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RESEARCH

The effect of 8-week corrective games on knee, ankle, and foot alignment in boys aged 9–11 years with pronation syndrome

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Abstract

Background Corrective games are engaging and enjoyable physical activities designed to address musculoskeletal imbalances and improve movement patterns. These games incorporate play and fun while promoting proper movement mechanics, making them an effective therapeutic tool for rehabilitation and physical therapy programs.

Objectives The study aimed to investigate the effects of an 8-week corrective games program on the q-angle, navicular drop, and Staheli index in 9–11-year-old students with pronation syndrome.

Materials and methods This study belongs to the randomized controlled trial and focuses on 9- to 11-year-old male students with pronation foot syndrome in the city of Farooj. A cluster random sampling method was utilized to select three primary schools, and students from third to sixth grade were included based on specific criteria while excluding others. Among the students diagnosed with pronation foot syndrome, 30 were randomly selected as a sample and divided into two groups: an experimental group (N = 15) and a control group (N = 15). The collected data were analyzed using SPSS version 22 software, and statistical tests such as the Kolmogorov–Smirnov test and repeated measures ANOVA were employed to analyze the data and draw conclusions.

Results The results of the covariance analysis showed significant differences between the experimental and control groups in terms of Q angle ($F = 7.69$, $p = 0.010$), navicular drop ($F = 4.65$, $p = 0.040$), and stability index ($F = 18.66$, $p = 0.001$). This means that with the control of the pre-test effect, significant differences were observed between the two groups in terms of Q angle, navicular drop, and Staheli index.

Conclusion The present study shows that corrective exercises are effective in aligning the knee, ankle, and foot positions in 9- to 11-year-old boys with pronation syndrome. Coaches and exercise specialists can use these research findings to improve the posture and enhance the lifestyle of individuals with lower limb misalignments caused by decreased mobility.

Keywords Corrective games · Knee · Ankle · Foot pronation · Q angle · Student

Introduction

Researchers have long been interested in studying human movements, particularly because improper posture can lead to musculoskeletal injuries. Pronation syndrome is an abnormality in the lower limbs that impairs biomechanics, fundamental skills, performance, and physical condition [1]. Pronation syndrome is characterized by excessive foot pronation, internal rotation, and knee valgus [2]. Following subtalar joint pronation, the hindfoot rotates externally, causing the talus bone to slide inward and downward, inducing internal tibia rotation and subsequent pressure on the patellofemoral joint [2, 3]. It is caused by muscle imbalance and stiffness, particularly in the external ankle muscles. Individuals with this syndrome may experience injuries such

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as Achilles tendonitis, plantar fasciitis, medial tibial stress syndrome, ankle sprains, tibialis posterior tendonitis, ACL injuries, and lower back pain [4, 5].

Abnormalities in the upper and lower limbs can lead to impairments in motor skills, as they disrupt the alignment of bones, physical characteristics of lower limb joints, neuromuscular control, and proper soft tissue support [6]. Changes in these factors can impact biomechanics, alter force patterns, affect proprioception and feedback, and lead to various injuries. Any abnormality in the upper and lower limbs can potentially lead to other abnormalities [7, 8]. Some studies have reported the prevalence of foot pronation as 21.1% [9] and 2.9% [10].

Proper knee, ankle, and foot alignment in childhood is essential for musculoskeletal health [11]. Foot pronation, the inward rolling or flattening of the foot arch, is common among children and can be flexible or fixed [12]. Flexible pronation is generally normal, but prolonged pronation can lead to foot pain and misalignment [13]. Fixed pronation requires specific interventions like orthotic devices. The prevalence of pronation varies across populations [9, 10], emphasizing the need for comprehensive evaluations by healthcare professionals to determine appropriate interventions for addressing foot pronation and its impact on lower limb alignment and function.

