ISSN (print) 2522-1906, ISSN (online) 2522-1914
PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
Vol. 10 No. 1, 2025

Original Scientific Article DOI: 10.15391/prrht.2025-10(1).05

Biomechanical impact of foot pronation on anterior knee pain – case controlled study

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Abstract

Purpose. The purpose of the study was to investigate the biomechanical difference and relationship between pronated foot posture and AKP in the Abu Dhabi region. Structural abnormalities of the foot can disrupt the normal lower extremity biomechanics, leading to abnormal kinematics and affecting the musculoskeletal health of individuals with anterior knee pain(AKP). In-depth research on the biomechanical link between tibial kinematics and pronated foot posture is crucial for clinical interventions.

Material & Methods. Involving 50 participants clinically diagnosed with AKP with or without pronated feet. The Kujala patellofemoral score for functional limitations, the foot posture index (FPI) for foot posture, and the dynamic valgus index (DVI) for the knee valgus angle were used as outcome measures. The studies were conducted in compliance with the requirements of the Helsinki Declaration of the World Medical Association "Ethical principles for medical research involving human subjects". A case-controlled study was conducted at a tertiary Hospital, in Abu Dhabi, UAE. The significance was set at $p<0.05$.

Results. Participants in the case group AKP with pronated feet (mean: 50.20±5.28) had statistically significant ($p <0.001$) lower Kujala scores as compared to the control group participants with neutral and supinated feet (mean: 83.90± 8.36). In addition, the correlation ($p = 0.04$) between the variables DVI and FPI was found to cause the altered foot pronation position that led to AKP.

Conclusions. The study findings indicated that the unusual loading among AKP participants on their patellofemoral joint may be influenced by the pronated foot. While managing the participants with AKP, musculoskeletal practitioners should consider foot posture, especially pronation, while evaluating individuals with AKP.

Key words: Pronated foot, anterior knee pain, Kujala score, foot posture, musculoskeletal health risk.

Introduction

Anterior knee pain (AKP) is one of the most prevalent musculoskeletal conditions and significantly affects the adolescent population(Piva et al., 2006; Van Linschoten et al., 2006). The understanding of the Healthcare professional about AKP may become unclear in a clinical setting, as it involves numerous factors, notably the determination of foot position(Austermuehle, 2001; Fredericson & Powers, 2002;).Foot alignment or posture plays an important role in maintaining optimal biomechanics functions of the lower limb(Alderink, 2001). Pronated foot alignment is simply described as collapsing or flattening of the medial longitudinal arch, which interns leads to abnormal foot alignment.This abnormal align-

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ment of the foot can lead to greater stress on the soft tissue structures around the knee and foot segments. Mechanically alter the kinetics of the talonavicular joint leads to a significant navicular drop, and it is directly linked to the overall function of the foot (Arndt et al., 2007). The previous literature supports the hypothesis that excessive foot pronation at the subtalar joint has a biomechanical link with the knee complex (Duffey, Martin, Cannon, Craven, & Messier, 2000). Excessive subtalar pronation leads to altering or delaying the normal tibial torsion and may cause compensatory motions at the tibiofemoral joint. As a result of that, it simultaneously increases the knee valgus angulation and decreases the contact surface of the patella and femur, leading to abnormal tracking of the patella, which is the reason for the excessive compression at the lateral patellar facet contributing to the anterior knee pain symptoms (Kaufman, Brodine, Shaffer, Johnson, & Cullison, 2011).

Based on the research evidence, it is further hypothesised that foot alignment plays a crucial role in the prevention of various musculoskeletal injuries in the lower limbs. (Chung, Lee, & Lee, 2016) Frequently researchers reported that muscle length tensions are a common target & treatment goal for anterior knee pain syndrome. However, the studies did not explain the relationship between Muscle length tension and AKP in their treatment approaches (Post, 2005; Pourahmadi et al., 2016; Witvrouw, Lysens, Bellemans, Cambier, & Vanderstraeten, 2000). Hence, the physiotherapy intervention needs to address the altered kinematic chain relations of the foot has an apparent biomechanical association with knee functions.

Musculoskeletal clinicians well know that the etiology of AKP is multifactorial; at the same time, it is crucial to the screening of foot posture, and it may help the clinicians to understand the musculoskeletal risk factors and rule out the biomechanical influence on AKP. Clinicians should consider several clinical reasons before the interventions to achieve their outcome in the management of AKP (Kuru, Dereli, & Yaliman, 2010; Powers, 2003).

