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DEFORMITIES OCCURRING IN THE ARCUS PLANTARIS OF HEALTHCARE WORKERS WORKING WHILE STANDING FOR A LONG TIME

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ABSTRACT:
IN TODAY'S WORLD, MANY PEOPLE SPEND A SIGNIFICANT AMOUNT OF TIME STANDING DUE TO THEIR WORK CONDITIONS. HEALTHCARE PROFESSIONALS, IN PARTICULAR, ARE AMONG THESE INDIVIDUALS. THE MAIN PROBLEM ADDRESSED IN THIS RESEARCH IS WHETHER PROLONGED STANDING CAN CAUSE DEFORMITIES IN THE ARCUS PLANTARIS AND IF SO, WHAT THESE DEFORMITIES ARE. FURTHERMORE, FOOT LENGTH CHANGES HAVE ALSO BEEN EXAMINED WITHIN THIS OCCUPATIONAL GROUP. IF WE COMPARE THE LATERAL VIEW OF THE FOOT ARCH TO A TRIANGLE, IT CAN BE OBSERVED THAT THE CALCANEAL INCLINATION ANGLE AND CALCANEUS-1ST METATARSAL ANGLE FORM TWO ANGLES OF THIS TRIANGLE. THE THIRD ANGLE OCCURS BETWEEN THE MIDSHAFT OF THE 1ST METATARSAL BONE AND THE PLANE ON WHICH THE FOOTRESTS UPON AS UNDERSTOOD FROM THIS EXPLANATION, THERE IS A RELATIONSHIP BETWEEN CALCANEAL INCLINATION ANGLE AND CALCANEUS-1ST METATARSAL ANGLE. AS CALCANEAL INCLINATION ANGLE DECREASES, CALCANEUS-1ST METATARSAL ANGLE INCREASES, I.E., FLATTENING OF THE FOOT ARCH OCCURS. THE REVERSE IS ALSO TRUE [10]. THERE ARE STATISTICAL DIFFERENCES BETWEEN WOMEN WORKING WHILE STANDING AND WORKING WHILE SITTING. RIGHT FOOT LENGTH AVERAGE VALUES (P=0.021), RIGHT FOOT CALCANEUS- 1ST METATARSAL ANGLE VALUES (P=0.023), LEFT FOOT CALCANEUS-1ST METATARSAL ANGLE VALUES (P=0.033) ARE HIGHER. BUT THERE IS NO DIFFERENCE IN MEN'S VALUES OR LEFT FOOT LENGTH AVERAGE IN WOMEN'S VALUES. İNDIVIDUALS WORKING WHILE STANDING FOR PROLONGED PERIODS SHOULD BE ENCOURAGED TO MAKE SHOE CHOICES THAT SUPPORT THEIR ARCUS PLANTARIS STRUCTURE. ADDITIONALLY, THEY SHOULD RECEIVE RECOMMENDATIONS REGARDING EXERCISES THAT SUPPORT THEIR FEET AND LEG AREAS.

KEY WORDS: ARCUS PLANTARIS, MEDIAL LONGITUDINAL ARCH, FOOT LENGTH

INTRODUCTION

In today's world, many people spend a significant amount of time standing due to their work conditions. Healthcare professionals, in particular, are among these individuals. The

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main problem addressed in this research is whether prolonged standing can cause deformities in the arcus plantaris and if so, what these deformities are.

Understanding the types of deformities that occur in the feet of individuals who stand for long hours, such as healthcare workers, soldiers, security personnel, and waiters/waitresses, would be a crucial step towards determining the changes that occur in the arcus plantaris. Treating these changes and providing recommendations for appropriate footwear or posture adjustments can significantly improve their quality of life.

The foot is the most distal segment in the lower extremity chain and represents a relatively small base of support upon which the body maintains balance, it seems reasonable that even minor biomechanical alterations in the support surface may influence postural-control strategies. Specifically, excessively supinated or pronated foot postures may influence peripheral (somatosensory) input via changes in joint mobility or surface contact area or, secondarily, through changes in muscular strategies to maintain a stable base of support [1,2].

