, and it is possible to reverse these changes in the postpartum period. This study aimed to measuring the association between musculoskeletal changes and plantar pressure during both pregnancy and postpartum period. The study sample comprised 20 pregnant women ( $24.40 \pm 5.43$  years) who were evaluated in the first, second, and third trimesters of gestation and in the late postpartum period. Plantar pressure was evaluated using the Footwork Pro platform in a bipedal static position with eyes open for 20 s and musculoskeletal changes were assessed on the basis of plantar pressure and data from pre- and postpartum questionnaires. *Post hoc* ANOVA, Tukey tests and the chi-square test were used. The results showed that morphological

and physiological changes in pregnancy are closely related to musculoskeletal changes and distribution of plantar pressure – with the hindfoot presenting higher plantar pressure values than the forefoot - causing discomfort and pain and compromising posture, stability, and gait during gestation and postpartum, indicating significant changes in plantar pressure (right foot –  $\Delta\%=42.74\%$ ,  $p \leq 0.001$ ; left foot -  $\Delta\%=41.35\%$ ,  $p \leq 0.001$ ) and musculoskeletal up to the third trimester of pregnancy, and a decrease on these changes in the postpartum period (right foot –  $\Delta\%=-5.99\%$ ,  $p \leq 0.001$ ; left foot -  $\Delta\%=18.09\%$ ,  $p \leq 0.001$ ).

**Keywords:** Biomechanics; Plantar pressure; Musculoskeletal changes; Pregnancy; Postpartum

## Introduction

The gestational period brings hormonal and anatomical changes generating musculoskeletal adaptations that can influence in the distribution of plantar pressure and alter postural biomechanics<sup>1</sup>. These anatomical changes include postural adaptations to promote gravitational balance, with the increased size of uterus and breasts leading to a greater concentration of the body mass in the anterior region of the body<sup>2,3</sup>. Pelvic anteversion, with or without lumbar lordosis, is one of the postural adjustments that is closely related to the spine, and can result in the increased anterior displacement of the center of gravity in pregnant women<sup>2</sup>. Furthermore, during pregnancy the functions of the rectus abdominal muscle are affected by the hormonal and anatomical changes, because transverse and longitudinal forces impose greater central traction on the muscle, becoming over-stretched and weak causing a diastasis that means the gap between the sections of the muscle to widen, compromising posture, stability and motion<sup>4</sup>.

In the third trimester of pregnancy frequently back and feet pain occurs due to the related changes in body's gravity center increase and to inadequate pressure distribution of bipedal

plantar altering the postural and walking stability causing change in postural biomechanics predisposing to increased risk of falls, prevalent condition in 25% of pregnant<sup>5</sup>.

Considering the morphological and functional changes during pregnancy tend to disrupt balance, posture and locomotion, as the possibility of reversing these changes in the postpartum period, the objective of this study was studying the association between musculoskeletal changes and plantar pressure during both pregnancy and postpartum period, that causes discomfort and pain, compromising posture, stability and gait during gestation and postpartum.

## Methodology

This study was a longitudinal, correlational, quasi-experimental study. The study participants comprised 20 pregnant volunteers, who became puerperal ( $23.65 \pm 5.14$  years), attending the prenatal services of the municipality of Belem Health State Service following these inclusion criteria: volunteer to the research, age between 18 to 35 years old, either primiparous or multiparous, confirmed pregnancy compatible with 3 months, single fetus, low risk, body mass index (BMI) less

than 30 kg/m<sup>2</sup>. Exclusion criteria included high-risk pregnancy, complications of pregnancy cycle, systemic diseases, vestibular disorders and musculoskeletal diseases prior to pregnancy.

This research was conducted in accordance with the World Medical Association's Declaration of Helsinki<sup>6</sup> and the National Health Council of Brazil (CNS 466/12). All volunteers signed the Informed Consent Form approved by the Ethics Committee for Human Research of the Gaspar Vianna Clinical Hospital Foundation under protocol numbered 104/2010.

