Static Foot Pressure and Percentage Contact Area of the Foot as an Assessment Tool for the Success of Anterior Cruciate Ligament Reconstruction: A Cross-sectional Study

ABHISHEK AGARWAL, SABEEL AHMAD, ABHISHEK SAINI, ASHISH KUMAR, PRATYAKSHA PANDIT

ABSTRACT

Introduction: Anterior Cruciate Ligament (ACL) plays a vital role in gait balancing and lower limb kinematics. Any injury to the ACL leads to gait imbalance and alterations in foot pressure distribution. The stability and biomechanics of the lower limb after ACL Reconstruction (ACLR) can be measured through foot pressure analysis, gait analysis, and percentage contact area of the foot, among others.

Aim: To evaluate the static foot pressure and percentage contact area of the foot in ACL deficient group, comparing it with the ACLR group and the normal healthy individual group.

Materials and Methods: An analytical cross-sectional study was conducted at the Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India from March 10, 2021 to March 15, 2023. A total of 15 patients in each group (ACL injury, ACLR patients, and normal healthy individuals) were included in this study. Foot pressures (static) were recorded in all three groups using the BTS P-WALK system with BTS Biomedical software, which included high-density sensors and a plate size of 700 × 500 × 5 mm. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software version 26.0. Chi-square and linear regression tests were used to analyse the differences between the groups.

Results: In the intragroup analysis, ACL deficient patients’ ipsilateral limbs showed lower foot pressure in the mid-foot (7±3.4), hind-foot (40.33±10.08), and whole foot pressure (110.19±34.7 Pascal (N/M²)) (p-value>0.05) compared to normal healthy individuals (126.06±19.4 Pascal (N/M²)) (p>0.05) and ACLR (125.06±14.3 Pascal (N/M²)) (p-value>0.05) groups, which suggested insignificant differences. The percentage contact area of the foot was significantly lower (43.15±3.4) (p-value<0.001) compared to normal healthy individuals (49.82±0.84) and ACLR (49.02±0.91) groups. However, in intergroup comparisons, the differences in mid-foot, whole foot pressure, and percentage contact area of the foot were significant (p-value <0.001) within the groups.

Conclusion: Although there is a wide range of variation in the values of static foot pressure and percentage contact area of the foot in ACL deficient patients, after ACLR, these values become nearly similar to those of normal healthy individuals at around one year after ACLR.

INTRODUCTION

ACL tears are commonly observed in athletes and young adults during sports activities or road traffic accidents, resulting in functional instability [1,2]. Various methods, such as knee laxity evaluation and assessment of extensor muscle strength, are used to evaluate functional outcomes after ACLR. However, these methods primarily focus on static tests and may not adequately capture dynamic evaluation [3,4]. ACLR not only addresses knee laxity but also improves the biomechanics of the lower limb. Gait pattern analysis, using kinematic and mechanical methods, has been proposed as a valuable approach for evaluating functional outcomes [5,6]. Foot pressure distribution measurement, a tool commonly used in gait analysis, can assess the stability and kinematic function of the limb in such cases. Abnormalities in foot pressure distribution and decreased muscle strength around the ACL deficient knee may lead to differences compared to normal individuals or the non affected lower limb [7]. While foot pressure analysis has been extensively studied in conditions such as diabetic foot, rheumatoid arthritis, neuropathic foot, stroke, and various other disease-related gait analyses [8-10], its application in ACL injury and postoperative rehabilitation is relatively rare [11,12]. Notably, present study focuses on measuring static foot pressure and the percentage contact area of the foot, which is unique compared to previous research. Therefore, the aim of this study was to investigate foot pressure asymmetry and discrepancies in the percentage contact area of the foot among patients with ACL injuries, those who underwent ACLR, and normal healthy individuals.

MATERIALS AND METHODS

An analytical cross-sectional study was conducted at the Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India from March 10, 2021, to March 15, 2023. This study was planned after obtaining ethical approval from the local ethical committee of KGMU (Ref. code: 102nd ECM IIB/ P114), and informed written consent was obtained from the patients for the publication of this article and for providing the scientific data for further research. A total of 15 patients were included in each group: ACL injury group, ACLR group, and normal healthy individual group.

