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Original Article

Active Child, Healthy Child Project: The Effects on Dynamic Balance of an Increase in Femoral Anteversion in Healthy Developing Children

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ABSTRACT

Objective: Increased femoral anteversion (IFA) is defined as the anterior rotation of the femoral head in relation to the transcondylar axis of the knee. The aim of this study was to determine the frequency of IFA in healthy developing children and to investigate the effects of IFA on dynamic balance.

Methods: School screening was conducted on 315 school-age children (6-14 years old, mean 9.9 ± 2 years), and IFA was determined in 26 children. From the same sample, 36 children with no IFA were selected as the control group. Data obtained from the Y balance test, handgrip strength with a digital dynamometer, IFA according to the Craig's test, and joint hypermobility according to the Beighton score were compared between the groups. Independent sample *t*-test and Pearson's correlation test were used in the statistical analysis.

Results: This study was carried out on a narrow universe of children mean aged 9.9 ± 2 years, and the incidence of IFA was determined as 8.3%. The Y balance scores were found to be higher in the IFA group than in the controls ($P = .049$ right, $P = .027$ left). There was no correlation between Craig's test and the Y balance test results ($r = 0.04$). No difference was found between the groups for muscle strength and joint hypermobility scores associated with balance.

Conclusion: Balance may not be one of the causes of frequent falls in children with IFA. Further studies are needed to further examine the biomechanical causes of falls, as studies to improve balance may not provide sufficient benefit to prevent fall-related trauma and injury in children with IFA.

Keywords: Increased femoral anteversion, balance, joint hypermobility, muscle strength

Introduction

The femoral head in anterior rotation in relation to the transcondylar axis is known as femoral anteversion.[1] The normal anteversion angle is 5°-15°, and values >15° are accepted as increased femoral anteversion (IFA). The femoral anteversion angle decreases after birth along with age, and by the time bone development is completed, normal levels are reached.[2] Increased femoral anteversion is generally diagnosed after the third year of life, which gradually decreases from 30-40 degrees at birth to 10-15 degrees in the adolescence period.[3] There can be familial predisposition, and it is generally seen bilaterally.[4]

The typical clinical appearance of children with IFA is the "W-sitting" position, with both patella facing inward when standing and walking, and the feet turning inward when walking.[5] Radiological methods and clinical measurement methods can be used to determine the femoral anteversion angle. The Craig's test, also known as the "trochanteric prominence test," was defined by Ruwe et al (1992) and has been shown to be one of the methods that can be used in the measurement of the femoral anteversion angle.[6]

Increased femoral anteversion causes important changes in walking, running, and similar functional activities. Individuals with IFA have been reported to fall 4-fold more when running, and 3-fold more when walking, compared to control subjects.[7] This information has been reported in literature for the adolescent period, especially for children in early adolescence. Anterior knee pain, femoroacetabular impingement syndrome, and labral tears can be seen in some children with IFA.[8] As the lower extremity function level of these children is lower than that of control

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subjects, this can restrict their participation in sports and leisure activities.[7] According to biomechanical studies, it has been reported that healthy developing children with IFA have higher hip and knee peak flexion angles than control subjects by reducing the hip and knee moment in the step phase of walking. Just as IFA can cause stumbling and falling by affecting the lower extremity movement mechanics, it can also cause traumatic injuries by increasing the risk of secondary trauma.[9] Although falls are seen in conditions affected by balance functions, such as lower extremity malalignment and joint instability, muscle weakness, and often insufficient neuromuscular coordination, the factors affecting falls in children with IFA are not sufficiently known.[10]

In individuals with IFA ≥50°, derotation osteotomy is known to be beneficial, but there is limited information in the literature related to the prevention or rehabilitation of problems due to IFA of lesser degrees.[5] The effects of interventions made to increase balance and muscle strength functions to prevent falls and develop functional balance in healthy children with IFA are not known. Therefore, it is important to determine the causes of falls in children with IFA to be able to develop preventative strategies and improve treatment methods.

The hypothesis of this study was that balance functions could be decreased in children with IFA who frequently fall. The aim of the study was to determine the effects of IFA on dynamic balance, muscle strength, and joint hypermobility.

Methods

Study Design and Participants

The data collection of this prospective, descriptive study was made in the scope of school screening and thus provided epidemiological data with respect to showing the incidence of IFA in healthy children. The study universe comprised children from 2 private primary and middle schools. The parents and children were contacted by the school management via a given brochure explaining the details of the project and a consent form. The parents and children who provided written informed consent were included in the study. A total of 315 primary and middle school students were included in the study, which was conducted between April and May 2022. Approval for the study was granted by the Non-interventional Research Ethics Committee of İstanbul Kültür University (Approval no:2019.24, Date: December 12, 2019).

