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ANALYSIS OF PLANTAR PRESSURE AND POSTURAL BALANCE DURING DIFFERENT PHASES OF PREGNANCY

Ribas SI & Guirro ECO

Postgraduate Physical Therapy Program, Universidade Metodista de Piracicaba, Piracicaba, SP – Brazil.

Correspondence to: Elaine Caldeira de Oliveira Guirro, Universidade Metodista de Piracicaba, Rodovia do Açúcar, Km 156, Taquaral, CEP 13400-911, Piracicaba, SP – Brasil, e-mail: ecguirro@unimep.br

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ABSTRACT

Objective: To analyze plantar pressure and postural balance during the three trimesters of pregnancy, and also to correlate these with anthropometric characteristics. Method: Sixty volunteers participated in this study, with a mean age of 23.3 ± 5.5 years. There were 15 subjects in each group: non-pregnant (C), first trimester (1T), second trimester (2T) and third trimester (3T). Evaluations were performed in bipedal stance with open eyes, using a pressure platform. The following variables were analyzed in the right and left feet: peak pressures in the whole foot (WFP), forefoot (FFP) and hindfoot (HFP); distance between the medial borders of the foot (width of support base); the distance from the center of force to the anterior (COF-A) and posterior (COF-P) limits of the foot; anteroposterior (AP) and mediolateral (ML) COF displacements; and the contact area (CA). Results: There were no differences in peak contact pressures and COF-A and COF-P distances between the groups. The AP displacement was greater ($p < 0.05$) in 3T than in 1T. There was no difference ($p > 0.05$) between the groups regarding ML displacement. There was a positive correlation between weight gained during pregnancy and CA for the 2T group, and between weight gain and WFP in the right feet in the 1T group. Conclusion: The results demonstrate the influence of the anatomical and physiological changes inherent to pregnancy on plantar pressure. They also suggest that postural equilibrium decreases in the third trimester, associated with greater AP displacement during this phase.

Key words: pregnancy; musculoskeletal equilibrium; foot.

RESUMO

Análise da Pressão Plantar e do Equilíbrio Postural em Diferentes Fases da Gestação

Objetivo: Analisar a pressão plantar e o equilíbrio postural nos três trimestres de gravidez, bem como a correlação com as características antropométricas. Metodologia: 60 voluntárias com idade média de 23,3 ± 5,5 anos, sendo 15 mulheres em cada grupo: não-gestantes (C), primeiro (1T), segundo (2T) e terceiro trimestre (3T). A avaliação foi efetuada por meio de plataforma de pressão na posição bipodal com os olhos abertos. As variáveis analisadas nos pés direito e esquerdo foram: pico de pressão em todo o pé (PT), no antepé (PA) e no retropé (PR); distância entre a borda medial dos pés (largura da base de suporte); distância do centro de força ao limite anterior (CFF) e posterior (CFC) dos pés; deslocamento ântero-posterior (AP) e médio-lateral (ML) do centro de força; e área de contato (AC). Resultados: Não houve diferença no pico de pressão de contato e na distância CFF e CFC entre os grupos. O deslocamento AP foi maior ($p < 0,05$) no grupo 3T em relação ao 1T. Não se observou diferença ($p > 0,05$) entre os grupos para o deslocamento ML. Houve correlação positiva entre peso ganho durante a gestação com AC para o grupo 2T e com PT no pé direito do grupo 1T. Conclusão: Os resultados demonstram a influência das mudanças anatômicas e fisiológicas inerentes à gestação na pressão plantar, além de sugerir uma redução do equilíbrio postural no 3T, relacionada ao maior deslocamento AP nessa fase.

Palavras-chave: gestação; equilíbrio musculoesquelético; pé.

INTRODUCTION

Pregnancy is characterized by different alterations which occur in every woman[1], among them, hormonal, anatomical, cardiovascular and pulmonary changes, along with edema and weight gain, which can possibly affect musculoskeletal balance and posture[2,3].

