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Relation between foot pain and plantar pressure in pregnancy

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Background/aim: Hormonal and structural changes that occur during pregnancy cause alterations in body biomechanics. These alterations reach their peak in the last trimester. Adaptive changes that appear in the foot result in pain in the foot and ankle. Pedobarography is a noninvasive measurement method that can be used to understand the origin of such pain.

Materials and methods: One hundred and thirty-one pregnant women who did not have a foot or ankle problem prior to pregnancy volunteered to take part in the study. Pain was quantified by a visual analog scale (VAS). A cut-off value of 2.95 was taken to divide the subjects into two groups: Group 1 (n = 70) with VAS scores of <2.95 and Group 2 (n = 61) with VAS scores of ≥2.95. Plantar pressure measurements were taken by Tekscan HR Mat using midgait protocol.

Results: Forces experienced by the total right foot area, right forefoot, and the midfoot for both feet were significantly higher in Group 2 ($P < 0.05$). Contact area was significantly larger in Group 2 ($P < 0.05$).

Conclusion: Results indicate that presence and severity of foot pain during pregnancy are related to the force distribution along the foot, especially at midfoot and the contact area.

Key words: Pregnancy, trimester, foot pain, visual analog scale, pedobarography

1. Introduction

Increase in body mass introduces a significant load on the musculoskeletal system that secures the erect posture. Studies on obese individuals and pregnant women showed that this situation introduces significant changes in gait and plantar pressure distribution (1–3). However, there is a difference in the increase in body mass during pregnancy compared to obesity and this is due to the effects of hormonal changes on the musculoskeletal system (4,5). These hormonal changes vary with the trimester and become more prominent in the last trimester (4).

Even though there is a gradual weight gain during pregnancy, this increase becomes more pronounced in the second trimester and onwards. As a result of overall weight gain and asymmetric enlargement of the abdomen in the ventral direction, the center of mass is forced to shift (6). This consequently introduces additional forces in the spine and lower limbs, altering the biomechanics and causing pain (7,8). Adaptive changes in plantar pressure distribution and the center of pressure occur in order to stabilize the static and dynamic balance in a pregnant woman and step width progressively increases until late pregnancy (1).

Pain is an unpleasant physiological response of the body to injurious stimuli. Foot pain is a frequent condition among the normal population. Ankle or foot pain can be related to one or more of bones, joints, ligaments, muscles, tendons, fasciae, bursae, nerves, skin, nails, or vessels. Various studies reported that the incidence of foot pain during pregnancy varied between 17% and 42% (9). Not only foot pain but also hip and knee pain are observed in high proportions of pregnant women (10). Increase in laxity of peripheral joints is one of the leading causes of joint-related pain (4,10). The height of the plantar arch decreases while the length and width of the foot increases with increased body weight (1,11). This is especially more pronounced in first pregnancies (12).

Numerous methods are being used to assess pain. Among these methods, the visual analog scale (VAS) is a valid and reliable method that can be used in both healthy adults and patients (13,14). It is widely preferred since it is a simple method that can be administered in a very short time. However, it has limited usability in elderly individuals with motor and cognitive impairment (15). Since VAS scoring for pain is subjective, not standardized, a scoring

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determining the levels of pain for different research groups need to be implemented (16,17).

Validity and reliability of measuring the plantar pressure distribution and balance by pedobarography, which is a noninvasive, safe, and easy-to-administer method, has been shown (18,19). We hypothesized that foot pain that occurs in pregnant women who did not have such complaints before could be related to the shifting of the center of mass from the midfoot where the plantar arches are due to biomechanical changes induced by pregnancy. With the use of pedobarography, we planned to measure the static and dynamic plantar pressure distributions among pregnant women in different trimesters and examine whether the plantar pressure distribution was related to foot pain.

2. Materials and methods

Ethics approval was obtained from the Clinical Research Ethics Committee of the Faculty of Medicine of Manisa Celal Bayar University before the commencement of the study. Subjects were selected from consecutive pregnant women who presented to the Obstetrics Outpatient Clinic in a 30-day period and had uncomplicated pregnancy, with no history of orthopedic, rheumatologic, endocrinological, or neurologic problems. A total of 131 healthy pregnant women volunteered to participate in the study. Eighteen subjects were in the first trimester, 43 were in the second trimester, and 70 were in the third trimester.