Corrective games (CG) are a valuable alternative to monotonous and tiring corrective exercises (CE) in physical education [14–16]. They effectively address body abnormalities, promote fundamental movement skills, and improve overall body alignment [15]. By incorporating play and fun, CG engages individuals, particularly children, in enjoyable physical activities while promoting proper movement mechanics [16]. These games are utilized in physiotherapy and rehabilitation to enhance therapy sessions, making them more enjoyable and interactive and increasing engagement, adherence, and motivation. In addition, CG contributes to improved physical fitness, motor skills, balance, coordination, and body awareness [14–18].

The q-angle, navicular drop test, and Staheli index are commonly used to assess lower limb alignment in individuals with pronation syndrome. A higher q-angle is associated with increased foot pronation, and a greater navicular drop indicates higher pronation [19]. The Staheli index evaluates the longitudinal arch alignment, and higher values indicate a flatter foot with reduced arch height [20].

Numerous studies have extensively investigated the effects of corrective games on various abnormalities in the upper limb, such as kyphosis, muscle strength, balance, and upper cross-syndrome [14–16, 18]. However, to date, no study has specifically focused on examining the effect of an 8-week corrective games program on knee, ankle, and foot alignment in boys aged 9–11 years with pronation syndrome. Healthcare professionals or trained therapists should always design and implement these games to ensure safety and appropriateness for each individual's specific needs. By improving physical condition, CG can help prevent lower extremity pain, and early assessments and corrective measures can prevent chronic pain. Therefore, the present study aimed to investigate the effects of an 8-week CG program on the q-angle, navicular drop, and Staheli index in 9–11-year-old students with pronation syndrome.

Research method

This study has been reviewed by the Research Ethics Committee of the Sports Sciences Research Institute and approved and registered with the code SSRI.REC-2311-2528 (R2). The present research is of an experimental type, and its population includes 9- to 11-year-old male students with pronation foot syndrome in the city of Farooj. A cluster random sampling method was used to select three primary schools, and students from 9 to 11 years old were examined based on inclusion and exclusion criteria. Among the students diagnosed with pronation foot syndrome, 30 were randomly selected as a sample and divided into two groups: an experimental group (N = 15) and a control group (N = 15). First, the participants and their parents will receive information about pronation foot syndrome, the research objectives, and the study procedures. If they express their willingness to participate, an informed consent form will be provided to their parents for completion and signature, allowing the children to participate in the research. After completing the questionnaire (with the assistance of parents), the participants will undergo an initial assessment.

During this process, we will measure their height and weight. To quantify the foot arch, we will measure the subtalar joint pronation angle using the Brody Index Test and evaluate it using Brody's method.

The inclusion criteria include male gender, age 9–11, written parental consent, subtalar joint pronation greater than 10 mm, grade 2 foot arch, tibiotalar angle less than 165°, no history of injury, surgery, or fractures in the lower limbs, and absence of specific diseases.

The exclusion criteria include participant dissatisfaction with the research process and more than two consecutive or three alternating absences.

Measurement tools include a scale, height measurement device, long-arm goniometer, chair for evaluating subtalar joint pronation, and a ball.

Evaluation of navicular drop

The participant is instructed to sit on a chair without shoes and place their foot on a box. The chair's height is adjusted so that the angle between the thigh and knee is 90°. The hip joint remains neutral, and the examiner places their thumb and index finger in front of the thin anterior edge of the navicular bone and the anterior and inferior aspects of the medial arch. The examiner touches the inner and outer edges of the prominent tibial tuberosity. The participant tilts their foot and ankle slightly inward and outward until they feel the depressions under their first and fifth metatarsals are at a level surface horizontally. Once the foot and ankle are in this neutral position, the location of the navicular bone prominence is identified and marked. Using a ruler, measure the distance from the navicular bone prominence to the box's surface in millimeters. Then, the participant was asked to stand in a way evenly distributed weight on both feet. This position measures and records the distance from the navicular bone prominence to the ground. The examiner subtracts the distance from the navicular bone prominence to the ground in the weight-bearing position (standing) from the distance in the non-weight-bearing position (sitting on the chair), and the resulting number represents the amount of navicular drop. The navicular drop measurement is repeated thrice for each participant, and the average is used for analysis [21, 22]. This test has the necessary validity to measure the amount of foot pronation. Its reliability coefficient has been reported as 85% by Müller et al. [23]. The Brody method confirmed a drop of over 10 mm in the navicular bone [24]. The Denis A footprint test can be used to diagnose second-degree flat feet. This involves standing on a mirror box with talcum powder on the soles of your feet (Fig. 1). If your foot's central and front parts leave identical imprints, it is a sign of second-degree flat feet [23].