The hormonal and hemodynamic alterations, coupled with the accumulation of fluid, fat and mechanical distress of pregnancy, cause mechanical disturbances in the ligaments and joints of the conjunctive tissue[4-6], which could contribute to an increase in joint mobility and increase the risk of ligament injury[3,7].

The enlargement of the uterus and breasts along with the increase in blood volume and water retention are responsible for weight gain during pregnancy. The average recommended weight gain during this period is 12 kg, but that varies greatly as it has been observed that only 30-40% of pregnant women gain the expected amount of weight[8]. Approximately half of this weight is gained in the abdominal area anterior to the line of gravity[6].

The increase in weight and the disequilibrium of the joint system caused by the increasing body mass and body size can shift the center of gravity (COG) and increase oscillation of the center of force (COF), resulting in an unstable postural balance and influencing the biomechanics of posture[9]. This alteration can increase the risk of falling, which occurs in 25% of pregnant women[10].

Due to the posture alterations which are evident during the gestational period and the expected changes in balance[11], musculoskeletal discomfort in the thorax and lower limbs is common[2,3,12] and can cause incorrect positioning of the feet, back and lower limb pain[6], changes in gait and even functional disability for some movements[1]. Therefore, the repercussions of pregnancy on the musculoskeletal system result in great adjustments in static and dynamic posture for women.

Maintaining balance in the upright position is a complex but common daily task, therefore it is important to study the implications of postural disorders[13].

In this context, and given the lack of literature on the subject, the purpose of this study was to analyze the behavior of plantar pressure and postural balance distribution in view of the alterations in the female body in every trimester of pregnancy, as well as to verify the relationship between the anthropometric characteristics of the volunteers and analyzed variables. The results obtained may improve physical therapy intervention in the adaptative musculoskeletal changes and their consequences during the gestational period.

MATERIAL AND METHODS

The study was approved by the Ethics in Research Committee of Universidade Metodista de Piracicaba, protocol no. 62/05. The volunteers were informed of the procedures of the study and signed a free and informed consent developed according to Resolution 196/96 of the National Health Council (NHC).

Volunteers

Seventy-two women were invited to participate in the study, and 60 of them were recruited after the first evaluation. The mean age was 23.3 ± 25.5. Fifteen women were in the first trimester (1T) or up to 12 weeks pregnant, 15 in the second trimester (2T) between 13 and 24 weeks pregnant, 15 in the third trimester (3T) or upwards of 25 weeks pregnant, and 15 were non-pregnant volunteers recruited for the control group (C). The date of the last menstruation (DLM) was used to calculate the volunteers' gestational week.

The criteria for inclusion in the study were low risk pregnancy, single fetus and absence of diabetes or other systemic pathologies, as well as absence of sensitivity, circulatory and skin alterations, neuropathy or vestibulopathy and musculoskeletal pathology before pregnancy.

The following exclusion criteria were adopted: fluctuations in the pregnancy cycle and obesity (body mass index higher than 30)[14]. From the total sample evaluated, 8 volunteers quit, citing lack of time, 3 were excluded for being overweight and 1 was excluded under suspicion of a neurological disorder.

The volunteers were submitted to a prior evaluation in which the following anthropometric (Table 1) data was analyzed: current weight and height measured on an anthropometric scale, model 31 (Filizola®); body mass index (BMI), based on the pre-gestational weight and the weight gained during pregnancy and calculated by subtracting the pre-gestational weight from the current weight.

Experimental procedure

Data was collected with the use of the Computerized Baropodometry System - Pressure Platform - Matscan® 5.1 (Tekscan®). The sample's frequency was 40 Hz, with a test time of 5 seconds.

The volunteer remained in an orthostatic position gazing at eye level with arms to the side and free support base within the marked area on the platform (Figure 1) and, the automatic calibration of the equipment was done using the volunteer's body weight measured on the anthropometric scale. Calibration is important to establish the validity of the pressure measures[15].