Irregularities and abnormalities in the normal structure of the medial longitudinal arch produce unbalanced and functionality-wise unstable conditions of the foot such as pes planus or pes cavus. Accordingly, pes planus is the loss of the medial longitudinal arch of the foot, which results with the entire bottom of the foot coming closer to the ground or directly touching the ground during standing or walking [3,4].

Pes planus (PP) and pes cavus (PK), which result from variations in medial longitudinal arch (MLA) height, are common arch problems. Studies on PP have shown that changes in arch height lead to postural abnormalities, muscle shortening, decreased foot strength and get tired easily and negatively impact on balance [5,6]. The main question addressed by this research is whether prolonged standing can cause deformities in the medial longitudinal arch and if so what are these deformities. Understanding how these deformities affect foot movements could help alleviate certain complaints.

The foot is composed of arch systems and this system resembles a "stone bridge". In the arch mechanism, there are bones called "keystone" which are doing same job as stone bridge keystone, intermediate connections (ligament) called “staples” which are connecting bones, beam structures (muscles and tendons) called “tie beam” which keep the bridge standing , and suspension structures (muscles) called “suspension bridge”. This whole system, that is, standing balanced and effective operation of the arc mechanism there are three basic arch systems in the foot [7] :

1. Medial longitudinal arch: This arch has completely collapsed in pes planus and planovalgus. The talus serves as the keystone supporting this arch. The sustentaculum tali lifts the talus, the navicular bone slides around the talus head and medial cuneiform slides around navicular bone. The inferior ligaments that hold the bones together are plantar ligaments. Spring ligament is most important among them. The tibialis posterior tendon also supports this structure. In unloaded conditions, plantar ligaments are relaxed. Contact with ground (compression on the foot arch), plantar ligaments stretch. The more these ligaments’ are utilized, the less collapse occurs in medial arch. The beam structures supporting here include plantar aponeurosis and tendons of flexor hallucis longus, flexor digitorum longus, flexor hallucis breves and flexor digitorum breves. Tibialis anterior and posterior muscles are dynamic suspension structures too that prevent collapsing arcus longitudinalis medialis [7,9]
2. Lateral longitudinal arch: The bone responsible for supporting this arch and acting as the keystone is the cuboid. The inferior structures that hold the bones together are plantar ligaments and the origins of short muscles. The structures that function as tension bands are plantar aponeurosis and tendons of abductor digiti minimi, flexor

digitorum longus, flexor digitorum brevis. Peroneus longus and brevis muscles also serve as dynamic suspension structures [7].

3. Transverse arch: The keystone bones are the cuneiforms. The inferior structures that hold the stones in right place are deep transverse ligaments and the origins of short muscles. Serving as a tension band, the structure that holds everything in place is the peroneus longus tendon, which also serves as a dynamic suspension [7].

Our analysis compared the medial longitudinal arch angles between desk workers and healthcare professionals who stand for long hours to determine if there were any significant differences. It is also interpreted and discussed how these changes might restrict movement and how can these changes be avoided. Additionally, we analyzed and compared foot length too and connection into length and arch inclination.

MATERIALS AND METHODS

Ethical Approval

All subjects who participated in this study signed written informed consent before participating. The Ethics Committee of Istanbul Atlas University (approval date and number (30.03.2023-25523) approved this study. This study was conducted according to the Declaration of Helsinki.

Research Design

The independent variable to be researched is the occupational group of healthcare professionals. The control group consists of individuals who work in desk jobs and generally their profession while sitting.

The number of volunteers we worked with in our project resulted in 86 healthcare professionals (49 female, 37 male) and 82 desk workers (36 male, 46 female). Pregnant or suspected pregnant employees, those who did not want volunteer, and employees who had previously experienced foot injuries resulting in deformities were excluded from the scope of the research. Male and female feet were evaluated separately due to anatomical differences such as size.