Assessment of knee *valgus* angle

The Q angle, or quadriceps angle, refers to the angle formed between the quadriceps muscles and the patellar tendon, and it differs between men and women due to anatomical differences in pelvic width [25]. To measure the knee valgus angle, the participant stands with legs and knees fully extended and neutrally rotated, with feet side by side. Using a marker, mark the anterior superior iliac spine (ASIS) as the superior anterior point. The center of the patella is determined and marked using concentric circles. The midpoint between the medial and lateral malleoli is marked as the center of the ankle using a standardized vernier caliper. The goniometer center is placed on the center of the patella, and the stationary arm touches the anatomical axis of the thigh at the proximal head of the ASIS. In contrast, the goniometer's movable arm touches the tibia's anatomical axis at the distal head of the midpoint of the ankle. The tibiofemoral angle (TFA) is measured using the goniometer to the nearest degree. In varus knees, this angle increases, while in valgus knees, this angle decreases [26]. In men, the typical Q angle ranges from 10° to 15°, while in women, it is usually higher, ranging from 15° to 20°. The increased angle in women is often attributed to their wider pelvis, which changes the alignment of the femur and knee. A higher Q angle is associated with a greater risk of knee problems, particularly patellar tracking disorders [25].

Evaluation of flat foot

Flat foot, also known as pes planus, is a common condition characterized by a lack of arch and foot pain. When individuals with this condition stand, their feet make contact with the ground without curvature. This condition is also referred to as a loose joint because the looseness of the joint leads to the loss of the arch during standing. Foot abnormalities can be evaluated based on the footprint and the Staheli arch index. For assessing the foot status, the Staheli arch index or AI (Arch Index) can be used [27]. To measure the foot arch, the narrowest part of the arch and the widest part of the heel are separately marked three times with a clear ruler, and the average of the three measurements is recorded. The measurement of the narrowest part of the arch (A) is divided by the widest part of the heel (B) according to the Staheli formula $\mathrm{AI}=A/B$ (Fig. 2). One researcher performs all measurements. The average arch index is calculated considering the standard deviation for the desired age and gender groups [28].

Corrective games (CG)

The corrective games (CG) protocol developed in this study employs a series of validated corrective exercises