Table 1. Values (mean ± standard deviation) for the anthropometric characteristics of control (C), first (1T), second (2T) and third (3T) trimester groups. n= 15.

Characteristics	Mean ± SD			
	C	**1T**	**2T**	**3T**
Age (years)	22 ± 1.21	24 ± 6.32	25.6 ± 7.5	21.6 ± 4.3
Mass (kg)	58.2 ± 1.2	60.5 ± 8.9	65.4 ± 18.20	72.8 ± 16.6
Pre-pregnancy weight (kg)	-	57.9 ± 8	60 ± 16.8	61 ± 15
Weight gained (kg)	-	2.6 ± 1.7	5.4 ± 3.4	11.8 ± 7.2
Height (m)	1.63 ± 0.04	1.63 ± 0.06	1.59 ± 0.04	1.6 ± 0.07

Figure 1. Pregnant woman's position during data collection. A: pressure platform; B: data analysis software.

Afterwards, the data was collected while the patient remained in static posture with bipedal support and eyes open. The procedure was repeated three times. The volunteers with eyesight problems wore corrective lenses during the procedure.

All evaluations took place in the evenings to limit the effects of daytime hormonal variations[16].

Data analysis

The parameters utilized for data analysis were the values of the peak contact pressure for the whole foot (WF), the forefoot (FF) and the hindfoot (HF) of the right foot (R) and the left foot (L); distance between the medial edge of the R and L foot (width of support base - LB); distance from COF to the anterior (COF-A) and posterior (COF-P) limit of the feet; the contact area (CA) and anteroposterior and mediolateral COF oscillations. Using the COF as a reference, the front part was considered the forefoot and the back part was considered the hindfoot.

Matscan® 5.1 records a 200 frame film. For the analysis of these variables, the total value was obtained by the mean of the values at frame 1, 100 and 200 of each of the three films of a collected position. For the analysis of COF oscillation, the data related to the anteroposterior (AP) and mediolateral (ML) amplitudes were converted to ASCII, using Research Foot 5.72 (Matscan®) software. These data were imported and analyzed using Microsoft® Excel. To normalize the data, the variables were multiplied by the value of the distance between the sensors (0.8382cm).

Statistical analysis

The sample was calculated using the Graphpad Statmate 2.0 (Power test) program, based on the means and standard deviations of the plantar pressure data for pregnant women obtained in a pilot study. Considering alpha error 0.05 and power test 80%, the recommended number of pregnant women for evaluation was 14 to 16.

The presumptions of data normality and homogeneity of variance were verified in SPSS 14.0 using the Shapiro-Wilks test and the Levene test, respectively.

Once the statistical significance of the normality and the homogeneity of variance were verified, the effects of the groups were compared by applying Anova-F, followed by the Tukey post-hoc test. The data that did not fit the requirements for parametric methods were verified by applying the Kruskal-Wallis test, followed by the Mann-Whitney test corrected by Bonferroni (α= 0.0056). To verify the degree of association between the anthropometric variables (current weight and weight gain) and the plantar pressure variables as well as the association between COF amplitude, the size of the base of support and the contact area of the feet, Spearman's correlation was applied to the parametric data and

Pearson's correlation was applied to non-parametric data. In all analyses, the alpha significance level was 5%.

RESULTS

Table 2 shows that there was no significant difference (p> 0.05) between groups regarding the total peak pressure in the forefoot and hindfoot of both feet. Group 2T displayed a narrower support base when compared with the control group. With regard to the distance from the COF to the anterior and posterior limit of both feet, there was no significant difference (p> 0.05) between groups. Group 3T displayed greater anteroposterior COF amplitude when compared with group 1T. There was no difference between the groups as to mediolateral COF amplitude. The contact area of the feet in both positions was also insignificant (p> 0.05).

