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ORIGINAL ARTICLE

The Effect of Foot Anthropometric Measurements on Pain and Functional Disability of Pregnant and Non-Pregnant Women

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Background: Weight gain during pregnancy, loosening of the foot ligaments with the release of relaxin hormone, anthropometric and biomechanical changes can be seen in the foot with the growing fetus. It was aimed to determine whether these changes that occur during pregnancy cause painful musculoskeletal problems by altering the proximal structures of the lower extremities and the structure of the spine.

Methods: Within the scope of this study, 210 women, half of whom are 3rd trimester of pregnancy (in the 28-40 weeks), aged between 18 and 40, with similar demographic characteristics are evaluated through measuring their navicular drops, hallux valgus angles, foot widths, foot lengths and tibial-calcaneal angles of both feet. Foot Function Index for foot-ankle, Kujala Patellofemoral Score for knee, Western Ontario and McMaster University Osteoarthritis Index (WOMAC) for hip, Oswestry Disability Index for waist and Modified Neck Disability Index for neck were used to determine pain and functional limitation.

Results: In this study, pain and functional disability in the waist, hip, knee, foot-ankle joints, navicular drops, hallux valgus angles and tibial-calcaneal angles were found to be significantly higher in pregnant women compared to the control group (P=0.00). It was observed that pain and dysfunction in all joints increased as navicular drop increased in both pregnant and non-pregnant women. In addition, it was determined that the increase in other anthropometric measurements in both groups caused pain and functional disability in most of the women, especially in the foot and ankle joints. However, the cause of joint pain and functional deficiencies was not related to pregnancy.

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Conclusions: It was observed that foot deformities and proximal region complaints were significantly higher in pregnant women, and foot deformities caused more foot-ankle pain and disability in both the study and control groups. No difference was observed in pregnant women with the control group.

Pregnancy causes various anatomical and physiological changes in the mother with the effect of weight gain that occur with the growing fetus and hormones. These changes cause some biomechanical problems [1-3]. Causing the weight gaining and triggering the release of the relaxin hormone, pregnancy increases the flexibility of the ligaments in the feet, and thus leads to some anthropometric changes [1,2,4]. Studies have reported increases in foot length, width and volume in pregnant women. In particular, changes were observed in the range of motion of the subtalar joint and the 1st metatarsophalangeal joints [5-7].

The increase in the flexibility of the ligaments during pregnancy, the increase in body mass and the shift of the pressure center towards the back of the foot cause various changes in the longitudinal arch and foot structure. These biomechanical changes of feet that occur during pregnancy cause painful musculoskeletal problems by changing the structure of the lower extremity proximal structures and the spine [1,8].

The recommended weight gain during pregnancy is between 11 and 16 kg. This weight is often taken from the abdomen [9]. As the abdomen grows and the center of gravity shifts forward, problems such as low back pain and pelvic pain occur [10]. Spinal pain is the most common postural problem. It is followed by lower and upper extremity pains, muscle cramps and peripheral neuropathies [8]. Pregnancy-related low back pain and lumbopelvic pain caused various limitations and negatively affected important parts of life [11]. The vast majority of cases continue after pregnancy and in later times [12].

In the literature, there are studies showing how foot deformities affect the proximal structures of the body in different populations [13-17]. However, there is a limited number of studies in which foot deformities and anthropometric measurements are made in pregnant women, their effects on the body are examined, and pregnant and non-pregnant women are compared. For these reasons, the aim of this study is to investigate whether foot deformities affect lower extremity and trunk musculoskeletal pain and disability, which are frequently encountered in pregnant women. It is also to determine the statistical differences with non-pregnant women in the control group.

According to the findings of our study, it is aimed to give recommendations to pregnant women such as personalized insoles, comfortable shoes that support the sole of the feet and exercise recommendations according to foot problems in order not to reduce the quality of life of postural problems in the foot and body.

METHODS

This study was approved by Afyonkarahisar Health Sciences University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (dated 01.10.2021 and numbered 2021/484).

Participants

Between January 2022 and June 2022, a total of 210 women, 105 non-pregnant and 105 pregnant women in the 3rd trimester (28-40 weeks), aged 18-40, with similar demographic characteristics, who applied to Afyonkarahisar Health Sciences University, Health Application and Research Center, Department of Obstetrics and Gynecology, were evaluated. In order to prevent possible changes that may occur and continue during pregnancy, non-pregnant women in the control group were selected from women who had not had a pregnancy before, and those in the study group were selected from women who had their first pregnancy. A total of 4 women, 2 pregnant and 2 non-pregnant, who had trauma from the foot-ankle, knee, hip, waist and neck region for various reasons, who had undergone surgery in these regions and had physical disabilities, were not included in the evaluation.