Calculation Method

MLA in the clinic was evaluated using dynamic and static methods. Dynamic measurements are performed with walking tests, while static measurements are carried out by examining foot measurements on taken graphs or using various instruments [10,12]. There is currently no universally accepted method for evaluating MLA (medial longitudinal arch) clinically or radiologically [10,13]. Radiological evaluations are generally conducted on lateral X-rays obtained under compression [10,13,14]. Several parameters such as calcaneus - 1st metatarsal angle, calcaneal inclination angle, talus - 1st metatarsal angle, arch height, lateral talocalcaneal angle, talo-horizontal angle are used to assess MLA using this method [10,13,15]. We used static methods, and we calculated significantly calcaneus-1. metatars angle to determine MLA inclination.

Arcus plantaris was examined in these radiological measurements. In the evaluation of arcus plantaris (arch of the foot), measurements will be based on medial longitudinal arch, which is the main component forming this arch.

The following criteria will be used:

1.) A straight line drawn between the most prominent point at the back of calcaneus and tip of distal phalanx parallel to ground plane (foot length).

2.) Calcaneal inclination angle formed between a line connecting two most prominent points under calcaneus and a line parallel to ground plane.

3.) Calcaneus-1st metatarsal angle formed by connecting first metatarsal axis with a line connecting two most prominent points under calcaneus [10]. (This is the target angle which is using for calculation of arcus plantaris inclination.)

An example is provided on how we calculate arcus plantaris inclination and foot length using a volunteer project participant's foot X-ray (Figure 1):

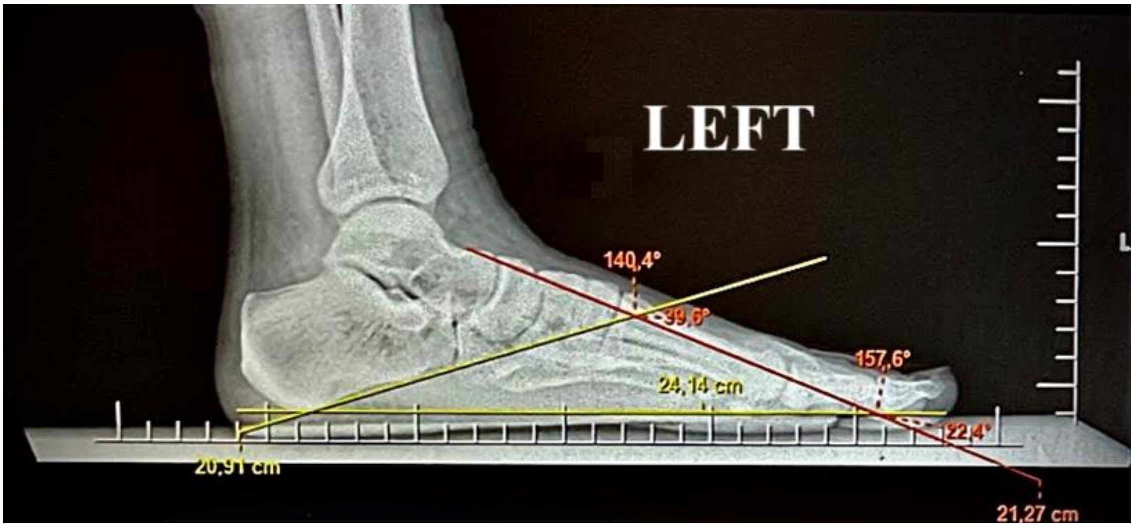

Figure 1: Calculation method of Arcus Plantaris Inclination

In addition to what was mentioned in this study, foot length changes were also examined

separately for men and women in these occupational groups.

The radiographs of both medial sides of each volunteer's feet were obtained in anteroposterior projection. In these images, the angles which are necessary for calculating the foot length and arch inclination were obtained and calculated by using the PACS (Clear Canvas) program. They were then categorized and noted based on gender (male/female) and foot side (right/left).

SPSS version 29.00 was used in the statistical study for the change in foot angles and lengths between sitting and standing male and female healthcare professionals.

RESULTS

Descriptive Statistics

Descriptive statistics of the measurement results are present on the table 1.

Table 1**.** Descriptive Statistics of Study

	N	Range	Minimum	Maximum	Mean Statistic	Std. Deviation	Variance
Right Calcaneus-1st metatarsal angle	168	46.50	105.70	152.20	130.6685	7.07193	50.012

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Left Calcaneus-1st metatarsal angle	168	45.00	102.80	147.80	129.9571	7.26050	52.715
Right Foot Length	168	12.71	20.41	33.12	25.6062	2.25354	5.078
Left Foot Length	168	10.86	20.76	31.62	25.5642	2.26280	5.120

When looking at the graph of individuals' right and left foot angles and lengths, there are 5 outlier findings in the distribution of right foot angles. Outliers are indicated by "o" and extreme outliers by "*" on figure 2.

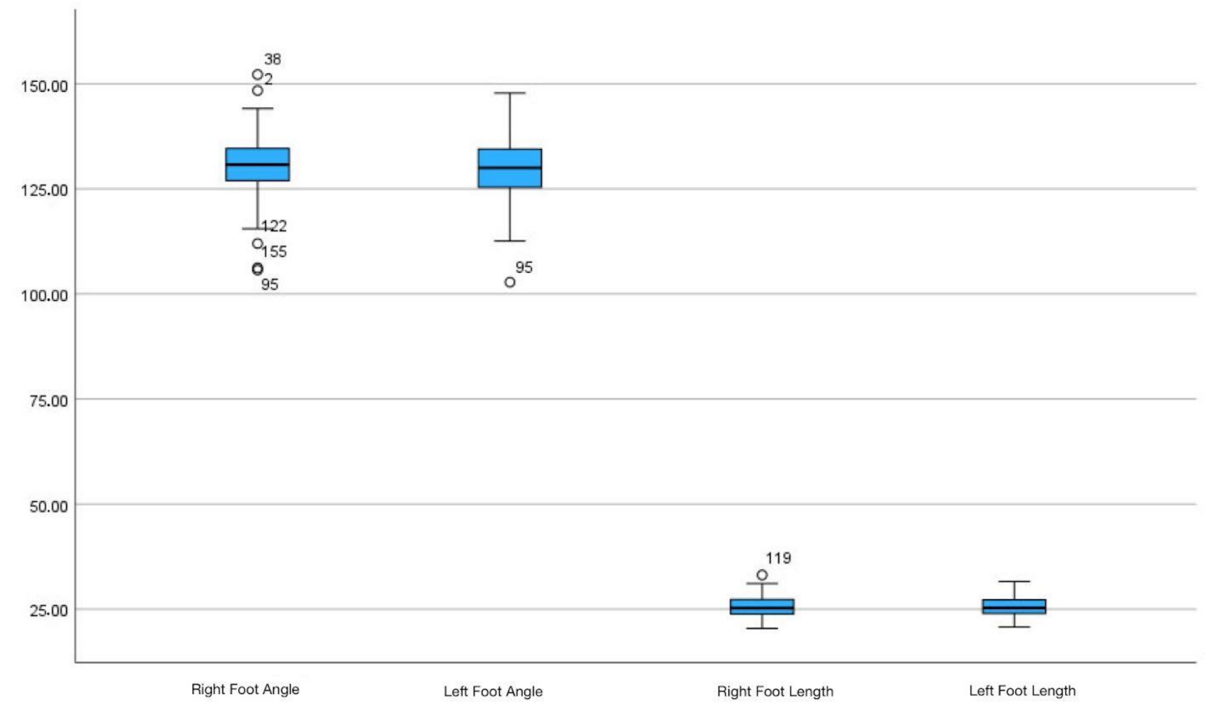

Figure 2. Outlier Findings' Distribution of Right Foot Angles

Number and distribution of the participants according to their working positions are given in Table 2.

Table 2. Distribution of The Participants According to Working Position

	Frequency	Percent	Valid Percent	Cumulative Percent
Women Working While Standing	**49**	**29.2**	**29.2**	**29.2**
Women Working While Sitting	**46**	**27.4**	**27.4**	**56.5**
Men Working While Standing	**37**	**22.0**	**22.0**	**78.6**
Men Working While Sitting	**36**	**21.4**	**21.4**	**100.0**
Total	**168**	**100.0**	**100.0**	

The distribution of the number of participants according to their working positions and gender is shown in Figure 3.

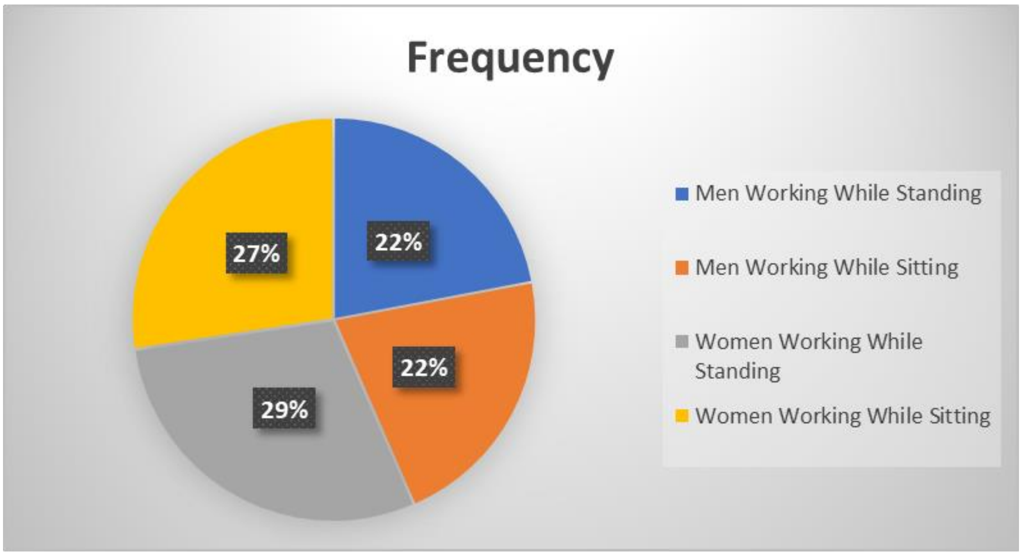

Figure 3. Distribution of The Participants According to Working Position and Gender

Explanation About Statistical Methods

Tests for means, regression analysis, analysis of variance and multivariate analyses are conducted assuming that the dependent variable is normally distributed. Otherwise, non-parametric statistical analysis methods are used. First, it is necessary to test the conformity of the variable to a normal distribution. The hypotheses are as follows:

H0: The data are normally distributed.

H1: The data are not normally distributed.

The results of One Sample Kolmogorov-Smirnov test which is given in table 3, include observation count, mean, standard deviation, maximum positive-negative differences used by the test statistic, the value of the test statistic and significance level.

Table 3. One Sample Kolmogorov-Smirnov Test

		Right Angle	**Left Angle**	**Right Length**	**Left Length**
N		168	168	168	168
Normal Parameters	Mean	130.6685	129.9571	25.6062	25.5642
	Std. Deviation	7.07193	7.26050	2.25354	2.26280
Most Extreme Differences	Absolute	.081	.038	.076	.061
	Positive	.061	.038	.076	.061
	Negative	-.081	-.036	-.053	-.031
Test Statistic		.081	.038	.076	.061
Asymp. Sig.(2 tailed)		.009	.200	.019	.200

Due to non-normal distribution of the right foot angle and right foot length variables, non-parametric tests should be used. As for the left foot angle and left foot length variables, parametric tests should be used as they are normally distributed.

Since right feet length and angle do not comply with normal distribution, Mann-Whitney U test is used for two independent samples. For left feet length and angle variables, independent samples t test is used.

Statistic Test Results

1.Right Foot Calcaneus- 1st Metatarsal Angle

According the statistic test results, women who are working while standing have wider right foot calcaneus- 1st metatarsal angle than women who are working while sitting (p=.023<.05). There is no statistically significant difference between the right foot calcaneus- 1st metatarsal angle of men who work standing and those who work sitting (p=0.93>α=0.05).