Currently, available literatures lacks in-depth exploration of the specific biomechanical factors for foot pronation and it is an association with AKP to the local population. In addition to existing knowledge of biomechanical contributing factors, this study considered the diverse population specifically within the Abu Dhabi region by including cultural and diversity factors, activity levels, and ethnic background to provide a more detailed understanding of the comprehensive biomechanical associations and influences of the AKP to address the research gap and provide the valuable insights for musculoskeletal clinical practice.

Interestingly, this study will help young musculoskeletal practitioners understand the importance of the comprehensive biomechanical assessment to identify the multifactorial risk factors and explore the biomechanical kinematic link between the pronated foot postures in subjects with anterior knee pain syndrome. Therefore, this study aimed mainly to address the difference between pronated feet and neutral/supinated feet and its biomechanical association with AKP in Abu Dhabi region.

Material and methods

Design

This cross-sectional study is a phase -1 part of our research work which invites 50 participants with AKP who visited for rehabilitation as a convenience sample. The studies were conducted in November 2023 onwards for 6 weeks compliance with the requirements of the Helsinki Declaration of the World Medical Association "Ethical Principles for Medical Research Involving Human Subjects". A case-controlled study was conducted at a tertiary Hospital, in Abu Dhabi, UAE.

Before recruiting the participants, this study method was approved by the Clinical Research Ethical Committee (reference number MCME. CR.310.MNOO.2023). The main trial (phase -2) study has been registered on ClinicalTrials.gov under the trial registration number NCT05917080.

Participants

Before the data collection, subjects were explained the purpose of the study and signed an informed consent form. In total, 50 participants of both genders (male and female) aged between 18 and 35 years with AKP accepted our invitation for this study. All participated AKP subjects, age, gender, and body mass index (BMI-kg/m^2) were marked in the data sheet. The severity of the AKP condition of the recruited participants was screened using the Kujala Patellofemoral Questionnaire (KPQ) according to inclusion and exclusion criteria. Participants who had KPQ scores 40 and above were included in this study(Willson & Davis, 2009). Among the included 50 participants, 30 AKP participants (n=26 Males and 4 Females) with pronated feet were grouped as case groups and 20 AKP participants (n=17 males and 3 females) without pronated feet were grouped as a control group (Figure 1). Subjects were excluded from the study according to the following criteria: history of meniscus or joint injury, surgery in and around the knee, participants under non-steroidal anti-inflammatory drugs or corticosteroids within 24 hours before the clinical assessment, positive patellar apprehension test, congenital or traumatic deformity, concomitant diagnosis of pre-patellar bursitis or tendonitis, Plica syndrome

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ISSN (print) 2522-1906, ISSN (online) 2522-1914
PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
Vol. 10 No. 1, 2025

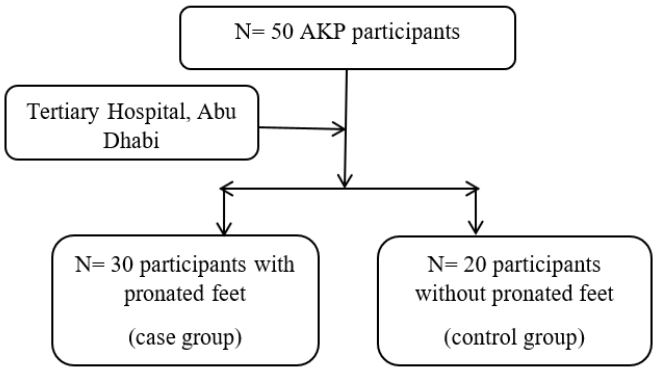

Figure 1. Distribution of subjects in the study. "AKP" and "N" were referred to Anterior knee Pain and the number of subjects.

& Osgood Schlatter's disease, malignancy & skin infection, Pregnant woman or lactating woman.

Outcome measures

The Kujala anterior knee pain scoring questionnaire was formulated in 1993, specifically for the AKP, with reliability, validity, and sensitivity of this scoring (Crossley, Bennell, Cowan, & Green, 2004). It consists of 13 items categorized to evaluate various levels of knee function. The response of each participant to each item and their cumulative score were added to a comprehensive index that ranges from 0 to 100 points. The maximum score of 100 signifies 'no impairment', while the lowest score of zero signifies 'maximum impairment'.

Version-6, Foot Posture Index (FPI-6) was used to assess foot pronation. FPI-6 is a user-friendly clinical assessment tool to assess the foot posture in all 3 planes without any special instruments. It has good reliability and validity. The individual item is assigned a score ranging from −2 to +2 points, with −12 indicating significant supination and +6 and +12 representing substantial pronation (Redmond et al., 2006). The score, "0 and +5" represents the neutral position. In a weight-bearing posture on both feet, the following six measurements were recorded by the researcher: antero-posterior foot alignment, medial longitudinal arch, supra- and infralateral malleolar curvature, head of talus palpation, talonavicular prominence, and calcaneal angle (Barton et al., 2011).