The women were informed about the study, and an informed consent form was signed by the women who agreed to participate in the study. Participants' age, height, weight and BMI

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(body mass index) were obtained. [BMI= (Weight/height^2) = (kg/m^2)]. Data were classified as pregnant and non-pregnant and demographic characteristics are given in table 1.

Procedure

Some anthropometric measurements of foot, such as navicular drop, hallux valgus angle, foot width, foot length, and tibial-calcaneal angle, were performed while standing. These measurements were made twice by two different researchers and their average values were written. We planned to investigate whether these measurements affect more proximal structures such as foot-ankle, knee, hip, waist and neck in terms of pain and functional disability. Scales with scientific validity and necessary permissions were used for pain and functional ability assessments in proximal structures. Foot Function Index (FFI) for the foot and the ankle, Kujala Patellofemoral Score for the knee, WOMAC Osteoarthritis Index for the hip, Oswestry Disability Index for the waist, and Modified Neck Disability Index for the neck are utilised. A goniometer was used to measure the hallux valgus angle and the tibial-calcaneal angle, and a mechanical caliper was used to measure the navicular drop, foot width and foot length. The data obtained from the study are important in terms of determining the anthropometric changes that can be caused by pregnancy and revealing the changes caused by foot deformities in the body of pregnant and non-pregnant women.

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Anthropometric Measurements of Foot

Navicular Drop: At first the distance between the ground and the lowest point of the navicular bone was measured with a mechanical caliper in the sitting position, and then in the standing position. The remaining distance was taken as navicular drop. If the navicular drop was between 0,6 and 0,9 cm, it was considered as normal MLA (medial longitudinal arch), and if it was 1 cm or more, it was considered as pes planus **(Figure 1-A, 1-B).**

Foot Length: The distance between the tuber calcanei and the longest fingertip in the standing position was measured in cm with a mechanical caliper **(Figure 1-C).**

Foot Width: In the standing upright position, the widest distance of the foot between the inner edge of the I. metatarsophalangeal joint and the outer edge of the V. metatarsophalangeal joint was measured in cm with a mechanical caliper **(Figure 1-D).**

Hallux valgus: In the standing upright position, the angle between the first metatarsal and the long axis of the first proximal phalanx was measured in degrees with a goniometer. Angles of 20° and above were accepted as hallux valgus **(Figure 1-D).**

Tibial-calcaneal angles: The angle between the midpoint of the calcaneal bone and the axis of attachment of the Achilles tendon to the calcaneal bone in the standing upright position was calculated by measuring with a goniometer **(Figure 1-E).**

Scales for Pain and Disability

Foot Function Index, one of the commonly used scales, was preferred for foot and ankle pain and functional evaluation. The total score is calculated by giving a score between 0-10 for each question on the scale, which includes questions about pain, disability and activity limitation. The total score is found by dividing the answered questions by the maximum possible score and multiplying by 100. As the score gets closer to 100, it is interpreted as pain, disability and activity limitation increase [18] (Total score Cronbach's alpha=0.87). Turkish validity and reliability analysis was conducted by Yalıman et al., 2014 [19].

Kujala Patellofemoral Score was included in the evaluation. There are 13 items on the scale that question walking, climbing and getting down the stairs, squatting, sitting for a long time with knee bent, pain, edema, atrophy. The total score that can be obtained varies between 0-100 from bad to good [20]. Turkish validity and reliability analysis was conducted by Kuru et al., 2010 [21] (Cronbach's alpha=0.84).

Western Ontario and McMaster University Osteoarthritis Index (WOMAC OA) was used to evaluate the hip. Scores that can be obtained from the scale are 0-20 for pain, 0-8 for stiffness, and 0-68 for physical function subgroup. An increase in scores indicates more symptoms and a decrease in physical function [22]. Turkish validity and reliability analysis was conducted by Tüzün et al., 2005 [23] (Cronbach's alpha>0.70).

The Oswestry Low Back Pain Disability Questionnaire, consisting of 10 questions, was used to evaluate low back pain and functional disability, and each question was scored between 0-5. The highest possible total score is 50. In the scoring, “1-10 points” is evaluated as dull, “11-30 points” as moderate and “31-50 points” as severe [24]. Turkish validity and reliability analysis was conducted by Yakut et al., 2004 [25] (Cronbach's alpha=0.938).