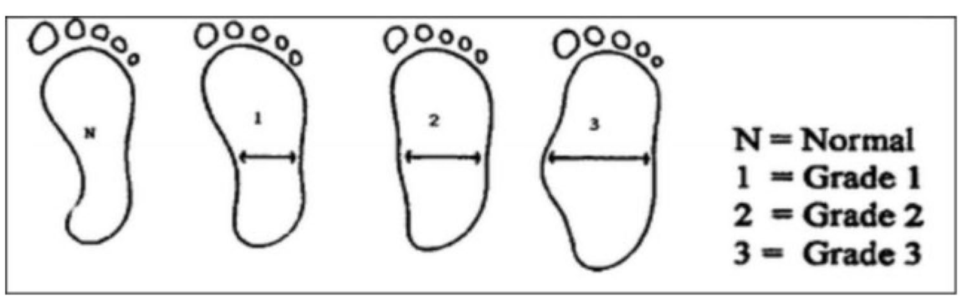

Fig. 1 Classification of plantar footprint based on the Denis method

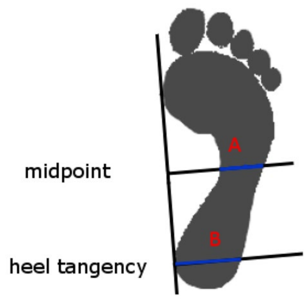

Fig. 2 Schematic illustration of Staheli plantar arch index

to address pronation syndrome and enhance fundamental motor skills. The primary focus of this protocol is to strengthen weakened muscles associated with foot pronation and improve the stability of the foot arch. A variety of exercises, including the "hip bridge," "windmill," and "knee wrestling," are specifically designed to target and strengthen the hamstrings, glutes, and external hip rotators. In addition, exercises such as "pedal play" and "carrying the ball with feet" improve ankle control and enhance foot arch stability. The intensity of the exercises gradually increases to progressively challenge and enhance performance. In the final weeks, advanced exercises such as the "kangaroo jump" and "bear walk" are introduced to strengthen the leg muscles and maintain proper foot alignment fully. The intensity of the exercises gradually increases over time to challenge and progressively enhance performance. In the final weeks, advanced exercises such as the "kangaroo jump" and "bear walk" are introduced to strengthen the leg muscles and maintain proper foot alignment fully.

This protocol is highly individualized, with the number of repetitions and duration of each exercise progressively increased to optimize outcomes. Each training session lasts between 50 and 60 min and consists of a warm-up, CG exercises, and a cool-down. The protocol was implemented for 8 weeks, with three sessions per week. The control group performed no specific corrective exercises during the 8 weeks and continued with their usual daily activities. All exercises were carried out under the guidance of a corrective exercise specialist.

Data analysis

The data were analyzed using SPSS version 22 software. The normality of the data was determined using the Kolmogorov–Smirnov test. Repeated measures ANOVA (2 × 2) will be used to compare the pre-test and post-test data in both the control and experimental groups after 8 weeks of CG and fundamental skills training and to compare the groups.

Table 1 The mean and standard deviation of age, height, and weight are distributed in different groups

Group	Number	Age Mean ± SD	Height Mean ± SD	Weight Mean ± SD
Control	15	9.86 ± 0.83	134.46 ± 5.27	30.66 ± 3.63
Experimental	15	10.20 ± 0.86	135.46 ± 4.77	31.06 ± 4.84

Results

Descriptive information regarding the age, height, and weight of the participants is shown in Table 1.

Based on the Shapiro–Wilk test for normality, Levene's test for equality of variances, and the homogeneity of regression slopes test, the assumptions for conducting the analysis of covariance (ANCOVA) on the variables "Q angle," "Navicular drop," and "Staheli index" were met. The Shapiro–Wilk test confirmed the normality assumption, as the significance values for all variables in the experimental and control groups were greater than 0.05. Levene's test indicated equal variances for all variables, and the homogeneity of regression slope assumption was also satisfied. The ANCOVA results are reliable and can be interpreted with confidence.

Table 2 presents the average (mean ± standard deviation) of the Q angle, navicular bone drop, and Staheli index in the experimental and control groups.

The results from the 95% confidence interval (CI) analysis for the experimental group showed significant improvements in all measured variables after the 8-week corrective games intervention. For the Q angle, the pre-test CI was [152.80, 160.66], which increased to [163.43, 171.63] in the post-test, indicating a meaningful rise in the tibiofemoral angle. Similarly, the navicular drop decreased, with a pre-test CI of [0.91, 1.01] and a post-test CI of [0.80, 0.88], demonstrating a reduction in foot pronation. The Staheli index, representing the foot arch, also improved, with a pre-test CI of [1.12, 1.18] and a post-test CI of [0.968, 1.048]. In contrast, the control group showed minimal changes across all variables, with the Q angle moving from [154.38, 161.74] in the pre-test to [155.90, 164.10] in the post-test, and similarly small variations for navicular drop and Staheli index.

