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Evaluation of stability of the subjects with toe in gait due to increase in femoral head anteversion angle during quiet standing

Evaluación de la estabilidad de los sujetos con punta en la marcha debido al aumento del ángulo de anteversión de la cabeza femoral durante la bipedestación tranquila

*Mohammad Karimi, **Keyvan Sharifmoradi, ***Razieh Tahmasebi,**** Maziar Sharbafi[1]
*Shiraz University of Medical Sciences (Iran), **Kashan University (Iran), ***Isfahan University of Medical Sciences (Iran), ****Technical University of Darmstadt (Germany)

Abstract. Background: Toe in gait may be due to metatarsus adductus, tibia torsion and femoral anteversion. It is controversial whether it influences standing stability or not. Therefore, the aim of this study was to evaluate the effects of toe in gait, due to an increase in femoral head anteversion, on standing stability. Method: 11 subjects with toe in gait due to an increase in femoral head anteversion were recruited in this study. There was also a control group matched with the toe in gait group. A Kistler force plate was used to evaluate the stability of the subjects during quiet standing based on center of pressure (COP) sways. Results: The mean values of center of pressure (COP) excursion in the anteroposterior direction were 14.41±4.66 and 23.41± 8.17 mm in normal and those with toe in gait, respectively (p-value <0.001). The difference between COP excursion in mediolateral direction in both groups was not significant (p-value=0.085). There was a significant difference between the velocity and path length of COP in both planes between the groups (p-value<0.05). Conclusion: Based on the results of this study, the subjects with toe in gait, due to increase in femoral head anteversion, are more unstable in quiet standing than normal subjects.
Key words: Toe in gait, femoral head anteversion, stability, quiet standing

Resumen. Antecedentes: la puntera en la marcha puede deberse a metatarso aducto, torsión de tibia y anteversión femoral. Es controvertido si influye o no en la estabilidad de pie. Por lo tanto, el objetivo de este estudio fue evaluar los efectos de la puntera en la marcha, debido a un aumento en la anteversión de la cabeza femoral, sobre la estabilidad en bipedestación. Método: en este estudio se reclutaron 11 sujetos con dedo del pie en la marcha debido a un aumento en la anteversión de la cabeza femoral. También hubo un grupo de control emparejado con el dedo del pie en el grupo de marcha. Se utilizó una plataforma de fuerza Kistler para evaluar la estabilidad de los sujetos durante la posición de pie en silencio en función de los vaivenes del centro de presión (COP). Resultados: Los valores medios de la excursión del centro de presión (COP) en la dirección anteroposterior fueron 14,41 ± 4,66 y 23,41 ± 8,17 mm en personas normales y con dedos en la marcha, respectivamente (valor de p <0,001). La diferencia entre la excursión COP en dirección mediolateral en ambos grupos no fue significativa (valor p = 0,085). Hubo una diferencia significativa entre la velocidad y la longitud de la trayectoria de COP en ambos planos entre los grupos (valor de p <0,05). Conclusión: Con base en los resultados de este estudio, los sujetos con dedos en la marcha, debido al aumento en la anteversión de la cabeza femoral, son más inestables en reposo que los sujetos normales.
Palabras clave: Dedo en la marcha, anteversión de la cabeza femoral, estabilidad, bipedestación.

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mohammad Karimi
mohammad.karimi.bioengineering@gmail.com
[1]Lauflabor Locomotion Lab, Institute of Sport Science, Centre for Cognitive Science, Technische Universität Darmstadt, Germany

Introduction

Toe in gait is defined as a walking style in which the child walks or runs and turns the foot inward instead of pointing straight ahead (1). It may be due to various reasons, such as metatarsal adductus (foot turns inward), tibia torsion (shank turns inward) and femoral anteversion (femur turns inward) (1, 2). In this pathology, the angle between the femoral neck and condyle is more than 16 degrees. An increase in femoral anteversion angle (angle between the femoral neck and axis of the knee) is one of the reasons of toe in gait. This angle is assumed to be 26 degrees at the age of 5, 21 degrees at the age of 9 and 16 degrees at age of 16 (2). If this angle increases, it would be defined as femoral anteversion (2, 3).

The etiology of toe-in gait is debated. It is usually bilateral and affects females more than males. It is associated with an increase in internal hip rotation, decreased external hip rotation and turning the patella and feet inward (4).

Actually, a change in alignment of lower limb structure increases the incidence of knee and hip OA (5, 6). Based on the results of the study done by Terajesen et al, the incidence of hip joint OA is significantly high in the subjects with increase in femoral anteversion, which may be due to change in point of application of loads or due to an increase in applied loads (7). Based on the few FEA (finite element analysis) studies, an increase in the anteversion angle of the hip joint increases the stress applied on the femoral head (5).

Stability during standing and walking may also be altered in the subjects with toe in gait due to an increase in femoral head anteversion. There is no doubt that postural stability relies on properly developed body structure, efficiency of neurons, and muscular systems (8). A decrease in postural stability increases the risk of falls during standing and walking.