Neck Disability Index was used to evaluate neck pain and functional disability. Each question is scored between 0-5, and increase in score indicates increased pain and disability. Scores between 0-4 is evaluated as no disability, 5-14 as mild disability, 15-24 as moderate disability, 25-34 as severe disability, 35 and above as complete disability [26]. Turkish validity and reliability analysis was conducted by Kesiktas et al., 2012 [27] (Cronbach's alpha=0.88).

Statistical Analysis

G*Power statistics program (Version 3.1.9.7) was used, the significance level for two independent groups was calculated by taking (alpha) α=0.05, power= 0.95, effect size (d)= 0.5 (medium). Data were analyzed using the ‘SPSS for Windows Version 26’ statistical software. Variables determined through measurements were expressed as mean±standard deviation. In comparisons between two groups, pregnant and non-pregnant women, the student's t test (t-test for the independent group) was used when parametric conditions could be met, and the Mann Whitney U test was used when they could not. Significance was taken as $p<0.05$.

Correlation of anthropometric measurements with scales defined for foot-ankle, knee, hip, waist and neck was checked. Pearson correlation analysis was performed for those with normal distribution, and Spearman correlation analysis for those who did not. P was accepted as $p<0.05$.

RESULTS

Within the scope of this study, 210 women, half of whom are 28-40 weeks of pregnancy (in the third trimester), aged between 18 and 40, with similar demographic characteristics were evaluated. The navicular drop, foot length, foot width, hallux valgus and tibial-calcaneal angle were measured for both feet. In addition, tests were performed for pain and functional disability in the neck, waist, hip, knee, foot-ankle joints. Mean±standard deviation was calculated and shown in table 2. Pain and functional disability in the waist, hip, knee, foot-ankle joints were found to be significantly higher in pregnant women (P=0.00). Navicular drops, hallux valgus angles and tibial-calcaneal angles were found to be significantly higher in pregnant women compared to the control group (P=0.00) (Table 2).

For pregnant and non-pregnant women, the correlation of navicular drop, foot length, foot width, hallux valgus and tibial-calcaneal angle for both feet with pain and functional disability for foot-ankle, knee, hip, waist and neck joints and were examined. It was observed that pain and disability of all joints increased as the navicular drop increased in both pregnant and non-pregnant women. In addition, it was determined that the increase in other anthropometric measurements in both groups caused pain and functional disability in most of the women, especially in the foot and ankle joints. However, the cause of joint pain and functional disability was not related to pregnancy. (Table 3,4).

DISCUSSION

Foot problems are very common in society. Pes planus, one of the most common foot problems, is defined as the decrease in the height of the medial longitudinal arch (MLA) [28-30]. Its incidence varies between 2% and 23% in people, and it has been reported as 10% between the ages of 18-45 [31-32]. It is more common in women and increases with age [33]. Pes planus causes gait problems, increased mechanical stress in the foot-ankle joints, deterioration of the structure of the knee joint, and internal rotation in the hip joint. In addition, anterior pelvic tilt causes an increase of lordosis in the lumbar, cervical region and kyphosis in the thoracic region [34].

Navicular drop between 6 and 9 mm was considered as normal MLA, and if it was 10 mm or more, it was considered as pes planus [35]. While Kosashvili et al reported in their study in 2008 that pes planus does not cause low back and knee pain when it is of low intensity, Ünver et al. stated in their study in 2019 it causes low back and knee pain when it is high intensity of pes planus [36-37].

An increase in the elasticity of the connective tissue is shown among the causes of pes planus for pregnancy. Pes planus lasts until postpartum and usually resolves after birth. Loss of height of the medial longitudinal arch affects weight bearing of the foot. This causes pain and discomfort in the proximal joints due to the deterioration of the biomechanics of the structure. Segal et al. reported that pregnancy may be the cause of pain and some musculoskeletal disorders such as loss of height of the medial longitudinal arch [38]. On the contrary, Ojukwu et al. no relationship was found between the severity of foot, knee and low back pain in pes planus in pregnant women [39].

As in the literature, in present study, if the navicular drop was 1 cm or more, it was considered as pes planus. Pes planus was observed in at least one foot in 51 pregnant women, while the medial longitudinal arch was normal in 54 pregnant women. In non-pregnant women, while pes planus was observed in at least one foot of 10 women, the medial longitudinal arch was normal in the feet of 95 women. Navicular drop was significantly higher in pregnant women than in non-pregnant women. ($p<0.05$). In addition, there was a positive correlation between the increase of navicular drop with pain and functional limitation in the foot-ankle, knee, hip, waist and neck joints of both pregnant and non-pregnant women.