The members of the experimental group were evaluated in the first, second, and third trimesters of pregnancy and in the postpartum period. Pre-Gestational body weight was informed by the participants. Weight and height were evaluated using an anthropometric balance model 31 (Filizzola<sup>®</sup>, São Paulo, Brazil), an arterial blood pressure was evaluated using a cuff (Cuff Type H4 REF. 21040 Wertheim, Germany), and respiratory auscultation was evaluated using a premium Rappaport stethoscope (Wenzhou Instruments Co., Ltd., China). The measurements were performed by the same examiner, always in the morning, following a standard methodology. The Footwork Pro platform (AM3-IST France), with 4,096 sensors, maximum pressure of 100 N/cm<sup>2</sup> per sensor and sampling rate of 150 Hz, was used for static measurement of plantar pressure and stabilometry. All the measures were performed according to International Standards for Anthropometric Assessment<sup>7</sup>. Each pregnant and puerperal woman was instructed to assume an inert relaxed bipedal orthostatic position (arms maintained alongside the body, barefoot, wearing clothes that would enable visualization of the feet, legs and knees), with eyes open and looking at a fixed point straight ahead at a distance of 1.50 m for 20 s. All participants were verbally encouraged throughout the activity. The pressure distribution on the plantar surface and stabilometric data were determined using the Footwork Pro pressure platform and Software (version 7.1). A questionnaire was used to obtain data on women's age, shoe size, general aspects of pregnancy and postpartum period (circulatory, musculoskeletal, genitourinary, cardiorespiratory and digestive systems concerns, edema, cramps, varicose veins and pain).

Statistical analysis was performed using SPSS 18.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics was used for sample characterization. Data distribution was assessed using absolute values and percentages for qualitative variables and average and standard deviation for quantitative variables. One-way analysis of variance was used to compare sample groups, with a level of significance of 5%, followed by *post hoc* analysis using Tukey test. The chi-square test was adopted comparing non-parametric data, with a level of significance of 5%.

## Results

The general characteristics of the sample is shown in Table 1, indicating the changes in the weight and BMI over the period of gestation and postpartum. Significant changes were observed in these parameters, with a marked increase from the first to the third trimesters of gestation, followed by a decrease in the postpartum period (Table 1). The constant increase in plantar pressure till the third trimester, followed by a decrease in the postpartum period in the majority of cases is presented in Table 2. The maximum mean pressure on the right and left

feet and the percentage distribution of load showed significant changes. Observing the plantar pressure this research finds that the hindfoot (composed by talus and calcaneus) showed higher pressure values, while the forefoot (composed by five toes and its metatarsus) recorded smaller values compared to hindfoot (Table 2).

As shown in Table 3, the musculoskeletal variables studied increased from the first to the third trimesters of pregnancy, followed by a decrease in the postpartum period. Edema of the lower limbs increased significantly during pregnancy and disappeared completely in the postpartum period, whereas edema of the upper limbs increased and decreased in the postpartum period in the same proportion (Table 3).

Concerning the amount of women developing varicose veins during pregnancy, Table 3 shows that this number decreased in the postpartum period. Table 3 also shows that some women also reported cramps in the legs and feet or only in the feet, and these cramps significantly increased during pregnancy and later decreased in the postpartum period in equal proportion.

Moreover, Table 3 shows that there was a significant increase in the number of women with pain in the legs and feet during pregnancy, and this pain decreased in the postpartum period. In the first two trimesters of pregnancy, Table 3 shows that the number of women with pelvic and lumbar pain significantly increased, with an evident peak in the third trimester, followed by a decrease (albeit non-significant) in the postpartum period.

The number of women with pain in the dorsal region during the third trimester of pregnancy and in the postpartum period increase was not significant, as shown in Table 3, whereas in the neck region, this increase was significant in the third trimester and postpartum period.

There was a significant increase in the number of women with abdominal diastasis during the third trimester of pregnancy and in the postpartum period, as presented in Table 3.

## Discussion

Biomechanical changes related to pregnancy, such as alterations in the center of gravity, weight, and BMI, are reflected in gait and may lead to musculoskeletal changes in the lower limbs, particularly cramp, varicose veins, fatigue in the trunk and leg regions, tension and muscle pain<sup>8</sup>. This research confirmed this affirmation as these complications were also observed in this researched group, most intensely in the third trimester of pregnancy. The postural biomechanics and hormonal changes during pregnancy can undermine the sacroiliac joint stability, whereas the increased body mass can lead to discomfort in the lumbar region. Moreover, it has been reported that weight gain can lead to overburdening of the lower limbs, particularly the legs, and can be an important risk factor for misalignment of the foot and ankle, owing to the uneven distribution of plantar pressure<sup>9-11</sup>. Hormonal changes that occur during pregnancy are also cause of modifications on postural mechanics, as hormone relaxing causes an increase in ligament laxity and consequent impairment of body biomechanics, which in turn, affects the static and dynamic structures of the skeleton<sup>12,13</sup>.

