Journal of Advances in Medicine and Medical Research

27(7): 1-6, 2018; Article no.JAMMR.44145
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

Assessment of Foot Biomechanics through Measuring of the Plantar Pressure during the Last Trimester of Pregnancy

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Authors' contributions

This work was carried out in collaboration between all authors. Author ASG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EAE and AAA managed the literature searches and make editing. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2018/44145
Editor(s):
(1) Dr. Sevgul Donmez, Faculty of Health Sciences, Gaziantep University, Turkey.
Reviewers:
(1) Shigeki Matsubara, Jichi Medical University, Japan.
(2) Liudmila Ivanova, Kuban State Medical University, Russia.
Complete Peer review History: http://www.sciencedomain.org/review-history/26327

Original Research Article

Received 27 June 2018
Accepted 07 September 2018
Published 20 September 2018

ABSTRACT

During pregnancy there are many changes in female posture which affect gait parameters.
Aim: The purpose of this study was to analyze changes in foot plantar pressure patterns in pregnant women in their third trimester versus non pregnant women.
Methods: Thirty female subjects contributed to this study were divided into two groups, pregnant (3rd Trimester) and non-pregnant.
Results: The pressure on the sole of the foot was higher by 55.5% in the navicular bone in pregnant women in their third trimester (T3) than in the control group (non-pregnant women) (4.6 ± 1.6 N/cm2 in the pregnant women in the third trimester (T3) vs. 2.5 ± 1.5 N/cm2 in the control group (non-pregnant women), $p < 0.05$).
Conclusion: The highest pressure amplitudes were found under the rear foot and the heads of

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metatarsal, while the lowest values of pressure were found under the cuboid bone, navicular bone and forefoot but the values significantly increased more in pregnant women in their third trimester compared with non-pregnant women.

Keywords: Biomechanics; foot plantar pressure; pregnancy; pedobarography.

1. INTRODUCTION

During pregnancy there are mechanical changes in the female body; pregnancy hormones; body weight affect gait parameters and increase mechanical loading on the joints [1]. The weight added about 12 Kg during pregnancy which increases the load on the back and lower extremities [2]. Furthermore, increased size of the uterus may change the center of gravity and is consequently compensated by anterior pelvic tilting and increases lumber lordosis. These changes affect female balance and gait [3].

The hormonal changes during pregnancy increase ligament laxity and muscle weakness [1], and weakness of the lower abdominal muscles has been associated with pelvic girdle pain in pregnant women [4].

More than 50% women complain from hip pain and up to 75% of them suffer from back and foot pain during pregnancy [5]; walking during pregnancy increased lower extremity joint movements especially hip abductors, hip extensors and ankle plantar flexor muscles [6]. The plantar pressure has been considered as an important biomechanical parameter to evaluate walking of the human. The distribution and magnitude of plantar pressure can provide useful information to diagnose varity of foot disorders [7].

The plantar pressure measurements during standing, walking and running can demonstrate the pathomechanics of foot disorders and give objective assessments for the disease. Several studies in foot biomechanics have reported that the plantar pressure variations are useful to determine pathological gait. Pathological gait can be divided on the basic etiology, either neuromusclar or muscloskeletal [8].

Many research groups used the potential of pressure measurement technology for the diagnosis and treatment of different foot disorders [9].

Pedobarografic measurements provide readings of the changes in distribution of plantar pressure and changes of pressure distribution in certain regions of the foot. Plantar pressure values are useful to determine the abnormal gait pattern in cases such as: rheumatoid foot, diabetic neuropathy and cerebral palsy [10].

The purpose of this study was to analyze changes in foot plantar pressure patterns in pregnant women in their third trimester versus non pregnant women using a pedobarograph.

2. SUBJECTS AND METHODS

A cross section study was adopted. A total of 40 females volunteers from the employers of Kafrelsheikh University, Egypt, out of which 30 were recruited for this study Fig. 1.

The purpose and nature of the study was explained to all participants. The females participating in the study signed an informed consent form before data collection. Recruitment began after approval of the Faculty of Physical Therapy Ethics Committee number P.T.REC/012/00179.

There were 2 equal groups (A&B). The study was done in a biomechanics lab at Faculty of Physical Education, Kafrelsheikh University from August 2017 to April 2018. Group A, pregnant women in their third trimester, had ages ranging from 25-30 years old and body mass index (BMI) ≥ 35 ≤ 40 kg/m2, and group B (control or healthy non-pregnant women) shared the same age range and BMI.

Exclusion criteria: both groups have no past history of any musculoskeletal problems, diabetes, preeclampsia and any vision problem.