The Dynamic Valgus Index (DVI) is used to measure dynamic knee valgus angulation. The measurement analysis was performed using image analysis with suitable, cost-effective software. Measurements captured by mobile phone camera (iPhone 14 Pro, Apple, USA, 2023), recorded by two-dimensional data from 3 meters of distance and a height of 45 cm in front of the subjects. The DVI is derived by adding the frontal plane projection angle (FPPA) of the knee joint to the hip FPPA. The hip FPPA is calculated as 90° minus the angle (α) between the pelvis segment and thigh segment. Furthermore, the knee joint FPPA is computed by subtracting the angle (β) between the thigh and shank segment from 180°. The knee projection angle generally increased by 10° or greater in a single leg squat with the knee flexion posture (Harris-Hayes et al., 2014; Salsich et al., 2012). The tool reported measurement reliability (ICC) ranges from 0.68 to 0.8 (Boling et al., 2006; Mølgaard et al., 2018; Scholtes & Salsich, 2017).

Statistical analysis

The Minitab Version 21.1.0 programme was used for the data analysis. Descriptive statistics were used to report the demographic data of the participants. The data was tested for normality using Shaprio-Wilk tests. Since the data was not normally distributed ($p>0.05$), the non-parametric Mann-Whitney U test was applied to analyze the Kujala scores between the case and control groups. Besides, the relationship with the severity of AKP participants's discomfort and pronated foot in the case group was tested using the chi-square test. The significance was set at $p<0.05$.

Results

The descriptive statistics presented in Table 1 show that the overall participants in the case and control groups were 28.62±4.75 years old with a BMI of 27.28±1.83. In the case group, participants with AKP (mean: 50.20±5.28) had more severe symptoms and physical limitations than people in the control group (mean: 83.90± 8.36) who had neutral and supinated feet. The difference was statistically significant (U = 0.000, $p<0.001$). Furthermore, the lowest mean rank of Kujala scores in pronated feet ($\bar{x}$ −15.50) compared to neutral/supinated feet ($\bar{x}$ −40.50) indicates that foot position plays a significant role in the severity of AKP symptoms. The DVI of most of the participants in the case group presented moderate knee valgus (56.7%) and severe knee valgus (43.3%). However, the majority of participants in the case group were overweight and presented with moderate knee valgus and severe knee valgus. The participants with AKP in the case group were found to have a significant relationship between the variables DVI and FPI, X^2 (1, N=30) = 4.22, $p<0.04$. Whereas, no significant relationship was observed between DVI and gender X^2 (1, N=30) = 0.632, $p=0.43$, BMI X^2 (1, N=30) = 1.35, $p=0.25$, Kujala score severity X^2 (1, N = 30) = 2.04, $p=0.15$. This finding indicates that pronated feet have a relationship with biomechanical changes in the knee valgus angle of participants in AKP.

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ISSN (print) 2522-1906, ISSN (online) 2522-1914
FIZICNA REABILITACIA TA REKREACIJNO-OZDOROVCI TEHNOLOGII
Vol. 10 No. 1, 2025

Table 1. Participants demographic data

Variables	Case group (pronated foot) n=30	Control group (neutral and supinated foot) n=20	Overall n=50
Age	28.0±5.4	29.5±3.53	28.62±4.75
Gender			
Male	26 (86.7%)	18 (90%)	44(88%)
Female	4 (13.3%)	2 (10%)	6(12%)
Weight	56±79.37	74.3±7.79	77.34±9.67
Height	169.37±8.88	166.25±5.86	168.12±7.89
BMI	27.58±1.85	26.84±1.74	27.28±1.83
Healthy weight	1 (3.3%)	-	
Overweight	29(96.7%)	20 (100%)	
Kujala Scores	50.20±5.28	83.90±8.36	63.68±17.94
Mild	-	17 (85%)	
Moderate	14 (46.7%)	3 (15%)	
Severe	16(53.3%)	-	
DVI			
No Valgus	-	15 (75%)	
Moderate Knee Valgus	17 (56.7%)	5 (25%)	
Severe Knee Valgus	13 (43.3%)	-	
FP1			
Pronated feet	8 (26.7%)	-	
Highly Pronated feet	22 (73.3%)	-	
Supinated feet	-	8 (40%)	
Normal feet	-	12 (60%)	

**Note: The variables are presented in Mean ±Standard deviation (Mean±SD) and Frequency (%)*

Discussion

The present study was aimed at investigating the biomechanical difference between pronated and neutral/supinated foot posture. In addition, pronated feet and their relationship with AKP in the Abu Dhabi region. Based on the study results, participants in the case group AKP with pronated feet had significantly lower Kujala Patellofemoral Score compared with participants without pronated feet. Besides, the AKP participants's FPI scores and DVI were found to have altered foot posture and knee angles compared to the participants in the control group. In line with the findings of this study, past studies concluded that anterior knee pain has multifactorial causes in clinical conditions (Akarcali et al., 2000).