**Table 1:** Descriptive statistics and one-way analysis of variance for general characteristics.

Variable	1 <sup>st</sup> Trimester	2 <sup>nd</sup> Trimester	3 <sup>rd</sup> Trimester	Postpartum	F	W
Age (years)	24.40 ± 5.43	-	-	-	-	-
Pregestational body weight (Kg)	53.20 ± 8.60	-	-	-	-	-
Body weight (Kg)	54.15 ± 8.85	59.35 ± 9.28	65.55 ± 8.96	59.9 ± 8.40	5.52	<0.01*
Height (cm)	156.85 ± 6.54	-	-	-	-	-
BMI (kg/m <sup>2</sup> )	22.03 ± 3.61	23.80 ± 3.12	26.24 ± 3.00	24.16 ± 3.06	5.82	<0.01*
Change in weight (Kg)	0.95 ± 3.98	6.15 ± 4.04	12.35 ± 4.78	6.70 ± 4.59	22.84	<0.01*
Number of pregnancies	2.00 ± 1.01	-	-	-	-	-

BMI=Body Mass Index

**Table 2:** Descriptive statistics and one-way analysis of variance for general characteristics.

Variable	1 <sup>st</sup> Trimester	2 <sup>nd</sup> Trimester	3 <sup>rd</sup> Trimester	Postpartum	F	P
<b>Barycenter to R foot</b>	6.97 ± 1.86	7.12 ± 1.55	7.97 ± 1.83	6.78 ± 1.30	2.01	0.12
<b>Barycenter to L foot</b>	6.37 ± 1.29	7.39 ± 1.91	7.38 ± 1.92	7.56 ± 1.52	2.08	0.11
<b>Avg. P of R foot</b>	0.47 ± 0.19	0.50 ± 0.08	0.55 ± 0.09	0.56 ± 0.12	2.16	0.10
<b>Avg. P of L foot</b>	0.50 ± 0.24	0.49 ± 0.10	0.58 ± 0.12	0.49 ± 0.12	1.77	0.16
<b>Avg. max. P of R foot</b>	1.17 ± 0.40	1.29 ± 0.30	1.67 ± 0.34	1.57 ± 0.36	8.79	<0.01*
<b>Avg. max. P of L foot</b>	1.33 ± 0.57	1.39 ± 0.43	1.88 ± 0.47	1.54 ± 0.51	4.98	<0.01*
<b>Load dist. (%) - R front foot</b>	22.01 ± 5.59	22.58 ± 4.49	20.59 ± 5.06	23.93 ± 5.16	1.48	0.23
<b>Load dist. (%) - L front foot</b>	22.77 ± 5.05	21.14 ± 4.83	21.91 ± 5.38	22.51 ± 5.34	0.40	0.76
<b>Load dist. (%) - R back foot</b>	26.08 ± 5.59	28.17 ± 4.32	27.29 ± 4.00	28.75 ± 5.32	1.14	0.34
<b>Load dist. % - L back foot</b>	29.24 ± 6.60	28.12 ± 6.17	30.21 ± 6.07	24.81 ± 5.91	2.87	0.04*
<b>Sur. cont. (cm<sup>2</sup>) - R foot</b>	85.89 ± 16.64	81.93 ± 11.89	85.12 ± 17.12	89.47 ± 12.96	0.87	0.46
<b>Sur. cont. (%) - R foot</b>	50.45 ± 3.52	50.45 ± 2.14	49.25 ± 2.55	49.25 ± 3.55	1.06	0.37
<b>Sur. cont. (cm<sup>2</sup>) - L foot</b>	83.87 ± 12.05	78.28 ± 20.39	87.40 ± 17.79	93.40 ± 20.53	2.48	0.07
<b>Sur. cont. (%) - L foot</b>	49.55 ± 3.52	49.55 ± 2.14	50.70 ± 2.54	50.75 ± 3.55	1.02	0.39
<b>Div. mass - R front foot</b>	45.60 ± 10.18	44.40 ± 7.24	42.70 ± 7.99	45.50 ± 9.13	0.48	0.70
<b>Div. mass - L front foot</b>	44.05 ± 10.13	43.15 ± 10.14	42.10 ± 10.17	48.65 ± 10.94	1.56	0.21
<b>Div. mass - R back foot</b>	54.40 ± 10.18	56.50 ± 7.10	57.30 ± 7.99	54.50 ± 9.13	0.56	0.64
<b>Div. mass - L back foot</b>	54.95 ± 10.28	55.85 ± 10.07	57.90 ± 10.17	52.35 ± 11.15	0.97	0.41

Lumbar and pelvic pain compromises gait and posture during pregnancy and affects a greater number of primiparous pregnant women and/or those with a history of pre gestational

lumbar pain in the third trimester<sup>14-16</sup>. With regard to pelvic pain, a study by Damen et al.<sup>17</sup> involving 163 pregnant women, aimed at identifying the relationship between pelvic pain and

**Table 3:** Descriptive statistics, chi-square test, one-way analysis of variance for the musculoskeletal variables of the study group.