The study inclusion criteria were defined as age in the range of 6-14 years, no health problem that prevented school attendance, and no musculoskeletal system disease.

To examine the differences in dynamic balance, grip strength, and joint hypermobility in the study participants with IFA as determined in the scope of the research compared to control subjects, the children were separated into 2 groups: the IFA group and the control group. Internal rotation of ≥60° on both sides of the hip joint, the external rotation angle at least 40° less than the internal rotation angle, and internal rotation of ≥30° in the Craig's test were accepted as the criteria to determine IFA.[6,11]

To discount an increase in external tibial torsion, children with a tight-foot angle of ≥10° were excluded from the study. In accordance with these criteria, 26 children were included in the IFA group. Angles determined with the Craig's test were in a wide range; 36 children who did not meet the IFA group criteria and were in the range of 0°-15° were selected as the control group.

Data Collection

The study was conducted in 2 primary and middle schools on the European side of Istanbul. Before starting the study, written permission was obtained from the management of each school. An online information meeting was held with the parents to provide information about the research project and to answer any questions. After this, only volunteers who provided written informed consent were included in the study.

All the data collection procedures were performed in the schools. The equipment required for the measurements and evaluations was placed in the rooms assigned by the school management. Demographic information such as age, gender, height, and weight were recorded, and then the measurements related to femoral anteversion angles, grip strength, dynamic balance, and ligament laxity were performed in sequence as a station-type study design. The demographic information was obtained as responses to questions asked by the researcher. To avoid a lack of concentration by the students when completing the questionnaire and demographic information, this part was conducted in a separate room from where the physical measurements were taken. Height was measured with a height scale (ADE M320600-01), and weight was measured with scales sensitive to 0.1 kg (ADE M320600-01).

Femoral Anteversion Angle Measurement

The hip internal rotation measurement was taken with the subject positioned prone and the knees in 90° flexion, and the degree of internal rotation reached by the hips with the effect of gravity was determined with a universal goniometer which can move 360°. The angle between the tibial shaft and the vertical axis was recorded as the hip internal rotation angle. For the external rotation measurement, the hip was moved into external rotation with the effect of gravity of the hip with the subject positioned prone and the knees in 90° flexion. The neutral position of the pelvis was protected, and the maximum external rotation angle was determined with the goniometer. The angle between the tibia shaft and the vertical axis was recorded as the external rotation degree. For the Craig's test, the subject was positioned prone with the knees in 90° flexion. Moving the hip into internal rotation, the most prominent point lateral of the trochanter major was identified with palpation, and the hip internal rotation angle was determined with the goniometer. The measurements were performed by 2 experienced physiotherapists with clinical experience.

Balance Measurement

The "Y balance test" was used for the measurement of dynamic balance. Three colored bands with a length of 150 cm and the back lines on the right and left were placed on the ground in a Y-shape at an angle of 135° with respect to the front line. The subjects were instructed to step with 1 foot on the center point where the lines forming the Y shape joined. Then the subject was instructed to reach as far as possible with the other foot in the 3 different directions of anterior, posteromedial, and posterolateral. The furthest distance that could be reached was measured by the researcher with a tape measure and recorded.[12] These measurements were performed barefoot to eliminate the effect of shoes on balance, and the hands were positioned lateral to the waist to eliminate the effect of the arms. The subjects were instructed to keep the body weight on the support foot while allowing minimum floor contact of the foot extended in the direction of the line. Each measurement was taken 3 times, and the average of the highest 2 was recorded. A composite score was obtained for the right and left sides by normalizing the data obtained according to leg length. The composite score was used in the statistical analysis. These measurements were performed by 2 researchers together.

Joint Hypermobility Measurement
Whole-body joint hypermobility was evaluated with the Beighton scale.[13] Nine different parameters in this test are scored as 0 or 1 point. A total score of ≥5 points is accepted as hypermobility. These measurements were taken by a single researcher.

Handgrip Strength Measurement
A hand-type digital dynamometer (T.K.K. 5401 Takei Scientific Instruments Co. Ltd., Niigata, Japan) was used in the measurements of grip strength. The subject was seated with the shoulders in adduction and neutral rotation, the elbow in 90° flexion, the forearm unsupported, and the wrist in a neutral position. To support the weight of the dynamometer, light support was given by the researcher. Each side was measured 3 times, with a 1-minute rest given between each repetition. The average of the 2 highest measurements was recorded as the muscle strength of that side. When it was taken into consideration that the subjects were in the growth and development period and there were differences between the muscle and skeletal systems between the ages of 6 and 14 years, the grip strength values were normalized according to body weight, and the normalized values were used in the statistical analysis (Newton/kg).