Initially, demographic data were collected from the subjects (Table 1). Subjects who did not have lower limb-related pain before pregnancy were asked if they experienced "pain or discomfort in their feet after pregnancy was confirmed" and instructed to place a mark on a 100-mm line that corresponded to their pain (0 = no pain, 100 mm = worst possible pain). Subjects were divided into two groups based on the arithmetic mean of VAS scores (2.95 mm): Group 1 comprised 70 subjects with VAS scores lower than the mean while Group 2 comprised 61 subjects with VAS scores equal to or higher than the mean.

Dynamic measurements of the subjects were made using HR Mat (TekScan, Inc., South Boston, MA, USA) with sensing area of 487.7 × 447.0 mm, 4 sensors/cm^2, pressure range of 862 kPa, and floor mat height of 0.57 cm at a frequency of 50 Hz. The reliability of HR Matscan in pedobarographic measurements was reported (18). HR Mat Research Software V.6.70-03 bundled with HR Matscan was used to acquire the data. Calibration of the pedobarograph was performed prior to measurements for each subject. Subjects were allowed to rest before and during measurements.

Dynamic pedobarographic data were acquired in midgait protocol, as described elsewhere (20,21). The subjects were asked to walk barefoot at their own pace and best comfort level. Three plantar recordings were acquired from each foot and these recordings were used to divide the foot into three regions, based on International Guidelines for Plantar Pressure Measurement: the hindfoot and midfoot account for 30% of the total foot length, while the forefoot accounts for 40% of the length (22). Further, three individual masks were constructed under the forefoot (metatarsal region, big toe, and lesser toes), resulting in a total of 5 plantar subregions. Maximum force (N), contact area (cm^2), contact pressure (kPa), peak contact pressure (kPa), and force-time integral (contact time, minimum force, maximum force, mean force, and impulse in Ns) were measured for these subregions.

Analysis was performed using SPSS 23.0 for Windows (IBM Corp., Armonk, NY, USA). All data were expressed as mean ± SD. The differences in demographic data between groups were tested by independent samples t-test. The normality assumption for continuous variables was tested using the Kolmogorov–Smirnov test. Differences in the means of normally distributed variables were evaluated by using a t-test whereas the Mann–Whitney U test was used for non-Gaussian variables. $P < 0.05$ was considered statistically significant.

3. Results

Demographic data pertaining to age, height, weight, and body mass index (BMI) of the subjects are presented in Table 1. When the demographic data and mean gestational week

Table 1. Demographic data (mean ± SD) and significance of the differences between groups

	Group 1 VAS < 2.95 cm	Group 2 VAS ≥ 2.95 cm	P
Age (years)	27.96 ± 5.48	28.19 ± 6.50	0.890
Height (cm)	157.96 ± 5.27	157 ± 4.92	0.490
Weight (kg)	69.71 ± 12.55	73.89 ± 13.32	0.242
BMI (kg/m^2)	27.94 ± 4.86	29.90 ± 4.68	0.137
Gestational week	26.54 ± 9.77	26.15 ± 8,99	0.814

were compared, we did not find statistically significant differences between Groups 1 and 2 (Table 1).

Pedobarographic data (force, contact area, contact pressure, peak force, and peak contact pressure) were acquired for the whole of the sole and predefined sections of the foot (hindfoot, midfoot, forefoot, big toe, and lesser toes). The data were acquired for the right and left foot separately. Comparison of the groups revealed that force was significantly increased at the whole sole of the right foot in Group 2 while contact area was significantly increased in both feet ($P < 0.05$). In Group 2, forces in the midfoot of both feet were significantly higher, whereas contact area was significantly higher for the left foot and contact pressure for the right foot. At the forefoot, only force and contact area at the right foot were significantly different between groups ($P < 0.05$) (Table 2).

When we investigated the vertical ground reaction force and impulse, the integral of force measurements, we found that there was a significant difference between groups only at the whole sole of the right foot. Force and impulse measurements at the midfoot of both feet were greater in Group 2 ($P < 0.05$) (Table 3).