The results of the covariance analysis showed significant differences between the experimental and control groups in terms of Q angle ($F = 7.69$, $p = 0.010$), navicular drop ($F = 4.65$, $p = 0.040$), and stability index ($F = 18.66$, $p = 0.001$). This means that with the control of the pre-test effect, significant differences were observed between the two groups regarding Q angle, navicular drop, and Staheli index. The results indicate that the mean values of Q angle, navicular drop, and stability index in 9- to 11-year-old students

Table 2 Statistical indices related to the research variables

Group	Q angle (°) Mean ± SD		Navicular drop (cm) Mean ± SD		Staheli index Mean ± SD	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Experimental	156.73 ± 7.76	167.53 ± 8.10	0.96 ± 0.10	0.84 ± 0.08	1.15 ± 0.06	1.008 ± 0.07
Control	158.06 ± 7.26	160.00 ± 8.10	0.94 ± 0.14	0.91 ± 0.11	1.11 ± 0.06	1.08 ± 0.04

with pronation syndrome have significantly increased compared to the control group (Table 3).

The value of eta squared for the Q angle is 0.222, meaning that approximately 22.2% of the variation in the tibiofemoral angle is due to the difference in the experimental group, and the test power to detect this difference was observed as 0.763. The value of eta squared for navicular drop is 0.147, meaning that approximately 14.7% of the variation in navicular drop is due to the difference in the experimental group, and the test power to detect this difference was observed as 0.548. The value of eta squared for the Staheli index is 0.409, meaning that approximately 40.9% of the variation in the stability index is due to the difference in the experimental group, and the test power to detect this difference was observed as 0.986. It concludes that the 8-week corrective exercises significantly affect the mentioned variables in students with pronation syndrome (Table 3).

Discussion

The present study aimed to investigate the effects of an 8-week CG program on the q-angle, navicular drop, and Staheli index in 9–11-year-old students with pronation syndrome. Research findings indicate that 9- to 11-year-old boys with excessive pronation have a higher average tibiofemoral angle (Q angle) compared to the control group. However, implementing corrective games (CG) over 8 weeks has a significant impact on reducing the Q angle in these students. The study also reveals that the average navicular drop in these students with pronation syndrome significantly decreases after eight weeks of CG, indicating a positive effect on the navicular drop. In addition, the average Staheli index, which measures foot alignment, significantly decreases in these students after eight weeks of corrective exercises. This highlights the significant effect of the exercises on improving the Staheli index in this group.

The q-angle refers to the angle formed by lines drawn from the anterior superior iliac spine to the patella's center and from the patella's center to the tibial tuberosity. An increased q-angle is associated with greater foot pronation. Abnormal q-angles are commonly seen in lower limb conditions, including pronation syndrome, characterized by excessive inward foot rolling during walking or running. In a study, a corrective games (CG) program significantly decreased the q-angle in students. This suggests the program positively influenced lower limb alignment, reducing excessive pronation tendencies. The intervention likely improved lower limb alignment and biomechanics by strengthening the muscles responsible for maintaining proper alignment. CG typically targets the muscles of the feet, ankles, calves, and thighs, crucial for controlling pronation. Strengthening these muscles will likely optimize lower limb alignment, which can reduce the q-angle.

The navicular drop test evaluates foot pronation during weight-bearing activities. A higher drop indicates increased pronation [27]. After the intervention, a statistically significant decrease in navicular drop was observed, indicating the program's potential to significantly improve foot posture and reduce excessive pronation in individuals with pronation syndrome. The positive effect can be attributed to the program's focus on relevant muscle groups, proprioceptive mechanisms, and strengthening intrinsic foot muscles. Improved dynamic stability, neuromuscular control, motor development, and postural control may have contributed to the observed improvement. This aligns with previous research showing the effectiveness of exercise interventions in improving foot mechanics and reducing pronation.