Variables	1 <sup>st</sup> Trimester	2 <sup>nd</sup> Trimester	3 <sup>rd</sup> Trimester	Postpartum	$\chi^2$	P
Edema LLLL	00 (0.0 %)	12 (60.0 %)	18 (90.0%)	00 (0.0 %)	34.16	<0.01*
Edema UULL	00 (0.0 %)	2 (10.0%)	5 (25.0%)	00 (0.0%)	0.38	0.71
Varicose veins	6 (30.0%)	10 (50.0%)	13 (65.0%)	8 (40.0%)	2.89	0.41
Cramp leg and foot	1 (5.0%)	8 (40.0%)	11 (55.0%)	2 (10.0%)	12.55	0.01*
Cramp foot	1 (5.0%)	4 (20.0%)	9 (45.0%)	1 (5.0%)	2.61	0.01*
Leg pain	5 (25.0%)	9 (45.0%)	20 (100.0%)	10 (50.0%)	11.09	0.01*
Foot pain	3 (15.0%)	8 (40.0%)	18 (90.0%)	8 (40.0%)	12.84	0.01*
Pelvic pain	11 (55.0%)	18 (90.0%)	20 (100.0%)	11 (55.0%)	4.40	0.22
Lumbar pain	11 (55.0%)	18 (90.0%)	20 (100.0%)	14 (70.0%)	3.10	0.38
Dorsal pain	0 (0.0%)	0 (0.0%)	4 (20.0%)	7 (35.0%)	1.12	0.26
Cervical pain	0 (0.0%)	0 (0.0%)	9 (45.0%)	11 (55.0%)	4.47	<0.01*
Abdominal diastasis	00 (0.0%)	00 (0.0%)	20 (100.0%)	18 (90.0%)	38.21	<0.01*

LLLL=Lower Limbs; UULL=Upper Limbs

sacroiliac joint laxity in the 36th week of pregnancy, found that 73 women had moderate to severe pelvic pain, whereas 90 women reported no pain or mild pelvic pain. In the present study, we found that a significant number of women exhibited higher levels of dorsalgia and cervicgia in the postpartum period when compared with the third trimester of pregnancy. This was generally caused by the lack of guidelines on the correct position during breastfeeding and infant care.

Pain occurs in the dorsal and cervical segments of the spine because the posterior muscles in these regions become more active to prevent anteriorization of the head in relation to the pectoral girdle. Notably, the shoulders curve, whereas the vertebral axis tilts slightly forward, shifting the weight backwards towards the back of the foot to counteract the weight of the expanding uterus<sup>18</sup>.

The anterior muscles of the trunk become distended, particularly the rectus abdominis muscle, and two segments related to the linea alba separate owing to the intra-abdominal pressure caused by the need for extra space to accommodate the growing fetus. This distension results in abdominal diastasis (which becomes an abnormal condition when it reaches 3 cm) at the end of pregnancy and in the postpartum period<sup>19,20</sup>.

Abdominal diastasis at the end of pregnancy and in the postpartum period can affect the abdominal muscles that control the pelvis and lumbar region, resulting in characteristic complaints related to lumbar and/or sacral perineural pain and predisposing to postural changes<sup>21,22</sup>.

A study by Goldberg et al.<sup>23</sup> about plantar pressure in pregnant women, corroborated this research findings observing that the hindfoot showed higher pressure values, while the forefoot presented smaller pressure values. These results are the same of our research findings. The same results were found by some researchers that evaluated women in the last trimester of pregnancy and found higher values of plantar pressure on the hindfoot and lower values in the forefoot. Karadag-Saygi<sup>5</sup> also observed prominent increased postural sway in anterior-posterior direction.

Considering the findings of morphological and physiological changes in pregnancy extending to the postpartum period causing alterations in the distribution of plantar pressure and in musculoskeletal balance, resulting in feet and back pain and discomfort, varicose veins, abdominal diastasis, compromising posture during gestation and postpartum, it is of the utmost relevance to study and discuss thoroughly this theme.

## Conclusion

This study observed that, considered that during pregnancy the body movements and the posture are altered by the modified gravity center (changing in the anteroposterior direction), and considered the likely adaptations posture of balance and walking and of skeletal alignment plus ligament laxity, these factors most often results in plantar pressure irregularly distributed. The results of this study also indicate progressive physiological, anatomical, and biomechanical changes that extended beyond delivery.

## Suggestions

Based on the results of the present study, we suggest that a health care program for pregnant women should include baropodometry from the onset of pregnancy to the postpartum period in order to positively contribute to the minimization of pain and discomfort related to changes in the distribution of plantar pressure and in musculoskeletal balance. This will help health care and sports professionals work with pregnant women balancing these changes that can lead to falls, discomfort, and pain and promoting a better quality of life for women throughout pregnancy and postpartum period.

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