It seems that altering the foot progression angle (angle between the line joining the center of heel to the second metatarsal head and the progression axis of walking) is changed in the subjects with toe in gait. This shifts the center of pressure in the mediolateral direction (9). Based on the results of the study done by Javid Khan et al, increased toe in and toe out angles in foot did not show any significant effects on postural stability and risk of fall (10). However, it should be emphasized that the stability during standing depends on alignment of lower limb bones relative to each other's, performance of musculoskeletal systems and also neural system to control the performance of muscles. It seems that the alignment of legs differs in the subjects with toe-in gait compared to normal subjects (an increase in anteversion angle of the femur decreases the external rotation of the hip joint in standing and finally decreases base on support) (7). The change in alignment of lower limb structure also influences the performance of the muscles, which finally increases joint contact forces. An increase in joint contact force will increase the incidence of hip OA in future (5, 7).

Based on the available literature, there was no study on the stability analysis of the subjects (children) with toe in gait due to an increase in the anteversion angle of the hip joint. Therefore, the aim of this study was to evaluate the stability of children with toe in gait during quiet standing. The main hypothesis associated with this study was that the stability of those with toe in gait differs from that of normal subjects.

Methods

Two groups of normal people and those with toe in gait were recruited for this study. Toe in gait group were selected from those with an increase in femoral head anteversion angle. It should be emphasized that toe in gait may be due to an increase in femoral head anteversion angle, tibia torsion and metatarsus adductus. The reason for toe in gait was evaluated by an Orthopaedic surgeon. The main inclusion criteria for selecting the subjects were having toe in gait due to an increase in femoral head anteversion angle, and without any other musculoskeletal disorders. All subjects with toe in gait had CT scan images of their hip joint. The main criterion to select the subjects with toe in gait was the anteversion angle of the femur (the angle between lines bisecting femoral head and neck and femoral condyles) based on CT scan images. Moreover, their style of walking was evaluated by an orthopedic surgeon. Femoral anteversion is defined as the angle between the femoral neck and axis of the knee. This angle is about 30-40 degrees in newborn children and decreased by 1-1.5 degrees per year until age 16 (11). This angle is assumed to be 26 degrees at age 5, 21 degrees at age 9 and 16 degrees at age 16 (11-13). If the anteversion angle of the femur is more than 16 degrees, it can be classified as femur anteversion [1].

The inclination angle is the angle between the line bisecting the femoral head and neck and the line bisecting the femoral shaft. This angle was also measured based on CT scan images of the femur. Usually it should be around 25 degrees (14).

CT scan images were obtained from the femur of the subjects for both the right and left sides. It was determined that the cause of toe in gait was an increase in femoral head anteversion angle. Both groups were matched based on age and height. An ethical approval was obtained from XXX University of Medical Sciences, ethical committee. A consent form was signed by the parents of each subject before data collection. The main criteria to select the subjects with toe in gait were: with an increase in femoral head anteversion angle, without any other musculoskeletal disorders which influence their standing and walking abilities. The normal subjects were matched with toe in gait subjects based on age and height. Table 1 shows the characteristics of the subjects who participated in this study. It should be noted that the number of subjects was determined based on the number of participants in the previous publications.

A Kistler force plate (50*60 cm, Switzerland) was used to evaluate the subject's stability during quiet standing. The subjects were asked to stand on the force plate in an anatomical position and look straight ahead at a point 2 m far from the subjects. They were asked to stand on the force plate for 60 seconds with their eyes open. It should be emphasized that the subjects were asked to stand in anatomical position (they were not asked to put their foot along a predetermined position). The data were collected with the frequency of 120 Hz and were filtered with Butterworth low pass filter with cut off frequency of 10 Hz (15, 16). The first 15 seconds and last 15 seconds of the data were removed, and only 30 seconds were used for the final analysis. Some parameters include excursion of COP (center of pressure) in mediolateral and anteroposterior planes, the velocity of COP sways in both AP and ML plans, path length of COP sway in anteroposterior and mediolateral plans were used for the final analysis. It was calculated based on the equations used by the authors in the previous publications (15-17).

The mean value of the aforementioned parameters was determined. Two sample t test was used to determine the difference between the mean values of each parameter between the groups. The normal distribution of the parameters was evaluated by the Shapireo-Wilk test.

Results

Eleven subjects with toe-in (7 girls and four boys)

were recruited in this study. There was also a control group of normal subjects matched with the first group based on gender, age and weight. The mean values of stability parameters of the two groups of subjects are shown in Table 2. The center of pressure (COP) excursion in the anteroposterior direction was 14.41±4.66 and 23.41± 8.17 mm in normal and those with toe in gait, respectively (p-value <0.001).