There was a positive, medium and significant correlation (p> 0.05) between the weight gained and the peak pressure of contact in all R feet in group 3T (r= 0.755); and with the contact area of the R (r= 0.576) and L (r= 0.574) foot in group 2T; and between BMI and the contact area of the R (r= 0.523) and L (r= 0.574) foot in the control group.

The correlation between the COF oscillation, the size of the support base and the contact area was analyzed. It was positive and significant (p< 0.05) only between the anteroposterior COF oscillation and the support base of the women in group 1T (r= 0.627). There was no correlation between the contact area of the feet and COF oscillation.

DISCUSSION

Throughout the gestational period, the center of force (COF) shifts toward the forefoot. To bring it back inside the support base, however, the tendency would be to increase the plantar pressure on the hindfoot, as reported by Nyska et al.[6] who found higher values of pressure in the hindfoot and lower values in the forefoot of women in the third trimester compared to non-pregnant women. In the present study, there was no such alteration and no difference in peak contact pressure in the three different trimesters. A possible explanation for these findings would be the individual differences in physiological adaptation during pregnancy, which could be a result of different types of physical activities performed during the gestational period[17].

The physiological manifestations of weight increase on the foot can be pain, irritation or discomfort in the lower limbs[18]. In normal feet, the plantar pressure values in the static position do not exceed 263 kPa (2.68 kg/cm^2) in any

Table 2. Values (mean ± standard deviation) for whole foot (WF), forefoot (FF) and hindfoot (HF) peak pressure of the right foot (R) and left foot (L); width (cm) of support base (SB); distance from center of force (COF) to anterior (COF-A) and posterior (COF-P) limit of the feet; anteroposterior (AP) and mediolateral (ML) COF amplitude (mm), and contact area (CA) in cm^2 of right foot (R) and left foot (L) of control (C), first (1T), second (2T) and third (3T) trimester groups. * p< 0.05 to respective C. $^{\#}$ p< 0.05 to respective 1T. n= 15.

		Peak pressure (kg/cm^2)			
	C	**1T**	**2T**	**3T**	**p**
WFR	1.00 ± 0.18	1.07 ± 0.32	1.05 ± 0.26	1.08 ± 0.24	0.82
WFL	1.13 ± 0.30	1.25 ± 0.40	1.22 ± 0.27	1.19 ± 0.23	0.76
FFR	0.51 ± 0.13	0.53 ± 0.16	0.54 ± 0.16	0.66 ± 0.23	0.9
FFL	0.53 ± 0.12	0.53 ± 0.11	0.54 ± 0.17	0.66 ± 0.20	0.9
HFR	1.00 ± 0.18	1.05 ± 0.33	1.04 ± 0.28	1.07 ± 0.25	0.90
HFL	1.13 ± 0.29	1.27 ± 0.40	1.21 ± 0.24	1.15 ± 0.27	0.64
		Width of support base (cm)			
SB	13.11 ± 2.79	10.74 ± 4.09	8.08 ± 2.26*	9.71 ± 3.47	0.1
		Distance from COF to anterior and posterior limits of the foot (cm)			
COF-A	15.06 ± 1.12	14.79 ± 1.23	14.88 ± 1.33	15.23 ± 3.26	0.93
COF-P	8.26 ± 0.83	8.33 ± 1.25	8.35 ± 0.91	8.91 ± 1.07	0.29
		COF amplitude (mm)			
AP	25.92 ± 1.33	26.16 ± 1.97	24.68 ± 3.63	25.09 ± 2.85$^{\#}$	0.2
ML	17.26 ± 1.83	15.65 ± 3.04	17.29 ± 2.29	18.61 ± 3.40	0.25
		Contact area (cm^2)			
CAR	93.69 ± 10.93	87.62 ± 10.82	91.65 ± 10.41	97.87 ± 14.63	0.14
CAL	99.00 ± 11.87	92.10 ± 13.48	94.94 ± 11.48	103.38 ± 15.97	0.12

segment[19]. In this present study, the highest peak pressure found was on the L hindfoot of group 1T (1.27 kg/cm^2), which demonstrates that the plantar pressure in the control group as well as the pregnant groups were normal. This suggests that there is no imminent risk of appearance of pain or discomfort in this population.