Pedobarograph apparatus, one of the instruments used in the field of biomechanics, was used to assess foot biomechanics through measuring the pressure on the plantar surface of the foot. It provided information about the high pressure areas in addition to the progression of the center of pressure. The idea about the use of a pedobarograph to measure the foot plantar

pressure (T&T medilogic Medizintechnik, GmbH Munich, Germany) is based on insoles inserted inside the shoes with capacitive sensors which provides us with information during rest and motion for both feet. Information during motion for both feet were collected as well, with the patients walking at their natural self-selected speed. The data for each sensor was sampled at the frequency of 60 Hz and transferred to a computer via a wireless connection. To assess foot plantar pressure distribution, the pressure amplitudes of all sensors were grouped into five anatomical masks [11]. These masks corresponded to five anatomical areas: the forefoot (toes), the metatarsal heads, the navicular bone, the cuboid bone, and the hind foot (heel) Fig. 2.

In a normal pattern of gait, during each gait cycle, the rear foot (heel) was the first part of the foot to recieve the stress and weight bearing of the human body. then moving to the toe through the midfoot and metatarsal area. During the study, the pressure on the sole of the foot and the contact area of each mask was measured. The pressure value should fit the full range from zero to the absolute maximum determined by the body mass and the contact area of one sensor [12].

Maximum pressure was defined as the greatest pressure in each anatomical area of the foot in a single step, and these values were averaged separately for each mask over 10 steps. The same procedures were done in the control group.

2.1 Sample Size

To avoid a type II error, a preliminary power analysis [power (1−α error P) = 0.95, α = 0.05, effect size = 1.599] determined a sample size of 12 for each group in this study. This effect size was calculated according to a pilot study on 12 participants (6 in each group) considering the pressure pattern as a primary outcome.

2.2 Statistical Analysis

The differences in pressure distribution were tested with t-test.

Means and standard deviations were calculated for the total subject sample for the data from the pedobarograph.

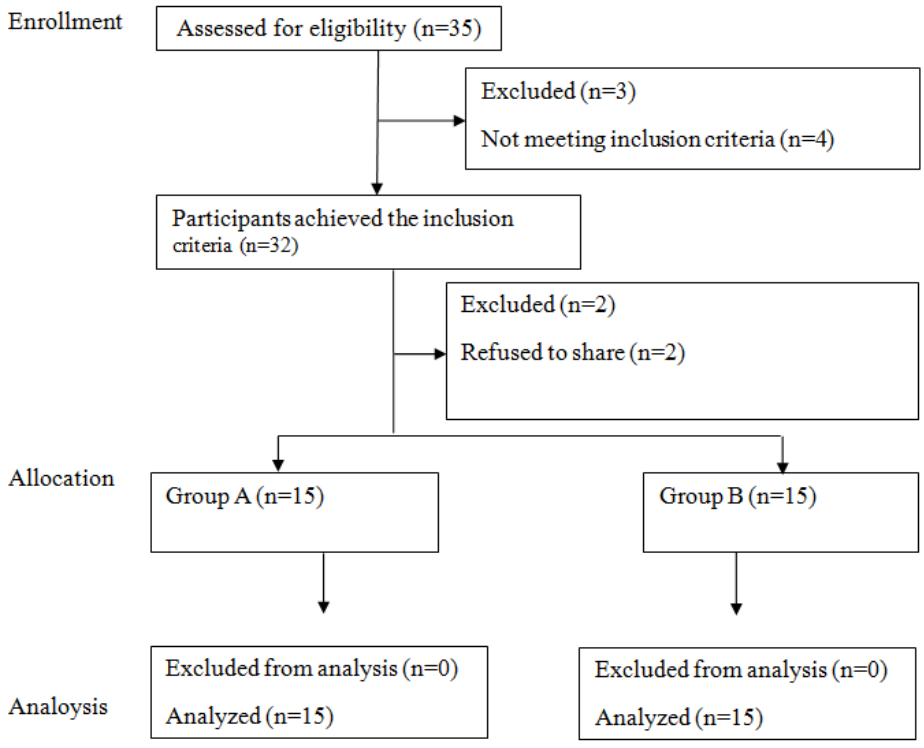

Fig. 1. Flow chart of the participants during the trial

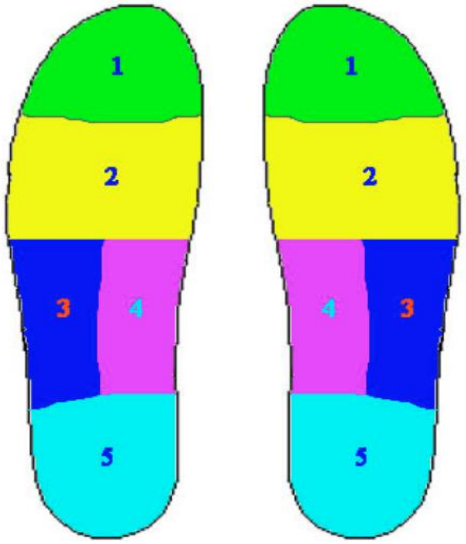

Fig. 2. Anatomical areas of human foot (Sviridenok, [11])

3. RESULTS

Our study proved that there is a statistically significant difference observed in the pressure amplitudes on the plantar aspect of the foot during walking between the pregnant women during the third trimester and the control group (non-pregnant healthy women).

For control subjects (non-pregnant women), the high pressure values were found under the heel in addition to the heads of metatarsal , while the low pressure values wer under the cuboid bone, navicular bone and toes.