4. Discussion

This sectional study was planned to establish if relationships existed between foot pain experienced by pregnant women and plantar pressure distribution, whether it be subsections of the foot (hindfoot, midfoot, forefoot, big toe, lesser toes) or the whole of the sole (total). In this study, foot pain experienced by pregnant women at different gestational weeks was quantified by VAS. Subjects were then allocated into one of two groups based on their VAS scores and plantar pressures were analyzed.

Table 2. Means (SD) of pedobarographic force (F), contact area (CA), contact pressure (CP), peak force (PF), and peak contact pressure (PCP). Significant differences between groups have been denoted with asterisks ($P < 0.05$).

		F		CA		CP		PF		PCP	
		Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Total	R	756.47 (150.79)	823.36* (175.12)	112.41 (13.60)	118.03* (14.76)	16.19 (3.23)	16.36 (2.91)	52.69 (13.44)	53.46 (15.00)	51.04 (13.02)	51.79 (14.53)
	L	765.98 (163.16)	810.62 (172.19)	112.28 (13.13)	118.13* (15.71)	16.12 (3.18)	16.29 (2.81)	52.79 (13.32)	52.78 (14.15)	51.14 (12.90)	51.13 (13.70)
Hindfoot	R	490.78 (113.56)	496.68 (98.18)	29.97 (3.70)	30.94 (3.97)	19.35 (3.89)	19.10 (3.43)	34.34 (9.29)	32.38 (7.13)	33.26 (9.00)	31.37 (6.91)
	L	504.46 (105.78)	508.76 (110.11)	29.81 (3.66)	30.94 (4.05)	19.95 (3.90)	19.70 (3.61)	35.02 (8.69)	33.92 (7.63)	33.93 (8.41)	32.86 (7.40)
Midfoot	R	136.12 (62.82)	173.29* (82.35)	26.33 (7.26)	28.44 (7.45)	6.06 (2.14)	6.86* (2.19)	14.04 (6.33)	14.85 (5.25)	13.63 (6.109	14.40 (5.07)
	L	131.34 (65.53)	160.07* (84.92)	25.65 (6.69)	28.57* (8.02)	5.96 (1.92)	6.12 (2.02)	13.23 (4.70)	13.76 (4.92)	12.82 (4.55)	13.35 (4.75)
Forefoot	R	580.69 (140.97)	640.60* (169.96)	39.38 (5.61)	42.29* (5.41)	16.89 (3.48)	17.59 (3.99)	44.78 (14.52)	44.53 (14.28)	43.38 (14.07)	43.14 (13.83)
	L	599.94 (158.01)	632.92 (157.36)	40.36 (5.50)	42.13 (6.01)	17.02 (3.74)	17.27 (3.59)	44.86 (14.12)	44.14 (15.31)	43.46 (13.68)	42.76 (14.83)
Big toe	R	134.33 (53.96)	132.57 (58.84)	8.60 (1.57)	8.43 (1.42)	16.72 (5.48)	16.59 (6.76)	38.85 (15.69)	39.68 (20.09)	37.65 (15.18)	38.44 (19.46)
	L	131.47 (56.57)	140.74 (54.57)	8.51 (1.24)	8.75 (1.91)	16.40 (5.92)	16.85 (4.82)	37.21 (17.82)	40.22 (16.74)	36.04 (17.26)	38.96 (16.21)
Lesser toes	R	62.07 (63.07)	56.92 (29.21)	8.04 (3.47)	7.85 (2.28)	8.33 (3.45)	8.22 (2.81)	20.42 (10.04)	20.58 (9.41)	19.84 (9.76)	20.07 (9.09)
	L	56.51 (33.32)	56.63 (27.29)	7.91 (2.45)	7.63 (2.33)	8.20 (3.23)	8.66 (2.62)	19.91 (9.38)	21.06 (8.27)	19.44 (9.01)	20.60 (7.92)

Table 3. Force-time integral: mean force ($Force_m$) (SD) and impulse values (SD). *: P < 0.05.