Inclusion criteria: ACL injury patients confirmed by physical examination and radiological findings (MRI) were included in the ACL deficient group. The ACLR group comprised previously operated patients for ACL injury in the same institute.

Exclusion criteria: Patients with neuropathic joints, multiligamentous injuries, high-grade meniscal tears, joint arthropathy, restricted joint range of motion, and any other limb pathology were excluded from the study.

Keywords: Foot pressure, Gait analysis, Kinematics, Pedobarography
Sample size: The minimum sample size required was determined based on a study conducted by Çetin E et al. [11]. Considering a 95% level of confidence, a 1.5 margin of error, and a standard deviation of 4.26, the minimal required sample size was 35. Taking into account the non response rate, a total sample size of 45 individuals was selected, with 15 patients in each group (ACl injury group, ACLR group, and normal healthy individual group).

Sampling: The patients were selected using systematic random sampling. The ACL injury group consisted of new patients randomly selected from a pool of ACL deficient patients, considering the inclusion and exclusion criteria. The ACLR group consisted of individuals who had previously undergone ACL reconstruction within the given study duration, not selected from the ACL deficient group. The normal healthy individual group consisted of healthy individuals from the general population without any knee injury or abnormality, who were requested to visit the centre for foot pressure analysis and percentage contact area of the foot. The leg included in the study was determined according to the ACL deficient and ACLR groups.

Pedobarographic evaluation, including static foot pressure and percentage contact area of the foot, was performed in the ACL deficient group, which was then compared with the pedobarographic values of the ACLR group (after one year of follow-up) and the normal healthy individual group. Foot pressures (static) were recorded in all three groups using the BTS P-WALK system with BTS Biomedical software, which included high-density sensors and a plate size of 700 × 500 × 5 mm [Table/Fig-1].

Subjects were asked to stand on a foot plate with their ACL deficient limb, ACLR limb, and a similar limb (right/left) for the control group. The values were recorded on the computer. Peak static foot pressure and percentage contact area of the foot were calculated by combining the forefoot, mid-foot, and hindfoot data from the mask data. The mean±Standard Deviation (SD) of two measurements from each foot (ACL injured, ACLR, and normal foot) were saved for analysis.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS 26.0 software. Chi-square and linear regression tests were used to calculate the mean±SD and analyse the differences between the ACL deficient, ACLR, and normal healthy individual groups. A p-value <0.05 was considered to be statistically significant.

RESULTS

A total of 15 patients were included in each group (13 males and 2 females) of ACL injury, ACLR (those who underwent ACL surgery one year ago in the same institute), and normal healthy controls. The average time between ACL injury and pedobarography was 3.1 months (ranging from two months to 11 months), and the surgeries were performed within one week. The age of the patients ranged from 21 to 46 years, with a mean age 24.26± 6.1 years. Demographic details are presented in [Table/Fig-2]. The BTS system divides the foot into various anatomical parts (forefoot- T1, T2, T3, T4, T5, M1, M2, M3, M4, M5, mid-foot, and hindfoot - MH, LH), and the pressure of different parts was calculated in Pascal (N/M²) [Table/Fig-3].

Intergroup comparison: There was a gross reduction in forefoot pressure (62.86±33.8 Pascal (N/M²)) (p-value<0.242), mid-foot pressure (7±3.4 Pascal (N/M²)) (p-value<0.175), hindfoot pressure (40.33±10.08 Pascal (N/M²)) (p-value<0.259), and whole foot pressure (110.19±34.7 Pascal (N/M²)) (p-value<0.328) [mean (SD)] in the ACL deficient limb group compared to the contralateral normal limb in the same patients. However, these differences were not statistically significant based on the p-values. When comparing the normal healthy individual group and the ACLR group, all forefoot, mid-foot, hindfoot, and whole foot pressures were almost equal to the contralateral limb of the same control healthy individual.

[p-value (Linear regression analysis)] (p-value<0.05 significant)

Statistical analysis was performed using SPSS 26.0 software, which included high-density sensors and a plate size of 700 × 500 × 5 mm [Table/Fig-1].