The highest mean pressure in non-pregnant women was found in the posterior of the hind foot under the central part of the heel (20.6 ± 2.4) and then anterior under the metatarsal heads (15.3 ± 2.6). The lowest pressure distribution was under the navicular bone (2.5 ± 1.5), under the cuboid bone (5.5 ± 1.6) and under the toes (3.8 ± 2.6).

In the pregnant women (third trimester) the highest pressure amplitudes were found under both the metatarsal heads (17.8 ± 2.9) and rear foot (22.24 ± 1.7), while the lowest pressure distributions were under the navicular bone (4.6 ± 1.6), under the cuboid bone (10.5 ± 1.9) and under the toes (6.9 ± 2.8).

The pressure value was higher by 55.5% in the navicular bone in the pregnant women in their third trimester than in the control group (non-pregnant women) 4.6 ± 1.6 N/cm2 in the pregnant women in their third trimester versus. 2.5 ± 1.5 N/cm2 in the control group (non-pregnant women), $p < 0.05$).

So the higher pressure values were found in both pregnant and non-pregnant women under the hind foot and the metatarsal heads, while on the other hand the low pressure values were all under cuboid, navicular bone and forefoot. However, these values significantly increased in the pregnant women as supposed to the non-pregnant, healthy women.

4. DISCUSSION

The Relaxin hormone in particular, which is one of the pregnancy hormones that prepare the body for labor, softens and dilates the cervix, and is an important cause of increased ligament laxity in the pelvis, affects the whole female body. In the feet, the increased ligament laxity leads to the flattening of arches, instability of ankles, possible contribution to lower back pain and alteration of gait pattern and weight bearing distribution on the sole of the foot. Flat feet adds stress on the foot and causes inflammation of plantar fascia and increases strain on the feet, calves and sometimes the back [13].

Naturally women also gain weight during pregnancy, which causes change in pregnant woman's center of gravity. This changes her stance and adds pressure to the feet and knees, plus changes in the weight bearing distribution off the foot may cause foot pronation and edema, making changes to gait pattern [13].

The dynamic plantar pressure distribution gives information about changes in posture during walking [14]. The pressure measurement while the subject is standing also gives important information on the load of the human body on the feet of people who suffer from various postural deformities [15].

Table 1. Demographic features of the two studied group

Variables	Group (A)		Group (B)		t value	Level of significant
	Mean	±SD	Mean	±SD		
Age (Yrs)	24.90	±2.48	24.65	±3.01	0.29	P<0.77
BMI ($Kg/m^{2)}$	37.21	±1.2	37.19	±1.25	0.06	P<0.95

Table 2. Summarized the mean values of the foot pressure pattern in pregnant women in their third trimester (T3) versus non pregnant women during walking (±SD)

Foot area	Non pregnant women	Pregnant women during third trimester (T3)
1-Toes	3.8 ± 2.6	6.9 ± 2.8
2- Metatarsal heads	15.3 ± 2.6	17.8 ± 2.9
3- Navicular bone	2.5 ± 1.5	4.6 ± 1.6
4- Cuboid bone	5.5 ± 1.6	10.5 ± 1.9
5- Heel	20.6 ± 2.4	22.24 ± 1.7

In normal pattern of gait during each gait cycle, the rear foot (heel) is the first part of the foot to receive the weight bearing of the body, then moving to the toe through the midfoot and the metatarsal area.

So the highest pressure amplitudes were found in both pregnant and non-pregnant women under the hind foot and the metatarsal heads, while the lowest pressure values were under cuboid bone, navicular bone and forefoot but the values significantly increase more in pregnant compared with non-pregnant women.

Our results matched with the study done by Karadag-Saygi, et al. [5] who proved that pregnant women had higher fore foot pressure on the right side, and increased fore foot contact time with longer floor contact times while either walking or standing.

It can suggested that forefoot pressures increases in the last trimester of pregnancy during standing and walking, as in this period there is prominent increased postural sway in the anterior-posterior direction which may be due to the increase in body mass and distribution.

Another study done by Tuncay et al. [16] proved that, due to the hormonal changes and increased body weight during pregnancy, the forces exerted at the soles of the feet shift from the posterior to the anterior, with consequent increases at the fore foot and mid foot. These changes are due to compensatory postural changes against the factors altering the trunk and pelvis biomechanics.

Thus, the present study did not provide any practically clinical usefulness. However, the present measurement is easy and reproducible. We showed here that pregnant women showed different pattern in pressures on the soles of the foot. Further study, especially in association with the patients' symptoms, may be of use. The present data may provide a basis for such future studies.

5. CONCLUSION

There is statistically significant difference in the pressure amplitudes on the plantar aspect of the foot while walking between pregnant and non-pregnant women.

CONSENT

The females participating in the study signed an informed consent form before data collection.

ETHICAL APPROVAL

Recruitment began after the approval of the Faculty of Physical Therapy Ethics Committee number P.T.REC/012/00179.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26327