Dumas et al.[20] observed that the support base is significantly wider at the end of pregnancy. However, in this study, the support base in group 2T was narrower than in the control group. Although the pregnant women were free to decide the position of the feet, the fact that they had to remain inside a marked space on the platform may have limited the size of the base, as it is known that postural stability depends on the perception of one's position in relation to the center of gravity and the surroundings.

Center of gravity (COG) is the place in the body where its mass is equally distributed[21]. Center of force is the projection of the COG within the support base and it results from the reaction forces of the ground with the support; it is a neuromuscular response to the shift in the COG[22]. Therefore, if a change in mass occurs, such as weight gain and abdominal increase in pregnant women, there will be a shift in the COG, which is reflected in the COF and causes a greater oscillation[9]. That has been verified in this study along with increased AP amplitude in group 3T when compared with group 1T and the control group.

Butler et al.[10] found a decrease in postural balance in pregnant women during the 2nd and 3rd trimesters when compared with non-pregnant women and, not only did this condition persist postpartum, but there was no correlation between postural balance and weight gain. This suggests that postural stability in this population is more related to hormonal, ligament and joint alterations than to abdominal increase or weight gain.

The degree of stability is higher when the COG is lower, the support base is wider, the projection of the COG remains inside the support base, and body mass is greater[9,21]. Therefore, it is possible to relate the increase in AP oscillation of the COF to the instability of the volunteers because, even though body mass has increased, it is not distributed evenly around the body and there may be asymmetrical looseness of the joints[22,23], which can cause higher instability.

No correlation was found between COF oscillation and weight or weight gain in pregnant women, which confirms the findings of Butler et al.[10].

There was no correlation between the size of the support base and AP amplitude of the COF or ML amplitude of the COF (except for women in group 1T), nor between the contact area of the feet and COF oscillation. These results infer that the size of the support base and the contact area of the feet had no influence on AP and ML postural oscillation of the COF.

In spite of divergences, some authors report that ligament changes and edema resulting from pregnancy cause an increase in the volume and size of the feet, which lead to an increase in the contact area[6]. However, in the present study, there was no difference in contact area between the groups, which suggests the unlikelihood of significant looseness of the ligaments of the feet or edema in the lower limbs during pregnancy[4].

The decrease in postural stability is related to the risk of falling. In fact, the risk of this event during pregnancy is similar to the risk observed in elderly individuals[11,24,25]. Therefore, physical therapy procedures such as balance training could reduce the risk of falls, prevalent in 25% of pregnant women[10].

In the literature, there are few studies which explain the changes that occur during this period of a woman's life, and they do not agree in relation to the postural standard adopted by pregnant women. Postural adaptation due to the changes during pregnancy probably occurs individually and according to previous postural characteristics.

As in the study by Dumas et al.[20], the women were already pregnant when they joined the present study. Therefore, it was not possible to analyze the posture before pregnancy.

The results of the present study show the relevance of methodology used to evaluate the baropodometric and stabilometric aspects of pregnant women, as they followed rigorous scientific criteria. The collected data have provided a better understanding of the biomechanical changes which occur during the gestational period, seeking more efficient physical therapy intervention, especially concerning the preventive aspects of the musculoskeletal discomforts.

CONCLUSION

Plantar pressure alterations were not observed in any of the evaluated trimesters. However, the higher AP oscillation found in group 3T, when compared with group 1T, suggests decrease in postural balance in that phase.

Overall, the anthropometric characteristics of the volunteers did not have any correlation with the analyzed data.

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