Another common problem in the foot is hallux valgus. Hallux valgus is defined as the lateral deviation of the big toe (hallux). The first metatarsophalangeal joint protrudes medially [40]. In the study of Menz et al. in 2011, it was reported that hallux valgus causes pain in the feet,

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knees, hips and lower back [41]. Kırdı et al. stated in their study that hallux valgus causes pain in the foot and this pain also affects body awareness [42]. Ponnapula and Boberg stated that there was no increase in the first metatarsophalangeal joint range of motion during pregnancy [2].

In this study, angles of 20̊ and more were considered hallux valgus, and it was seen in at least one foot of 7 pregnant and 10 non-pregnant women. For non-pregnant women, there was a positive correlation between the hallux valgus angle and both right and left foot-ankle pain and functional disability.

The hormone relaxin released during pregnancy can cause changes in the length and width of the feet [43]. With increasing body weight, knees, feet and ankles are overloaded, resulting in a flattening of the medial longitudinal arch [44]. Alcahuz-Griñan et al., in their study in 2021, showed that foot length and width increased especially in the third trimester of pregnancy, the plantar arch flattened and these changes disappeared postpartum [45]. Ponnapula and Boberg 2010 stated that there was no increase in the first metatarsophalangeal joint range of motion, foot length and foot width in the arch of the foot during pregnancy [2].

In study, when we examined the width and the length of both feet, there was no statistically significant difference between pregnant and non-pregnant women and no correlation with joints pain and functional disability.

Alcahuz-Griñan et al., in their study in 2021, reported that the foot causes to pronation in the third trimester of pregnancy, and Vico Pardo et al., in their study in 2018, stated that foot pronation increased in the later weeks of pregnancy, but this increase caused pain in the lower back and lower extremities in very few women [45-46].

In this study, the tibial-calcaneal angle in pregnant women was significantly higher than in non-pregnant women. While there was a correlation between the tibial-calcaneal angle of both feet with foot-ankle pain and functional limitation for pregnant women, there was a correlation between this angle with foot-ankle and knee pain and functional limitation for non-pregnant women.

CONCLUSIONS

Most of the foot anthropometric measurements of pregnant women are significantly higher than those of non-pregnant women. Pain and functional disability of the joints other than the neck of pregnant women are significantly higher than those of non-pregnant women. In addition, it was determined that the increase in anthropometric measurements in both groups caused pain and functional deficiencies in most of the women, especially in the foot and ankle joints. However, this is not due to pregnancy. In order to eliminate these effects, foot orthoses are applied inside the shoes. In addition to the various arch-enhancing orthoses, the most current orthoses are recommended as specially designed insoles for use in shoes. These insoles must support the foot medially, fit the foot perfectly and be personalized. In this way, it is ensured that the body weight is evenly distributed over the proximal regions. In addition, exercises that strengthen the muscles of the feet may be recommended to patients.

Limitations

This study was conducted in women in the third trimester of pregnancy. If measurements were made in the 1st and 2nd trimesters, we would have examined how much the deformities changed and the difference in pain and disability in the body. Further studies can be done to determine the differences between trimesters of pregnancy.

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Conflict of Interest: None reported.

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Figure 1. A. X=Navicular distance in the sitting position**; B.** Y=Navicular distance in the standing position. X-Y=Navicular drop**; C.** Foot Length; **D.** Foot Width - Hallux valgus; **E.** Tibial-calcaneal angle.

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Table 1. Demographic characteristics of pregnant and non-pregnant women

	PREGNANT (n=105) (Mean±SD)	NON-PREGNANT (n=105) (Mean±SD)
Age (year)	27,10±5,11	23,19±5,36
Length (cm)	160,60±5,49	162,97±6,75
Weight (kg)	76,20±13,91	59,90±11,12
BMI (kg/m$^{2)}$	29,50±4,98	23,07±6,65

BMI= Body mass index

Table 2. Mean±standard deviation and p values **of navicular drop, hallux valgus, foot width, foot length, tibial-calcaneal angle** measurements in the both feet and **Neck Disability Index, Oswestry, Womac, Kujala, FFI scales** of pregnant and non-pregnant women