The difference between COP excursions in the mediolateral direction in both groups was not significant (p-value=0.085). The mean value of the velocity of COP in anteroposterior and Medio- lateral directions were 433.74±187.21 and 522.7±223.01 mm/min, respectively in normal subjects, compared to 2542.16±168.31 and 2618.46±1578.83 mm in toe in subjects (The differences was significant). The path length of COP in both Medio-lateral and anteroposterior directions significantly differed in both groups (p-value=0).

Table 1: The characteristics of the subjects participated in this study

Groups	Age (year)	Weight (Kg)	Height (m)	In-R (degree)	In-L (degree)	Ant-R (degree)	Ant-L (degree)
Normal	11.5±1.45	40±4.5	1.52±0.14	----	----	----	----
Anteversion	11.4±1.7	39.5±3.7	1.5±0.13	131.63±5.66	131.45±5.64	46.84±12.9	50.26±13.14

In-R=inclination angle in right side, In-L= inclination angle in left side, Ant-R= anteversion angle in right side, Ant-L= anteversion angle in left side

Table 2: The mean values of stability parameters of both normal and those with anteversion angles during quiet standing

Parameters	Anteversion	Control	95% Confidence Interval of the Difference	Effect size	Power	P-Value of difference
COP excursion in anteroposterior plane (mm)	23.41±8.17	14.41±4.66	-14.9 -3.1	0.33	0.855	0.00
COP excursion in mediolateral plane (mm)	38.56±23.00	27.52±11.95	-27.3 5.26	0.091	0.27	0.08
Velocity of COP in anteroposterior plane (mm/min)	2542.16±1989.91	433.74±187.21	-3365 -851	0.038	0.914	0.00
Velocity of COP in mediolateral plane (mm/min)	2618.46±1578.83	522.79±223.01	-3098.5 -1092.8	0.487	0.985	0.00
Path length of COP in anteroposterior plane (mm)	1271.08±994.95	216.87±93.60	-1682 -425.5	0.038	0.914	0.00
Path length of COP in mediolateral direction (mm)	1309.23±789.42	261.40±111.51	-1549.2 -546.4	0.487	0.985	0.00

COP=center of pressure

Discussion

It is controversial that those with toe in gait have instability during standing and walking which may influence their risk of falls. There is no literature on the stability of children with toe in gait during quiet standing. Therefore, this study aimed to evaluate the stability of children with toe in gait due to an increase in the anteversion angle of the hip joint during quiet standing.

The results of this study showed that those with toe in gait, due to an increase in hip joint anteversion angle, are more unstable than normal matched children during quiet standing. They are unstable in both Medio-lateral and anteroposterior planes. This is due to not only a change (increase) in COP excursion but also due to an increase in COP path length and velocity, Table 2. Therefore, it may be concluded that this group of subjects had more postural instability and may be at more risk of falling. It should be emphasized that stability in this research was evaluated based on excursion, velocity and path length of COP in both anteroposterior and mediolateral planes. The difference between the stability of the subjects with toe-in gait with that of normal subjects was not due to a sudden change in motion of center of mass (COM) but it may be due to extra motion of COM throughout the standing time (as there was a significant difference between the Cop path length and velocity). Therefore it may be concluded that this group of subjects is more unstable than normal subjects due to a change in the alignment of leg structures. This may influence muscle performance, which finally increases joint contact forces.

The main reason for the decrease in stability of children with toe in gait may be due to a change in the base of support of this group of subjects during quiet standing. Actually, an increase in the anteversion angle of the hip joint turns the foot inward and decreases the base of support during quiet standing. Moreover, it may increase the need of subjects to contract muscles to stabilize the body while standing. This may increase the sways of the center of mass, which finally decreases stability. A few studies in literature evaluated the stability of those with toe in gait. The only research was done by Javid Khan et al who evaluated the induced posture of toe in and toe out foot in a group of normal subjects. The

change in the alignment of the foot did not influence the stability of the subjects. However, it should be noted that normal subjects participated in the research done by Javid Khan et al (10). However in the current research, the subjects with toe in gait deformity were recruited. Clinicians can use the output of this research to improve the stability of this group of subjects by using of appropriate treatment approach.

The results of this research study may highlight the point that the stability of those with toe in gait decreased compared to normal subjects, which may finally influence muscles performances and joint contact forces. Therefore, it is essential to change the alignment of leg structures through conservative treatment or surgery.

There is a limitation associated with this study. The main limitation was that only stability during quiet standing was evaluated in this study. Therefore it is recommended that dynamic stability while walking be assessed in this group of subjects.

Conclusion

The results of this study showed that the stability of the subjects with toe in gait, due to an increase in hip joint anteversion angle, is less than that of normal subjects, which may be due to a decrease in the base of support.

Declarations

Ethics approval and consent to participate: An ethical approval was obtained from Isfahan University of Medical Sciences.

Consent for publication: All of authors have the same responsibility regarding the content of the paper.

Availability of data and materials: Data are available based on request.

Competing interests: None

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Authors' contributions: MTK was responsible for analysing the data, KS was responsible for data collection, RT was responsible for writing the paper.

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