Statistical Analysis
Data obtained in the study were analyzed statistically using The Statistical Package for Social Sciences version 25.0 software (IBM Corp.; Armonk, NY, USA). Conformity of the data to normal distribution was assessed with the Kolmogorov–Smirnov test and the Shapiro–Wilk test. Descriptive statistics were stated as mean ± standard deviation values and number and percentage. All the data conformed to normal distribution, so comparisons between the groups were made with the independent sample *t*-tests, and Pearson's correlation analysis was used to determine the relationship between the data. A value of $P < .05$ was accepted as statistically significant.

Results

An evaluation was made out of a total of 315 children with a mean age of 9.9 ± 2 years. All the measurements in the methodology of the study were applied to all the study participants. Of the total sample, IFA was determined in 26 children, giving a frequency of 8.3%. The children with IFA were determined to be 61.5% female and 38.46% male.

The mean age and body mass index (BMI) values of the IFA group were determined to be lower than those of the control group (Age: 8.8 ± 1.5 vs 10.2 ± 1.9 years, $P = .02$; BMI: 16.7 ± 4.4 vs. 20.2 ± 4.2, $P = .03$). From the whole sample, 56.6% of the children attended primary school, and 43.5% attended middle school. No child with IFA was aged >12 years.

The hypermobility scores of the IFA group were determined to be statistically significantly higher than those of the control group (4 ± 2.8 vs. 2.8 ± 2, $P = .047$). Hypermobility was determined in 42% of the IFA group and in 19.4% of the control group.

When questioned about the dominant lower extremity, all the study subjects stated that the right side was dominant.

The results of the "Y balance test," measured to evaluate dynamic balance, were higher for both the right and left sides in the IFA group than in the control group (right side: $P = .049$, left side: $P = .027$) (Table 1).

No significant difference was determined between the groups with respect to the left and right side grip strength values measured with a digital dynamometer to determine general muscle strength (right side: $P = .095$, left side: $P = .07$) (Table 1).

Table 1. Comparisons of the Age, Body Mass Index, Balance, and Grip Strength Values of the Increased Femoral Anteversion Group and the Control Group

		IFA n = 26	Control n = 36	*P*
Age (years)		8.8 ± 1.5	10.2 ± 1.9	.02*
BMI (kg/m²)		16.7 ± 4.4	20.2 ± 4.2	.03*
Beighton score		4 ± 2.8	2.8 ± 2	.047*
Hip internal rotation (º)	Right	70.8 ± 7.3	33.7 ± 6.4	<.001*
	Left	70 ± 7.5	35.5 ± 6	<.001*
Hip external rotation (º)	Right	28.6 ± 7.49	54.7 ± 7.7	<.001*
	Left	27.8 ± 6.8	51.4 ± 10	<.001*
Craig's test (º)	Right	34.2 ± 5.3	8.3 ± 4.8	<.001*
	Left	34.1 ± 4.5	8.4 ± 4.6	<.001*
Y balance test (cm)	Right	73.3 ± 9.8	65.9 ± 18.5	.049*
	Left	73.1 ± 10.1	64.9 ± 17.9	.027*
Handgrip strength (Newton/kg)	Right	0.38 ± 0.1	0.38 ± 0.9	.95
	Left	0.35 ± 0.07	0.36 ± 0.08	.70

IFA, increased femoral anteversion; º, degree of joint angle.
*Statistically significant parameters, $P < .05$.

In the evaluation of the relationship between femoral anteversion and balance functions, no significant relationship was determined between the "Y balance test" and Craig's test results ($r = 0.24$, $P = .62$).

Discussion

As a result of the clinical measurements taken from healthy children in this descriptive study, IFA was determined at a rate of 8.3%. This finding, obtained from the screening of a narrow universe of primary and middle school-aged children, is one of the first results of the frequency of IFA reported in the literature. The dynamic balance function values determined with the Y balance test were found to be higher in the IFA group compared to the control group. No statistically significant difference was determined between the groups with respect to the handgrip strength. Joint hypermobility scores of the participants in the IFA group were found to be higher than those of the controls.