	PREGNANT Mean±SD	NON-PREGNANT Mean±SD	P
Navicular drop (R)	0,89±0,27	0,71±0,17	0,00
Hallux valgus (R)	14,61±2,62	13,77±3,40	0,00
Foot Width (R)	9,36±0,71	9,23±0,72	0,17
Foot length (R)	23,06±1,35	23,06±1,28	0,99
Tibial-calcaneal angle (R)	6,04±1,20	5,10±1,09	0,00
Navicular drop (L)	0,83±0,25	0,68±0,15	0,00
Hallux valgus (L)	14,27±2,31	13,20±3,33	0,00
Foot Width (L)	9,31±0,71	9,18±0,71	0,18
Foot length (L)	23,00±1,36	23,00±1,28	0,97
Tibial-calcaneal angle (L)	5,77±1,12	5,02±1,00	0,00
Neck Disability Index	5,25±5,31	4,20±4,66	0,18
Oswestry	33,52±17,96	7,09±13,62	0,00
Womac	22,43±26,00	3,63±9,74	0,00
Kujala	81,10±14,52	94,73±10,05	0,00
Foot Function Index	24,77±23,19	4,22±8,99	0,00

R. Right **L.** Left

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Table 3. Correlation of navicular drop, foot length, foot width, hallux valgus and tibial-calcaneal angle measurements with Neck Disability Index, Oswestry, Womac, Kujala and Foot Function Index scales for pregnant women

CORELATION PREGNANT	Neck Disability Index		Oswestry		Womac		Kujala		Foot Function Index	
	r	p	r	p	r	p	r	p	r	p
Navicular drop R	0,335**	0,000	0,274**	0,005	,263**	0,007	-0,414**	0,000	0,331**	0,001
Hallux valgus R	0,048	0,628	-0,040	0,687	0,009	0,931	-0,129	0,189	0,192*	0,049
Foot Width R	0,185	0,058	0,145	0,139	0,140	0,154	-0,042	0,674	0,198*	0,043
Foot length R	-0,048	0,628	0,021	0,834	-0,061	0,537	0,092	0,352	0,055	0,578
Tibial-calcaneal angle R	0,175	0,074	0,030	0,762	0,135	0,171	-0,165	0,093	0,322**	0,001
Navicular drop L	0,272**	0,005	0,197*	0,044	0,212*	0,030	-0,335**	0,000	0,260**	0,007
Hallux valgus L	0,013	0,894	-0,068	0,493	-0,013	0,897	-0,086	0,384	0,106	0,284
Foot Width L	0,173	0,077	0,136	0,168	0,162	0,098	-0,057	0,563	0,168	0,086
Foot length L	-0,053	0,589	0,049	0,621	-0,057	0,566	0,090	0,362	0,056	0,571
Tibial-calcaneal angle L	0,125	0,203	0,024	0,806	0,122	0,215	-0,128	0,195	0,264**	0,006

R. Right **L.** Left

**Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed)

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Table 4. Correlation of navicular drop, foot length, foot width, hallux valgus and tibial-calcaneal angle measurements with Neck Disability Index, Oswestry, Womac, Kujala and Foot Function Index scales for non-pregnant women

CORELATION NON-PREGNANT	Neck Disability Index		Oswestry		Womac		Kujala		Foot Function Index	
	r	p	r	p	r	p	r	p	r	p
Navicular drop R	0,244*	0,012	0,417**	0,000	0,333**	0,001	-0,305**	0,002	0,448**	0,000
Hallux valgus R	-0,163	0,096	0,050	0,612	0,166	0,090	-0,174	0,076	0,331**	0,001
Foot Width R	-0,078	0,429	0,049	0,618	0,024	0,806	-0,151	0,125	0,030	0,763
Foot length R	-0,024	0,809	-0,015	0,879	-0,117	0,233	-0,064	0,514	-0,014	0,886
Tibial-calcaneal angle R	-0,077	0,432	0,036	0,713	0,051	0,603	-0,208*	0,034	0,173	0,077
Navicular drop L	0,226*	0,020	0,401**	0,000	0,290**	0,003	-0,281**	0,004	0,388**	0,000
Hallux valgus L	-0,196*	0,045	0,003	0,974	0,131	0,183	-0,152	0,122	0,277**	0,004
Foot Width L	-0,006	0,951	0,079	0,423	0,050	0,610	-0,201*	0,040	0,038	0,697
Foot length L	-0,013	0,891	-0,006	0,953	-0,107	0,276	-0,055	0,574	-0,004	0,971
Tibial-calcaneal angle L	-0,024	0,812	0,112	0,254	0,113	-0,024	-0,252**	0,009	0,232*	0,017

R. Right **L.** Left
**Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed)