DOI: 10.22122/jrrs.v14i5.3358 Published by Vesnu Publications

Observational Study of Weight Distribution on the Feet and Moment Arm of the Ground Reaction Force around the Ankle in Standing Position in Women with Flatfoot

Leila Ghazaleh[1], Marzieh Behnampoor[2]

Original Article

Abstract

Introduction: By reduction or absence of the medial longitudinal arch in flatfoot deformity, a large part of the contact forces of the body weight transmit to the upper joints. The present study investigated weight distribution on the lower limbs and the external moment around the ankle in women with flatfoot.

Materials and Methods: The statistical population included women students aged 19 to 25 years in Alzahra University, Tehran, Iran. The control group was composed of twelve healthy women, and 37 with flatfoot deformity were divided into three experimental groups. Those in the experimental group 1 had unilateral flatfoot deformity, group 2 had rigid bilateral flatfoot deformity, and group 3 had flexible bilateral flatfoot deformity. The displacement of the center of pressure in the mediolateral and anteroposterior directions was calculated for assessing weight distribution on the lower limbs and the external moment around the ankles. Force plate and 8 motion analysis cameras were used to collect data. MATLAB and SPSS software were used to calculate the displacement of the center of pressure and statistical analysis, respectively.

Results: Experimental groups 2 and 3 and the control group significantly used the right leg for bearing body weight ($P < 0.001$); while in the experimental group 1, there was no significant difference in weight distribution on a flat or normal foot. There was no significant difference in the mean displacement of the center of pressure between the experimental and control groups. Only in experimental groups 2 and 3, there was a significant difference between the mean displacement of the center of foot pressure under the right and left feet ($P = 0.020$).

Conclusion: Women with bilateral flatfoot are more subjected to external moment acting on one foot, which is the same foot that bears body weight in a standing position for a longer time.

Keywords: Flatfoot, Ground reaction force, Weight distribution, Ankle

Citation: Ghazaleh L, Behnampoor M. **Observational Study of Weight Distribution on the Feet and Moment Arm of the Ground Reaction Force around the Ankle in Standing Position in Women with Flatfoot.** J Res Rehabil Sci 2018; 14(5): 257-65.

Received date: 21.08.2018 Accept date: 17.10.2018 Published: 06.12.2018

Introduction

The medial longitudinal arch (MLA), which plays an important role in body weight-bearing, is reduced or eliminated in individuals with flatfoot (FF). If the decrease or loss of MLA takes place both in the closed kinetic chain (during weight-bearing) and in the open kinetic chain (without weight-bearing), the individual will suffer from a rigid or pathological FF, and if it takes place only in the closed kinetic chain, he will suffer from a flexible or physiologic FF (1). FF can be either bilateral or unilateral (2), with the bilateral and unilateral FF deformities involving both feet and only one foot, respectively. With increasing age from childhood to adulthood, the incidence rate of FF deformities decreases, with this rate being about 20% in young people (3). It is also more common in women compared to men at a young age (4).

The results of investigations show that Joints condition, anatomy, and subsequently, the lower extremity biomechanics in patients with FF change compared to healthy individuals, so that when an individual with FF performs a movement in a closed kinetic chain, the subtalar joint becomes pronated and the heel moves into valgus (5,6). Changes in the foot result in the internal rotational force applied to the leg (7),

1- Assistant Professor, Department of Sport Physiology, School of Sport Sciences, Alzahra University, Tehran, Iran
2- School of Sport Sciences, Alzahra University, Tehran, Iran
Corresponding Author: Leila Ghazaleh, Email: l.ghazaleh@alzahra.ac.ir

knee posture change, and pain in this joint (8).

Among the skills, exercises, and daily movements performed in the closed kinetic chain, the simplest movement can be double standing. Among the forces that create moment around the lower limb joints in double standing position are the body weight and ground reaction force. (GRF). The body weight and GRF are applied to the center of gravity (CG) and the center of pressure (COP), respectively (9). In double standing position, the COP moves in the mediolateral (ML) and anteroposterior (AP) directions between the two lower limbs (9).

The displacement of COP in the ML direction is affected by the weight distribution on the lower limbs (9). Based on the studies, when standing, weight distribution on the two legs is asymmetric in healthy individuals (10). In people with FF, studies have been focused on the distribution of pressure in different areas of the soles (11-13). Although researchers believe that examining the symmetry of weight distribution on the legs in patients with injuries may be important (14), the weight distribution on the legs in patients with FF has not been evaluated so far. Investigation of body weight distribution on the legs in patients with FF is of importance in various aspects. In these patients, if the asymmetric distribution of body weight on the legs is greater or as in healthy individuals, one foot is always affected by high volume of force, which may increase the likelihood of injury to the lower limb joints, as the MLA not only contributes to the weight distribution, but also acts as a shock absorber (15). MLA dissipates much of the force exerted on the feet during weight bearing before it enters the long bones such as the leg and thigh bones (16). With the loss or decrease of MLA height, the foot will be more rigid leading to a greater impact from our body weight to be transmitted to the higher joints such as knee, hip and waist (17). Therefore, it can be stated that if the individuals with FF tend to lean towards one foot while standing, it is more likely to be exposed to external forces because it has to bear a greater proportion of the body weight. Additionally, as the MLA height decreases or disappears, the mechanism of the shock absorption is not working properly and the joints of that lower limb are more likely to be injured.

The COP displacement in the AP direction is affected by the displacement of the CG of the body and under the control of the ankle muscles (9). Given the studies, the leg and ankle muscle function is impaired in patients with FF and changes relative to the healthy individuals (18,19). This change in muscle function in patients with FF can affect COP control, subsequently affecting the external moments acting on the ankle joint and other lower limb joints. The results of the study by Kim et al. (20) also confirmed this finding. They concluded that the muscle force and the vertical GRF play the role of a mechanical lever system so that the differential COP movement can be interpreted as a moment arm for the vertical GRF. (20). Therefore, if the COP displacement in the anterior direction is greater in patients with FF in comparison to the healthy subjects, due to the increase in the length of the moment arm of vertical GRF, the external moments and forces applied on the ankle in the AP direction increase, thus increasing the risk of the lower extremity injuries in patients with FF. To test this hypothesis, it is necessary to measure the mean COP displacement relative to the ankle joint in patients with FF and compare it with the healthy individuals.

In accordance with the results of studies, there is little information on COP control during double standing in patients with FF (21). Tahmasebi et al. reported that in double standing position, the COP excursion was significantly higher in subjects with FF compared to the healthy subjects (21). Chao and Jiang concluded that in double standing position, there was no difference in the COP excursion in the AP direction between the patients with FF and healthy subjects and only some of the COP displacement measures could indicate the difference between the two groups (22). Chao and Jiang (22) and Tahmasebi et al. (21) conducted their studies to compare the postural stability between the healthy individuals and patients with FF and examined the COP displacement variables in the standing posture; the results of the two studies were inconsistent. It should be noted that the COP displacement measures examined in the two studies (21,22) were among the measures used in various studies to investigate the postural stability. However, in order to respond to the hypothesis presented in the current study, it is necessary to measure mean displacement of the COP relative to the ankle joint in the anterior direction.

The present study was accomplished aiming to investigate the COP displacement in the ML and AP directions, the weight distribution on the lower limbs, and the external moments acting on the ankle among the individuals with FF and healthy subjects.

Materials and Methods

This cross-sectional study was approved by the Research Ethics Committee, Institute for Sport Sciences, Ministry of Science, Research, and

Technology, Tehran, Iran, under code IR.SSRI.REC.1398.532. The statistical population of the study included female students aged 19 to 25 years old. For sampling, the female students of Alzahra University Tehran, Iran, who volunteered to participate in the study were screened for FF. The sample size was determined using G*Power software (23). Using the software, the sample size needed to achieve the effect size of 0.80 (according to the software convention, this value is for the large number for the paired sample t-test) at the significance level of 0.05 and statistical power of 0.95 was determined to be at least 10 subjects.

The participants were screened for FF in two stages. In the first stage, based on the clinical procedure (24), the individual's soles were evaluated in the standing position and in case observing signs of a decrease or disappearance of the MLA, convexity of the inner edge of the foot, or heel valgus in the foot, the individual would enter the second screening stage. At the second stage, the footprint method and the Staheli index were applied (25,26). In this method, the individual would first stand on a stiff surface impregnated with ink and immediately on the white paper to imprint the sole on the paper (27). After recording the footprint of the right and left feet, the quality of the footprint was evaluated. If the print of the outer edges of the foot on the paper was not of good quality, the test would be repeated. According to the Staheli index, if the ratio of the two lines was greater than 0.8, the individual had a FF abnormality. The two lines in the Staheli index included the minimum width of the midfoot and the maximum width of the hindfoot (25). The values of the two lines were measured on each of the footprints and then the ratio was calculated. The navicular drop test (NDT) was adopted to determine the type of the FF anomaly. Based on this test, if the difference in navicular height between the standing position (weight bearing) and sitting position (without weight bearing) was more than 10 mm, the individual would suffer from a flexible FF (28). The navicular height was measured when the subtalar joint was in the neutral position.

The study inclusion criteria included age range of 18 to 25 years (29), normal body mass index (BMI) (30), and no history of neuromuscular diseases (31). The FF deformities of the subjects in the experimental groups had to be confirmed at both screening stages. In addition, the lack of the FF deformities had to be confirmed in the subjects in the control group at both stages of screening. The study exclusion criteria were having a history of foot and ankle surgery (32) and lower extremity length difference of greater than 2 cm (33). After screening and performing the FF diagnostics tests, 12 and 37 individuals without and with a FF abnormality were chosen respectively for the control group and for the three experimental groups. The three experimental groups were respectively one group with unilateral FF (experimental group 1, n = 13) and two groups with bilateral FF (experimental groups 2 and 3, n = 11 and n = 13, respectively). The criterion of difference between the two experimental groups with a bilateral FF was the type of the anomaly (rigid or flexible). It should be noted that in the experimental group 1 (with unilateral FF), 6 and 7 patients had the anomaly in the right foot and in the left foot, respectively.

In order to comply with the ethical aspects, through the information contained in the consent form, the subjects were informed about the foot examination method, implementation of tests at the laboratory, as well as the method of dissemination of the results and signed the informed consent form.

In order to perform the tests and collect data on the dependent variables, the subjects were required to stand quietly and bilaterally on both legs in three repetitions and for 35 s in each repetition. The subjects were asked not to move their arms, feet, and body during the test run and to look at a screen located 3 m away from them along their eyes (14). Moreover, the break interval between the repetitions was considered 1 minute.

The study dependent variables included body weight distribution on the lower limbs and the size of the moment arm of the GRF around the ankle. To measure these variables, 8 motion analysis cameras (Oqus 5+, Qualiysis, Sweden) and a force plate (9286BA, Kistler, Switzerland) were utilized. The cameras were used to record the instantaneous position of four 12-mm reflective markers placed on the lateral malleolus and heel of the subjects, and the force plate was applied to record the COP instantaneous position. In order to measure the weight distribution on the feet, the percentage of time in which the COP was shifting to each foot (markers mounted on the lateral malleolus) during the lateral displacement was calculated. The midpoint of the two markers mounted on the lateral malleolus was the boundary of the COP deviation to each foot. The mean time percentage of the COP deviation toward each foot (right or left) was recorded as the weight distribution time percentage for the same foot and was introduced into the statistical analysis (34). To estimate the the moment arm of GRF around the ankle joint in the AP direction the COP displacement relative to the,

Table 1. Demographic and other characteristics, as well as the number of the subjects in each group

Variable / Group	Experimental group 1 (n = 13)	Experimental group 2 (n = 11)	Experimental group 3 (n = 13)	Control group (n = 12)
Characteristics of subjects' feet	Healthy-flat	Flexible-Flexible	Rigid-Rigid	Healthy-Healthy
Height (cm)	162.77 ± 2.98	162.73 ± 4.52	162.08 ± 5.60	163.37 ± 4.07
Weight (kg)	61.69 ± 8.14	66.08 ± 9.98	60.15 ± 5.89	59.00 ± 7.90
Body mass index (kg/m^2)	23.43 ± 3.34	24.97 ± 3.82	22.94 ± 2.43	22.11 ± 2.62

Data were reported as mean ± standard deviation (SD).

heel marker was measured instantaneously and ultimately, the mean COP displacement was analyzed. All weight distribution and COP displacement calculations were performed by MATLAB software (v2009b, the Mathworks Inc., Natick, MA, USA) and the kinematic and kinetic data were collected at a sampling frequency of 200 and 1000 Hz, respectively. To eliminate the effect of unwanted signals, the data were filtered using the Butterworth filter (fourth-order and cutoff frequency of 10).

The one-way analysis of variance (ANOVA) test was used to compare the mean COP displacement in the AP direction among the four groups. The assumptions of this test, including the ratio or interval measurement scale and independence of the groups, were observed. In the present study, the ratio measurement scale was applied for the dependent variable and the study groups were independent from each other in terms of the presence or type of deformity, such that the control group lacked any symptoms of FF deformity . The experimental groups were also completely independent from each other in terms of the type of FF. Furthermore, the homogeneity of variance test and Shapiro-Wilk test were exploited to check the homogeneity of variance of the independent variables and the normal distribution of the data, respectively, which both were confirmed; as in examining the homogeneity of variance of the dependent variables among the groups, the Levene test results were not significant ($P > 0.05$). Besides, the Shapiro-Wilk test result was not significant as well ($P > 0.05$). The time percentage of the weight distribution on the legs and the mean COP displacement in the AP direction between the subjects' feet in each group were compared using the paired sample t-test. Finally, the data were analyzed in SPSS software (version 25, IBM Corporation, Armonk, NY, USA) and $P < 0.05$ was considered as the data significance level.

Results

The demographic and other characteristics, as well as the number of the subjects in each group are presented in table 1.

In order to answer the two important questions of whether the difference in weight distribution on the legs (percentage difference in COP deviation between feet) was significant in the subjects of different groups and that to which foot the subjects were leaned and applied more of the body weight, the paired sample t-test was used, the results of which are presented in tables 2 and 3.

Given the data in table 2, the weight distribution on the legs was significantly asymmetric in all groups ($P < 0.001$).

The results of comparison of the COP deviation time percentage between the flat and healthy feet in the experimental group 1 and the right and left feet of experimental groups 2 and 3 and the control group are presented in table 3. Since 6 and 7 of the 13 patients in experimental group 1 with unilateral FF deformity had the anomaly in the right foot and in the left foot, respectively, it was necessary to compare the distribution of weight on the flat and healthy feet in this group. Based on the findings displayed in table 3, experimental groups 2 and 3 and the control group used the right leg significantly to maintain body weight ($P < 0.001$). In experimental group 1, there was no significant difference in the weight distribution on the flat and healthy feet.

Table 2. Center of pressure (COP) deviation time percentage difference during test run in the experimental groups and the control group

Group	COP deviation time percentage difference between feet (mean ± SD)	df	t	P value
Experimental group 1	80.89 ± 28.20	13	17.68	< 0.01*
Experimental group 2	78.85 ± 28.22	11	16.03	< 0.01*
Experimental group 3	81.23 ± 28.35	13	17.89	< 0.01*
Control group	77.74 ± 27.42	12	16.53	< 0.01*

* Significant correlation at the level of $P < 0.050$

COP: Center of foot pressure; SD: Standard deviation; df: Degree of freedom

Table 3. Center of pressure (COP) deviation time percentage difference between the flat and healthy feet in the experimental group 1 and the right and left feet in the experimental groups 2 and 3 and the control group

Group	Foot	COP deviation time percentage of right and left feet (mean ± SD)	COP deviation time percentage difference between feet (mean ± SD)	t	P value
Experimental group 1	Flat	51.38 ± 39.38	2.71 ± 78.75	0.12	0.91
	Healthy	48.67 ± 39.36			
Experimental group 2	Right	87.54 ± 13.02	75.06 ± 26.05	9.56	< 0.01*
	Left	12.47 ± 13.02			
Experimental group 3	Right	80.08 ± 22.46	59.71 ± 45.21	4.76	< 0.01*
	Left	20.37 ± 22.78			
Control group	Right	80.60 ± 21.22	61.19 ± 42.45	4.56	0.01*
	Left	19.40 ± 21.23			

* Significant correlation at the level of P < 0.050
COP: Center of foot pressure; SD: Standard deviation

Data obtained from comparing the length of the moment arm of GRF around the ankle (mean COP displacement in the AP direction) revealed no significant difference in the COP displacement between the experimental groups and the control group (P > 0.05) (Figure 1).

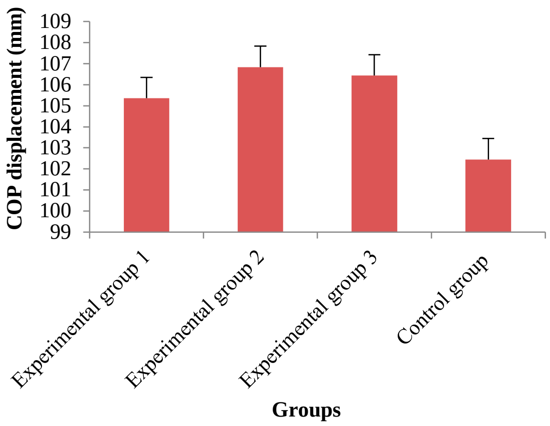

Figure 1. Comparison of mean center of pressure (COP) displacement in the anteroposterior (AP) direction among the groups

The results of comparison of the mean COP displacement in the AP direction between the flat and healthy feet in the experimental group 1 as well as between the right and left feet of the experimental groups 2 and 3 and the control group are presented in table 4. Given this table, in the experimental group 2, there was a significant difference in the mean COP displacement under the right and left feet in the AP direction between the two feet (P = 0.02). In the experimental group 3, there was also a significant difference in the mean COP displacement under the right and left feet in the AP direction between the two feet (P = 0.04).

Discussion

The results indicated that the weight distribution on the leg was significantly asymmetric in all groups. In addition, the results of comparison of the COP deviation time percentage between the flat and healthy feet in the experimental group 1 and the right and left feet in the experimental groups 2 and 3 and the control group indicated that the experimental groups 2 and 3 and the control group significantly used their right leg to support the body weight, whereas in the experimental group 1, there was no significant difference in the weight distribution on the flat and healthy feet.

Table 4. Mean center of pressure (COP) displacement in the anteroposterior (AP) direction between the flat and healthy feet in the experimental group 1, and the right and left feet in the experimental groups 2 and 3 and the control group

Group	Foot	COP displacement (mm) (mean ± SD)	t	P value
Experimental group 1	Flat	102.04 ± 16.91	-2.05	0.06
	Healthy	108.68 ± 19.06		
Experimental group 2	Right	112.31 ± 19.26	2.91	0.02*
	Left	101.37 ± 18.70		
Experimental group 3	Right	108.25 ± 12.96	2.37	0.04*
	Left	104.62 ± 14.26		
Control group	Right	99.09 ± 10.53	-1.84	0.09
	Left	102.31 ± 12.58		

* Significant correlation at the level of P < 0.050; COP: Center of foot pressure; SD: Standard deviation

Comparison of mean COP displacement in the AP direction among the groups also showed no significant difference in the COP displacement between the experimental groups and the control group. In addition, only in the experimental group 2 and 3, there was a significant difference in the mean COP displacement in the AP between the right and left feet, so that the COP displacement under the right foot was significantly higher than the left foot in the two groups.

Investigation of the weight distribution on the legs in the present study showed that people with FF asymmetrically distributed body weight on the legs like the healthy people, regardless of the unilateral or bilateral and type of the deformity (rigid and flexible). Previous studies have confirmed this in healthy individuals (10,35). Prado-Rico and Duarte stated that in the healthy young people, weight was asymmetrically distributed on the legs in the standing position, and this asymmetry was more pronounced among women than in men (35). Since the weight distribution on legs in people with FF has not been evaluated in the studies so far, it was not possible to compare the results of weight distribution in people with FF with previous studies. In general, there are few studies on the distribution of weight on the lower limbs. Researchers acknowledge that in describing norms of asymmetry of loading of the left or right leg during standing and postural control in healthy humans it is very important to compare the results to posture asymmetry in various injuries or diseases. (14). However, despite their efforts, this has not yet materialized. To complement the results regarding the asymmetric weight distribution on the legs in people with FF, it was necessary to determine which leg they often use to support body weight and whether they act like healthy individuals in leg selection.

The findings revealed that the subjects in the control group used mainly the right leg for body weight tolerance in the standing position, which is in line with the findings in the study by Gutnik et al. (10). They examined the 18-35-year old individuals and found that GRF mainly tended to the right leg during double standing (10). The remarkable results in subjects with FF were that the subjects in the experimental groups 2 and 3 who had bilateral FF, as the control group, used mainly the right leg to bear the body weight, whereas in the experimental group 1 who had unilateral FF abnormality, there was no difference in the weight distribution on the flat and healthy feet. In other words, people with unilateral FF used mainly the flat foot in some of the repetitions and the healthy foot in other repetitions to bear weight. This result could be one of the important findings of the present study. Accordingly, it can be stated that when the feet are symmetrical in structure (when both feet are healthy or abnormal), the individual often uses a specific leg (right leg) to support weight, but when the feet structure is asymmetric in an individual (a healthy foot and a flat foot), he does not lean on a fixed leg to support body weight.

Although the higher use of one leg for weight bearing in the standing posture is a normal function of the body, in people with bilateral FF, it can be a threat to the joints of the lower limb that support body weight. In the standing position,, MLA helps to distribute body weight on the foot (15). In both types of FF (rigid and flexible) in the standing posture, the MLA height decreases or disappears (1). By the removal or decrease of the MLA height, much of the body weight-related contact force is transferred to higher joints such as the knee, thigh, and waist (17). The results of the study by Levinger et al. suggested that the lower extremity injuries is more likely to occur in people with FF (36). Moreover, Iijima et al. achieved significant results by examining the extent of the knee injury in individuals with FF. They reported that people with bilateral FF were more likely to suffer from pain associated with knee osteoarthritis compared to those with unilateral FF (37). They interpreted this finding as people with unilateral FF may use their healthy foot to compensate for the function of FF when performing motor tasks (37). The findings of the present study also showed that despite the individuals with bilateral FF, the subjects with unilateral FF did not rely on one leg when bearing body weight, and used both legs to support the body weight. Therefore, it can be declared that since people with bilateral FF make more use of one of their leg and foot to support the body weight, it is more likely that leg and foot is exposed to contact forces due to body weight and injury compared to the others.

Results of comparing the mean COP displacement in the AP direction among the groups showed that there was no significant difference in the COP displacement between the experimental groups and the control group. Chao and Jiang also carried out a study to evaluate the postural stability and compared the COP displacement indices in subjects with FF and healthy controls. The results of their study indicated that only some of the COP displacement measures showed a difference in the postural stability between the healthy individuals and patients with FF (22). It should be noted that the COP displacement measure used in the present study was not calculated to assess the postural stability in patients with FF, but to estimate the GRF moment arm around the ankle joint. Comparison of the aforementioned variable between the right and left feet of the subjects showed that there was no difference in the mean COP displacement under the right and left feet of the healthy subjects and subjects with unilateral FF in contrast to the subjects with bilateral FF. In other words, in the healthy subjects and subjects with unilateral FF, the length of the moment arm of GRF around the right ankle was equal to that around the left ankle. The reason why the individuals with unilateral FF acted as healthy individuals, according to the assumption by Iijima et al., may be due to the compensation of the flat foot function by the healthy foot in these individuals (37), but interestingly, the individuals with bilateral FF performed differently from the control group and the experimental group 1; as in these subjects, there was a significant difference between the length of moment arm of GRF around the right ankle joint and that around the left ankle joint. In other words, the length of moment arm of GRF was longer when the COP was deviated to the right foot compared to when the COP was deviated to the left foot. This may be due to the weakness of the foot muscles in people with bilateral FF (38).

Winter stated that in double standing position the COP moves between the two feet and its displacement in the AP direction is controlled by the ankle muscles (9). In people with bilateral FF, since the anatomic structure and muscle function change in both feet, it is not possible to compensate for the functional weakness of one foot by the other one (like what occurs in unilateral FF) and the COP control is weakened. Thus, in people with bilateral FF of the rigid and flexible types, the moment applied by the external GRF force on the right ankle joint is greater than that value on the left ankle.

It can be claimed that, in terms of the moment that GRF exerts on the foot, ankle, and other lower extremity joints, in the patients with bilateral FF one of the leg is more subject to the external moment than the other, and the important point is that this leg is the one that support body weight in a longer time in the standing position. Therefore, it seems that the rehabilitation professionals and therapists need to place greater emphasis on the weight bearing foot in the individuals with bilateral FF when providing training and therapeutic programs to these individuals. However, further investigations are required to identify the weight-bearing foot in individuals with bilateral FF using simple tests and clinical methods.

Limitations

There was no important limitation on the method and tools used in the present study, but due to the lack of similar studies regarding weight distribution in patients with FF, it was not possible to compare the results of the experimental groups with those of the previous studies.

Recommendations

Performing similar studies with more complex motor tasks such as standing longer, jumping, climbing stairs, and other activities in which greater force is applied to the lower limb joints is recommended.

Conclusion

The results of this study showed that subjects with bilateral FF (rigid and flexible types), like the healthy subjects, distribute asymmetrically more body weight on the right leg in double standing position.. Furthermore, unlike healthy individuals, the length of moment arm of GRF around the right ankle is larger than that around the left ankle. In subjects with unilateral FF, the weight distribution is symmetric and the length of moment arm of GRF around the right and left ankle joints are equal.

Acknowledgments

The present study was based on the analysis of the results of an independent study approved by the code of ethics IR.SSRI.REC.1398.532 in the Research Ethics Committee, Institute for Sport Science, Ministry of Science, Research, and Technology and set up at Alzahra University. The authors would like to appreciate all study contributors.

Authors’ Contribution

Leila Ghazaleh: Study design and ideation, attracting funding for the study, the study support, executional, and scientific services, providing study equipment and samples, analysis and interpretation of results, specialized statistics services, manuscript arrangement, manuscript expert assessment in scientific terms, confirmation of the final manuscript for submission to the journal office, responsibility for maintaining the integrity of the study process from beginning to publication, and responding to the opinions of the reviewers, Marzieh Behnampoor, attracting funding for the study, providing the study equipment and samples, collecting the data.

Funding
The study was based on the analysis of the results of an independent study approved by the code of ethics IR.SSRI.REC.1398.532 in the Research Ethics Committee, Institute for Sport Science, Ministry of Science, Research, and Technology and implemented at Motion Analysis Laboratory, Alzahra University. The university did not comment on data collection, analysis, and reporting, manuscript preparation, and final approval of the study for publication.

Conflict of Interests
The authors declare no conflicts of interest. Dr. Leila Ghazaleh has funded the basic studies related to this paper and has been working as an Assistant Professor, Sport Biomechanics, Department of Sport Physiology, School of Sport Sciences, Alzahra University since 2016. Marzieh Behnampoor has been an undergraduate student in sports science at the School of Sport Sciences, Alzahra University since 2014.

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