In literature, IFA is generally determined in 2 different ways using radiological methods (magnetic resonance imaging, computed tomography, ultrasonography) and clinical methods (maximum hip internal and external joint range of motion, and the Craig's test). A strong correlation has been reported between the Craig's test as one of the clinical methods and radiological methods.[6]

Studies that have examined the mechanics of walking have reported that IFA leads to significant differences in the pelvis, hips, and foot mechanics compared to control subjects.[14] Leblebici et al[7] examined the functional results of IFA and reported that children with IFA fell approximately 4-fold more than their peers when walking (14.2%) and especially during running activities (60%), and that there was a weak correlation between the frequency of falls and the hip internal rotation angle (rho = −20.248).[6] The IFA was determined with similar methods in these studies. Although this information in literature shows that IFA increases the frequency of falls for biomechanical reasons, falls may occur for a variety of reasons. Balance disorders are accepted as among the most important reasons for falls. Even though IFA is known to increase the frequency of falls, the causes of falling are not fully known. Lower extremity movement mechanics and lack of balance are thought to be possible reasons that can lead to falls. However, the data in literature on this subject are limited.

The Y balance test scores, measured to evaluate the dynamic balance of the children with IFA in this study, were found to be higher than those of the control group. This result suggests that balance-related problems are not one of the causes of frequent falls in children with IFA. In a study by Tuncer et al,[15] the postural stability and postural control results of healthy individuals aged 10-15 years with IFA were reported to be statistically lower than those of control subjects.[15] These results differed from those of the current study, but this difference could have been due to the effect of the methods used to measure balance. It is not known whether or not there is benefit to be had from exercise interventions to improve balance with the aim of reducing the frequency of falls in children with IFA and to prevent secondary problems such as musculoskeletal system injuries due to falls. Similarly, there is limited information related to which sports activities will be safer for these children or which sports activities could reduce the frequency of falls by developing the balance function.

Increased laxity of ligaments, which are the primary element of joint stability, also known as joint hypermobility, is commonly seen in children. Joint hypermobility has been reported to be seen at rates between 8.8% and 64.4% in children aged 6-15 years.[16,17] Information in literature has shown that joint hypermobility has a negative effect on balance in children. In a study by Hjalmarsson et al,[18] the balance functions of children aged 8-16 years with joint hypermobility determined with the Del Mar scale were reported to be lower than those of the control subjects. Kristensen et al[19] reported that in the static balance measurements of girls aged 14-15 years with joint hypermobility determined with the Beighton score, the postural oscillations were higher than those of girls without hypermobility. In the current study, the hypermobility scores determined with the Beighton score were found to be higher in the IFA group than in the control group (P=.047). Joint hypermobility was determined in this study at a rate of 42% in the IFA group and 19.4% in the control group. The current study results of the effects of hypermobility on balance were seen not to be consistent with other findings in literature, as statistically higher Y balance test results were found in the IFA group than in the control group. The difference in the results was thought to have been affected by the methods used in the studies to measure balance and joint hypermobility.

Muscle weakness has been reported to be another factor that could have an effect on balance. Muehlbauer et al[20] reported a strong relationship between balance and lower extremity muscle strength in healthy children aged 7-10 years.[20] In terms of reflecting general muscle strength, there has been reported to be a high correlation of handgrip strength with general muscle strength.[21] Handgrip strength was measured in this study with the aim of determining general muscle strength. The handgrip strength measurements were measured bilaterally with a digital dynamometer, and when the results obtained were examined when normalized according to bodyweight, there was found to be no significant difference between the IFA and control groups. In a previous study by the current authors, there was also found to be no difference in hip abductor muscle strength between children with IFA and the control group.[14] The results of this study related to muscle strength were consistent with data in the literature, and these results suggest that muscle strength has no effect on the frequent falling of children with IFA.

Limitations

A limitation of the study was that the children were not questioned about the frequency of falls and that there was no direct evaluation of the relationship between falls and walking with feet turned inward, lower extremity muscle strength, and body awareness of the children with IFA. Although femoral torsion can be determined by physical measurement methods performed in the clinic, radiological measurement is accepted as the gold standard. The fact that IFA was not measured radiologically in this study is one of the limitations of our study. Since the data on the cases were obtained from school screening, radiological evaluation was not performed.

Conclusion

The data obtained in this study demonstrated that IFA was determined at a rate of 8.3% in 315 healthy children aged 6-14 years, who were evaluated in the context of school screening. That the dynamic balance values of the children with IFA were no lower than those of the control group, but were actually determined at a statistically significantly higher level, shows that the increased frequency of falling due to IFA may not be related to dynamic balance. Thus, it was thought that the high rates of falling reported in children with IFA were not related to balance.