Kosashvili et al. (2008) conducted a study that identified the pronated foot as a risk factor among multifactorial causes, biomechanically linked to lower extremity malalignment and anterior knee pain. Additionally, a study among runners found a significant association between pronated foot posture and anterior knee pain (Smith et al., 2018). This indicates biomechanical changes that affect both the atheletic and non-atheletic communities that suffer from AKP. Similar to these findings, the present study found that pronated feet have a relation with the DVI of AKP participants and confirms that foot posture alignment issues, especially pronated feet, cause AKP.

On the other hand, among the adolescent population, the study reported no significant correlation between pronated foot and anterior knee pain(Starkey & Brown, 2015). This indicates that the biomechanical impacts between the adolescent and adult ages were different, and that does not cause AKP. However, the assessment of foot posture plays a significant role in gait parameters and injury prevention (Alderink, 2001). On the other side, optimal foot posture is necessary to gain adaptability in different terrains to equally distribute the body weight and shock-absorbing functions (DeLisa, 2001) The altered foot posture, such as pronated feet, would cause biomechanical dysfunctions to influence greater stress on the proximal joints of the lower extremities.

Our study results showed that participants's gender and BMI did not directly have a relationship with the AKP. Recent studies have explored the impact of gender and BMI on AKP and its rela-

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tionship with foot posture. According to Zumwalt et al. (2023), in female genders, biomechanical factors such as Q-angle and wider pelvis contributed to the exacerbated effects of pronated foot posture (Zumwalt, 2023). This does not align with our findings since the majority of participants were male (88%), and it is recommended that gender-specific biomechanical assessment be advocated for further exploration.

In addition, Davis et al. (2020) found a positive correlation between a higher BMI and an increased risk of knee pain and altered foot biomechanics (Davis et al., 2020). Even though the statistical relation was not found in the present study, the majority of participants were overweight, had changes in knee angle DVI, and reported AKP. Biomechanical evaluation for participants with a higher BMI may contribute to pronated foot posture, which leads to abnormal shearing force on the knee and a higher risk of anterior knee pain.

According to Haddad et al. (2020), the Kujala score, FPI, and DVI have moderate evidence in evaluating patients with anterior knee pain. However, there are variations in the supportive literature used as primary assessment tools. Although Smith et al. (2018) strongly relied on the FPI and visual gait analysis, our study was more detailed in biomechanical assessment through the DVI, providing a more detailed understanding of dynamic knee valgus. This comprehensive approach is strongly recommended for evaluating and correcting biomechanical dysfunctions contributing to AKP (Smith et al., 2018). Although previous studies may have adopted a more segmented approach, focusing on isolated factors such as foot posture or knee alignment, our study emphasises the interconnectedness of biomechanical factors and the need for a holistic assessment strategy.

This study will be an eye-opener for musculoskeletal clinicians. It will help them to develop critical skills in the biomechanical basis of an evaluation to effectively manage the AKP subjects and critically explore the association between excessive subtalar joint pronation and abnormal compression at the patellofemoral joint. At the same time, musculoskeletal specialists can focus on the biomechanical intervention to correct the subtalar joint pronation.

Conclusion

This study supports the biomechanical relationship between pronated foot posture and anterior knee pain. It indicates that the pronated foot posture biomechanically influences on subjects with AKP. Hence, this study strongly advocates that, before any targeted interventions, musculoskeletal clinicians need to use the comprehensive assessment tools of the Kujala score, foot posture index, and dynamic valgus index in clinical practice with detailed biomechanical evaluation and correction in the management of anterior knee pain.

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Supplementary Information

Article details

The online version available at
https://doi.org/10.15391/prrht.2025-10(1).05

Acknowledgements
We would like to thank the entire Physiotherapy Team members

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& Patient Administrators at Mediclinic Tertiary Hospital, Abu Dhabi, UAE for their support in facilitating this research study..

Conflict of interest
All the authors declare that they have No Conflict of interests.

Ethical approval and consent to participate
Participants was signed a written informed consent before the participation. Participants signed a written informed consent before intervention. The study was approved by the Clinical Research Ethical Committee under reference number MCME. CR.310.MNOO.2023.

Funding Statement
This article did not receive financial support from the state, public or commercial organizations.

Received: September 15, 2024; Accepted: January 22, 2025
Published: February 28, 2025

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