Subjects were asked to stand on a foot plate with their ACL deficient limb, ACLR limb, and a similar limb (right/left) for the control group. The values were recorded on the computer. Peak static foot pressure and percentage contact area of the foot were calculated by combining the forefoot, mid-foot, and hindfoot data from the mask data. The mean±Standard Deviation (SD) of two measurements from each foot (ACL injured, ACLR, and normal foot) were saved for analysis.

Statistical analysis was performed using SPSS 26.0 software. Chi-square and linear regression tests were used to calculate the mean±SD and analyse the differences between the ACL deficient, ACLR, and normal healthy individual groups. A p-value <0.05 was considered to be statistically significant.

A total of 15 patients were included in each group (13 males and 2 females) of ACL injury, ACLR (those who underwent ACL surgery one year ago in the same institute), and normal healthy controls. The average time between ACL injury and pedobarography was 3.1 months (ranging from two months to 11 months), and the surgeries were performed within one week. The age of the patients ranged from 21 to 46 years, with a mean age 24.26± 6.1 years. Demographic details are presented in [Table/Fig-2]. The BTS system divides the foot into various anatomical parts (forefoot- T1, T2, T3, T4, T5, M1, M2, M3, M4, M5, mid-foot, and hindfoot - MH, LH), and the pressure of different parts was calculated in Pascal (N/M²) [Table/Fig-3].

Intergroup comparison: There was a gross reduction in forefoot pressure (62.86±33.8 Pascal (N/M²)) (p-value<0.242), mid-foot pressure (7±3.4 Pascal (N/M²)) (p-value<0.175), hindfoot pressure (40.33±10.08 Pascal (N/M²)) (p-value<0.259), and whole foot pressure (110.19±34.7 Pascal (N/M²)) (p-value<0.328) [mean (SD)] in the ACL deficient limb group compared to the contralateral normal limb in the same patients. However, these differences were not statistically significant based on the p-values. When comparing the normal healthy individual group and the ACLR group, all forefoot, mid-foot, hindfoot, and whole foot pressures were almost equal to the contralateral limb of the same control and ACLR groups. However, all p-values were >0.05, indicating that these differences were not significant [Table/Fig-4].
However, when considering the percentage contact area of the foot, the mean±SD was found to be significantly reduced (43.15±3.4) in ACL deficient limbs compared to the contralateral limb in the same patients (57.18±4.0) (p-value <0.001). In contrast, in the normal healthy individuals (49.82±0.84) (p-value <0.001) and ACLR (49.02±0.91) (p-value <0.001) groups, the ipsilateral percentage contact area was almost similar to the contralateral limbs, showing significance in terms of p-values (p-value <0.001) [Table/Fig-5]. The difference in mid-foot, whole foot pressure, and percentage contact area of the foot was significant (p-value <0.001) within the groups [Table/Fig-6].

### CONCLUSION(S)

There is a wide range of variation in the values of static foot pressure and percentage contact area of the foot in the ACL deficient group. After one year of follow-up, these values in the ACLR group are nearly similar to those of the normal healthy individual group. This assessment tool can be used to evaluate the biomechanics and stability of the ACLR limb and determine if patients can safely return to their previous level of physical activity.

**Author's contributions:** AA and AK conceived and designed the study and provided research material. SA and AS collected, organised, and interpreted the data, and SA wrote the draft and provided logistic support. PP is statistician who has been involved in the statistics part of this manuscript. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

### REFERENCES


Abhishek Agarwal et al., Static foot pressure and percentage contact area of foot as an assessment tool for success of ACL Reconstruction

PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India.
2. Senior Resident, Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India.
3. Assistant Professor, Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India.
4. Professor and Head, Department of Sports Medicine, King George Medical University, Lucknow, Uttar Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sabeel Ahmad,
529D/308, Kalyanpur, West Ring Road, Lucknow-226022, Uttar Pradesh, India.
E-mail: drsabeel5@gmail.com

PLAGIARISM CHECKING METHODS:
- Plagiarism X-checker: Jun 09, 2023
- Manual Googling: Jul 14, 2023
- iThenticate Software: Jul 17, 2023 (2%)

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: Jun 07, 2023
Date of Peer Review: Jun 30, 2023
Date of Acceptance: Jul 19, 2023
Date of Publishing: Sep 01, 2023