Joint hypermobility was determined to be higher in the children with IFA than in the control group, and there was no difference between the groups in respect of muscle strength. These results suggest that dynamic balance and joint hypermobility affecting balance, as well as the parameters related to muscle strength, may not be the underlying causes of frequent falls in children with IFA. Therefore, there is a clear need for further studies to investigate the relationship between falls, especially in walking and running activities, and the lower extremity biomechanical characteristics that aim to prevent and control falling.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of İstanbul Kültür University (Approval no: 2019.24, Date: December 12, 2019).

Informed Consent: Written informed consent was obtained from the participants who agreed to take part in the study.

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References

1. Mooney JF 3rd. Lower extremity rotational and angular issues in children. *Pediatr Clin North Am*. 2014;61(6):1175-1183. [CrossRef]
2. MacEwen GD. Anteversion of the femur. *Postgrad Med*. 1976;60(4):154-156. [CrossRef]
3. Staheli LT. Rotational problems of the lower extremities. *Orthop Clin North Am*. 1987;18(4):503-512. [CrossRef]
4. Staheli LT, Corbett M, Wyss C, King H. Lower-extremity rotational problems in children. Normal values to guide management. *J Bone Joint Surg Am*. 1985;67(1):39-47. [CrossRef]
5. Lincoln TL, Suen PW. Common rotational variations in children. *J Am Acad Orthop Surg*. 2003;11(5):312-320. [CrossRef]
6. Ruwe PA, Gage JR, Ozonoff MB, DeLuca PA. Clinical determination of femoral anteversion. A comparison with established techniques. *J Bone Joint Surg Am*. 1992;74(6):820-830. [CrossRef]
7. Leblebici G, Akalan E, Apti A, et al. Increased femoral anteversion-related biomechanical abnormalities: lower extremity function, falling frequencies, and fatigue. *Gait Posture*. 2019;70:336-340. [CrossRef]

8. Naqvi G, Stohr K, Rehm A. Proximal femoral derotation osteotomy for idiopathic excessive femoral anteversion and intoeing gait. *SICOT J*. 2017;3:49. [CrossRef]
9. Passmore E, Graham HK, Pandy MG, Sangeux M. Hip- and patellofemoral-joint loading during gait are increased in children with idiopathic torsional deformities. *Gait Posture*. 2018;63:228-235. [CrossRef]
10. Rombaut L, Malfait F, De Wandele I, et al. Balance, gait, falls, and fear of falling in women with the hypermobility type of Ehlers-Danlos syndrome. *Arthritis Care Res (Hoboken)*. 2011;63(10):1432-1439. [CrossRef]
11. Kozic S, Gulan G, Matovinovic D, Nemec B, Sestan B, Ravlic-Gulan J. Femoral anteversion related to side differences in hip rotation. Passive rotation in 1,140 children aged 8-9 years. *Acta Orthop Scand*. 1997;68(6):533-536. [CrossRef]
12. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther*. 2009;4(2):92-99.
13. Smits-Engelsman B, Klerks M, Kirby A. Beighton score: a valid measure for generalized hypermobility in children. *J Pediatr*. 2011;158(1):119-123, 123.e1-123.e4. [CrossRef]
14. Apti A, Akalan NE. Does increased femoral anteversion can cause hip abductor muscle weakness? *Children (Basel)*. 2023;10(5):10(5):782. [CrossRef]
15. Tuncer D, Gurses HN, Senaran H, Uzer G, Tuncay I. Evaluation of postural control in children with increased femoral anteversion. *Gait Posture*. 2022;95:109-114. [CrossRef]
16. Vougiouka O, Moustaki M, Tsanaktsi M. Benign hypermobility syndrome in Greek schoolchildren. *Eur J Pediatr*. 2000;159(8):628. [CrossRef]
17. Lamari NM, Chueire AG, Cordeiro JA. Analysis of joint mobility patterns among preschool children. *Sao Paulo Med J*. 2005;123(3):119-123. [CrossRef]
18. Schubert-Hjalmarsson E, Öhman A, Kyllerman M, Beckung E. Pain, balance, activity, and participation in children with hypermobility syndrome. *Pediatr Phys Ther*. 2012;24(4):339-344. [CrossRef]
19. Juul-Kristensen B, Johansen K, Hendriksen P, Melcher P, Sandfeld J, Jensen BR. Girls with generalized joint hypermobility display changed muscle activity and postural sway during static balance tasks. *Scand J Rheumatol*. 2016;45(1):57-65. [CrossRef]
20. Muehlbauer T, Besemer C, Wehrle A, Gollhofer A, Granacher U. Relationship between strength, balance and mobility in children aged 7-10 years. *Gait Posture*. 2013;37(1):108-112. [CrossRef]
21. Wind AE, Takken T, Helders PJ, Engelbert RH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Pediatr*. 2010;169(3):281-287. [CrossRef]