		Total		Hindfoot		Midfoot		Forefoot		Big toe		Other toes	
		R	L	R	L	R	L	R	L	R	L	R	L
$Force_m$	Group 1	57.33 (11.33)	57.97 (11.75)	18.14 (5.16)	18.82 (5.03)	6.12 (3.19)	5.68 (3.03)	26.86 (7.06)	27.37 (7.70)	4.38 (2.10)	4.29 (2.31)	1.80 (1.61)	1.77 (1.29)
	Group 2	61.83* (12.91)	61.24 (13.21)	18.87 (5.10)	19.15 (5.29)	8.07* (4.57)	7.08* (4.19)	28.98 (8.27)	28.87 (7.76)	4.24 (2.66)	4.30 (1.82)	1.64 (0.89)	1.83 (1.70)
Impulse	Group 1	43.08 (9.03)	43.68 (8.82)	13.55 (3.74)	14.09 (3.53)	4.64 (2.62)	4.30 (2.36)	20.24 (5.57)	20.61 (5.59)	3.29 (1.60)	3.29 (1.95)	1.34 (1.09)	1.34 (1.00)
	Group 2	47.78* (13.50)	47.26 (14.27)	14.54 (4.68)	14.80 (5.30)	6.27* (3.73)	5.46* (3.30)	22.43 (7.92)	22.28 (7.78)	3.26 (2.13)	3.32 (1.52)	1.25 (0.68)	1.40 (1.30)

Irrespective of the gestational week, the mean VAS score was 2.95 cm. Subjects with a score of <2.95 cm were assigned to Group 1 (very mild or no pain) while subjects with a score of ≥2.95 were assigned to Group 2 (moderate or severe pain). The rationale behind taking the mean VAS score as the cut-off point was that our aim was not to make a pain classification but to determine if a relation existed between pedobarographic parameters and intensity of pain. Different cut-off values have been used in various studies on pain intensity, though a VAS score of 1–4, 5–44, 45–74, and >75 mm has been considered as "no pain", "mild pain", "moderate pain", and "worst possible pain", respectively (15,17). However, studies that aimed to determine the cut-off value have been carried out on different clinical cases, comparing VAS scores measured at two different times.

A number of studies reported that foot pain occurs especially in the 2nd and 3rd trimesters, with an incidence of 31%–42% (7,10). In the present study, subjects in Group 2 comprised 46.56% of all subjects. Compared to previous studies, our results indicate that the mean VAS score taken as the cut-off point can be used in the differentiation of "no pain or mild pain" and "moderate pain". However, there were no significant differences in foot pain between Groups 1 and 2 with respect to gestational week (P = 0.814).

We found significant differences between the two groups in the force distributions at the right forefoot and midfoot at both feet (Table 2). It has been shown that, throughout pregnancy, plantar force distribution shifts from the hindfoot to the midfoot and forefoot (23,24). Increased force, especially at the midfoot and forefoot, is related to foot pressure.

Contact area is the part of the sole that touches the floor. There was a significant difference between the two groups when the whole of the sole was analyzed (Table 2). Chiou et al. and Ponnapula and Boberg reported that foot size increased during pregnancy and argued that this could be related to foot pain (7,25). Our results showed a positive relationship between the contact area and the intensity of pain.

Increased contact pressure only at the right midfoot was significantly different between the groups (Table 2). This indicates that factors altering the foot biomechanics were responsible for foot pain. In contrast to the study by Gaymer et al. (26), we found that increased midfoot plantar pressure was related to pain. Various researchers reported that foot alterations due to the increase in body weight as well as hormonal changes during pregnancy played roles in foot pain (3,27).

There were no significant differences between groups in peak force or peak contact pressure, neither at the whole of the foot nor at any individual subregion.

When the force-time integral (impulse) was analyzed for both groups, force and impulse measurements especially at the midfoot were significantly higher in Group 2 (Table 3). These findings indicate that mean force and force per unit time increased when the foot and the floor were in contact. Increases in $Force_m$ and impulse measurements appear to be related to increased foot pain.

In conclusion, during pregnancy, forces exerted at the soles of the feet shift from the posterior to the anterior as a result of hormonal changes and increased body weight, with consequent increases at the forefoot and, more prominently, at the midfoot. This may be secondary to compensatory postural changes against the factors altering the truncal biomechanics (increased body weight and anteriorly enlarging abdomen) and walking by increasing the base of support. Force and contact area measurements taken at the midfoot and forefoot were significantly higher in pregnant women with higher than average foot pain, as determined by VAS scores.

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