The Staheli index assesses the alignment of the longitudinal arch of the foot, with higher values indicating a flatter foot with reduced arch height. Pronation syndrome involves

Table 3 Results of the covariance analysis for the variables of Q angle, navicular drop, and Staheli index

Variable	Source of change	SS	DF	AS	*F*	Sig	ES	TP
Q angle	Between groups	402.23	1	402.23	7.69	0.010	0.222	0.763
Navi drop	Between groups	0.149	1	0.049	4.65	0.040	0.147	0.548
Staheli index	Between groups	0.064	1	0.064	18.66	0.0001	0.409	0.986

SS sum of squares, *DF* Degrees of freedom, *AS* average of squares, *F* F value, *Sig* Significance level, *ES* Eta squared (effect sizes), *TP* Test power excessive inward rolling of the feet, leading to flattened arches and potential biomechanical issues [28]. This study significantly improved the Staheli index after the corrective games (CG) program. The program positively impacted the development and maintenance of the longitudinal arch, resulting in a more optimal foot structure. The improvement in the Staheli index may be attributed to CG targeting muscles and structures that support the foot arches, such as the intrinsic foot muscles, tibialis posterior, and plantar fascia. Strengthening these components likely helped restore a more normal arch position and improve foot alignment.

Several studies have investigated the impact of CE and CG on different aspects of physical abnormalities. Golchin et al. found that systematic CE improved ankle proprioception in individuals with pronation distortion syndrome [29]. Dadashpour et al. demonstrated the effectiveness of a strength exercise program in correcting abnormal foot pronation, specifically targeting the hip abductor and lateral rotator muscles [30]. Tavana Kermani et al. showed that CG improved kyphosis in adolescent girls [18], while Salamat et al. found that CG helped prevent and correct upper crossing syndrome in boys aged 10–13 years [16]. Najafi et al. indicated that CE increased tibialis anterior activity and decreased gastrocnemius activity in girls with lower limb pronation syndrome [31]. Ghaderian et al. studied the effect of jump rope exercises on foot arches, showing significant changes in the normal arch group [17]. These studies suggest the potential benefits of incorporating corrective exercises and CG into interventions targeting physical abnormalities. The results highlight the importance of strength training, specific muscle targeting, and engaging in CG to improve proprioception, foot arch alignment, and correct abnormal foot pronation. Such interventions can be valuable for various age groups, including children and adolescents. The results of the past research are consistent with the current study and show that corrective games and corrective movements can reduce the relevant anomalies [16–18, 29–31]. The reasons for the consistency of the results of this research with previous studies are likely due to the impact of CG on muscle coordination and recruitment, improvement of proprioception in joints, stimulation of joint and muscle receptors, and facilitation of the sensory-motor system process after physical exercises in various ways.

The findings of this study support the implementation of an 8-week CG program as a potential intervention for improving the q-angle, navicular drop, and Staheli index in 9–11-year-old students with pronation syndrome. Addressing excessive pronation and improving foot alignment can positively impact these students' musculoskeletal health and function. This study had limitations that included a relatively small sample size and a short post-intervention follow-up period, so the program's long-term effects could not be assessed. Future research with larger sample sizes and longer follow-up periods will provide a more comprehensive understanding of the effects of CG programs on individuals with pronation syndrome. This research establishes a foundation for future studies focused on long-term outcomes, optimal program designs, and the exploration of similar interventions for other musculoskeletal issues in children, broadening preventive care scope within pediatric populations.

Conclusion

In conclusion, the 8-week corrective games (CG) program demonstrated significant benefits in improving the q-angle, navicular drop, and Staheli index among 9–11-year-old boys with pronation syndrome. The findings indicate that this intervention effectively reduces excessive pronation and enhances foot alignment, which is crucial for musculoskeletal health in this age group. While the study had limitations, such as a small sample size and its focus on male participants, the findings still highlight the potential benefits of corrective games programs in addressing lower limb alignment problems. Future research with larger cohorts and extended follow-up will be essential to fully understand the long-term effects and optimize these interventions for broader application in pediatric populations.

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Data availability No datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate For participating minors under the age of 16 years, informed consent was obtained from the parents, legal guardians, or next of kin. The parents or legal guardians were fully informed about the nature of the study, and their consent was obtained before any minors were involved in the research. The Human Ethics Research Committee approved this study of the Sport Sciences Research Institute of Iran according to compliance with the Ethical Standards in Research of the Ministry of Science, Research and Technology, with the IR.SSRI.REC-2311-2528 (R2) code.

Competing interests The authors declare no competing interests.

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