2.Left Foot Calcaneus- 1st Metatarsal Angle

According the statistic test results, women who are working while standing have wider left foot calcaneus- 1st metatarsal angle than women who are working while sitting (t=2.160 ,p=0.033 < α=0.05). There is no statistically significant difference between the left foot calcaneus- 1st metatarsal angle of men who work standing and those who work sitting (t=0.596, p=0.553 >α=0.05).

3.Right Foot Length

According the statistic test results there is a difference in the right foot lengths averages between women working while standing and women working while sitting (p=.021<.05). There is no statistically significant difference between the right foot lengths averages of men who work standing and those who work sitting (p=0.762 >0.05).

4.Left Foot Length

According the statistic test results women left foot lengths averages do not change between working while standing and sitting. (t=1.866, p=0.065>0.05). There is no statistically significant difference between the left foot lengths averages of men who work standing and those who work sitting (t=.697, p=.488>0.05).

DISCUSSION

In current study, results of statistical analysis shows that it can be interpreted that right foot is wider and longer and left foot is wider in women whose work standing than work sitting.

The finding we want to emphasize in our study is that individuals who stand for long periods of time have a wider calcaneus-1st metatarsal angle, which forms the medial longitudinal arch. This can lead to pathological problems such as pes planus. A more definitive conclusion can be reached through a study that involves observing for years individuals who are working while standing. Such a study would evidence that the calcaneus-1st metatarsal angle widens over time.

Another emphasis in our study the increase in arch angle and foot length specifically in women who work standing up. Previous research by Torun et al. [10] evaluated MLA by measuring the calcaneal inclination angle and calcaneus-1st metatarsal angle and found no significant difference between genders but observed that both angles were related to foot length.

In our measurements, we found that the calcaneus-1st metatarsal angle is wider in women who are working while standing compared to those who are working while sitting, while no difference was observed between men who are working while sitting or standing. This is an interesting difference that requires further investigation into its cause both women and men. We also found a correlation between foot length and calcaneus-1st metatarsal angle width similar to this previous study.

The predominance of this change in women suggests that it may be due to anatomical differences between men and women's feet. Previous analysis about anatomical differences between male and female feet showed that the average male participants' feet are longer than that of the female participants' feet, while the female feet are relatively narrower but higher than those of the male participants [16]. Narrow and high foot may be sensitive to standing for long periods.

Treatment can be surgical or conservative depending on symptoms and clinic evaluation. Conservative treatment options are activity modifications, weight loss, analgesics, anti-inflammatory drugs, physiotherapy, and orthotic approaches [17-18].

Individuals working while standing for prolonged periods should be encouraged to make shoe choices that support their arcus plantaris structure. They should receive re-commendations regarding exercises that support their feet and leg areas.

Açak et al. [19] studied with insoles that can be adjusted according to the height of the patient's arch, and they observed a decrease in pain scores for individuals with pes planus. Furthermore, the transition to a more active lifestyle was supported, leading to lose weight for the patients. In conclusion, custom-made insoles based on individual arch heights reduced pain and facilitated the transition to an active lifestyle, resulting in weight loss and muscle strengthening for the patients.

Many studies have shown that short foot exercises, in particular, have positive effects on pes planus disease. For example, Okamura et al. [20] evaluated that whether plantar intrinsic foot muscle strengthening exercises improve static and dynamic foot kinematics in indivi- duals with pes planus. After 8 weeks exercise period foot posture index scores related to calcaneal inversion/eversion improved significantly and the time required for navicular height to reach the minimum value decreased significantly. Therefore, short-foot exercise might effectively prevent or treat injuries related to the pes planus alignment of their right body parts within society. This should be further researched and discussed.

CONCLUSION

According to our studies, we observed the calcaneus-1st metatarsal angle, which is a component of the medial longitudinal arch, is wider in women who stand for long periods. It was also observed that their right foot arch height is higher too. This indicates that prolonged standing can lead to damage in the arch and foot structure. This process can be prevented with various exercises or orthopedic shoes.

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