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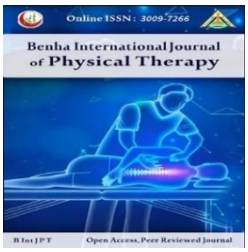

Original research

Effect of Designed Physical Therapy Program on Correction of Intoeing Gait in Typically Developed Children

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Abstract

Background: In-toeing is one of the most familiar gait abnormalities in children and young toddlers. Excessive femoral anteversion is the commonest reason for persisting in-toeing gait and alteration of gait function in children. **Purpose:** To determine the effect of a designed physical therapy program on the correction of in-toeing caused by increased femoral anteversion in typically developed children. **Methods:** Thirty-four children with an in-toeing gait pattern from both genders; age ranged from 4 to 8 years; participated in this study, based on a previous pilot study of five children. They were randomly allocated from Damietta governmental hospitals. We divided them into two equal groups, the control and the intervention. The control group did not receive any physiotherapy program (they will receive the designed program after finishing treatment for the control group), while the intervention group received the designed physiotherapy program. Range of motion of hip internal and external rotation and foot progression angle were used to measure the femoral anteversion angle and angle of in-toeing, respectively. Each child was measured 2 times, at baseline (pre) and after 3 months (post). **Results:** Statistical analysis of the results demonstrated that within-group comparison showed a statistically significant amount of change in internal rotation, external rotation range of motion of the hip joint, and foot progression angle in the treatment group compared to the control group. For the intervention group, the amounts of change in internal hip rotation, external hip rotation, and foot progression angle are (-4.71±0.45), (3.94±0.60), and (0.94±0.21), respectively, while for the control group the amounts of change are (-0.88±0.30), (2.56±0.47), and (0.62±0.18), respectively. **Conclusion:** The designed physical therapy program improved the foot progression angle and internal and external hip range of motion and hence corrected the intoeing gait pattern.

Keywords: Femoral anteversion, Foot progression angle, Intoeing, Rotational gait pattern.

Introduction

In-toeing is one of the rotational abnormalities of the lower limbs (metatarsus adductus, internal tibial torsion, and femoral anteversion) that are the common causes of intoeing. The most frequent causes of referrals for pediatric orthopedic consultation are lower extremities rotational deformities. A variety of causing pathologies are responsible for these disorders. The causes of referrals are mostly family concerns about whether these deformities will affect the growth and gait patterns of their children or not. In pediatrics, most of the rotational variations of lower extremities are benign and resolve spontaneously by time with no prominent restriction, although a few number need surgical intervention or conservative treatment. It is essential to understand the causes of that problem and the normal variation regarding the cost and psychological load of surgical intervention in children. The outcomes of surgical and conservative treatments in such rotational deformities are limited[1].

Femoral anteversion, internal tibial torsion, and metatarsus adductus. One or more of these conditions are referred to by the general term "in-toeing'. Extensive research on in-toeing shows that most youngsters resolve on their own with no assistance. Frequently, the anomaly represents a natural variance in lower limb development. Typically, inadequate resolution does not lead to any functional issues in youngsters. Children with in-toeing gait frequently see a doctor due to parental concerns about trips and falls, as well as the child's potential for participation in sports in the future and school activities or cosmetic appearance concerns. Bracing, corrective shoes, insoles, and other mechanical devices were the most frequent and commonly used treatments for these deformities but are now discontinued[2].

It is reported that only 3% of children who were referred to a pediatric orthopedic surgeon with an in-toe gait were indicated for surgical treatment. While other children referred to physiotherapy, orthotics, or diet and weight reduction[3].

There are no standardized guidelines or definite recommendations for treatment of in-toeing that have been accepted. The initial response is the conservative treatment and reassurance. On the other hand, braces, casts, or modifications to shoes are not recommended in experiments. For older children with clear abnormalities, surgery is advised [4].

There are two major goals in regard to the treatment of in-to-gait children. Cosmetic reasons are the first indication for treating those children. While the other reason is to decrease the deformity so as to eliminate the possible risks of joint problems. Recent research has proven the issues related to excessive femoral anteversion, including patella-femoral malalignment-induced anterior knee pain, femoral acetabular impingement, and lateral tears. Increased femoral anteversion angle was claimed to increase the incidence of hip osteoarthritis. There are two types of treatment for in-toeing gait: surgical and conservative. The most common conservative treatments for children with in-toeing gait are medical shoes, insoles, night splints, Dennis-Brown splints, twister cables, Thera Togs, and ground reaction foot orthosis. For children with in-toeing gait, physical therapy is another suggested conservative treatment approach. Stretching the external rotator muscles can decrease the foot progression angle (FPA) and lessen in-toeing gait in children with in-toeing gait due to an imbalance of the internal and external hip rotators[5].

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Hence, the study aspired to evaluate the effect of a designed physical therapy program as a conservative approach for correcting the in-toeing gait, which is caused only by increased femoral anteversion in typically developed children in the age range of 4 to 8 years.

Methods

Study design:

The current study is a randomized controlled clinical trial. Each participant's caregiver signed a consent form to authorize the participation of their children in this study.

Ethical approval:

The ethical committee of Cairo University's Faculty of Physical Therapy accepted the current study (No. P.T.REC/012/005054), and it was conducted in strict accordance with the guidelines outlined in the most recent edition of the Declaration of Helsinki code of ethics. Before beginning the study procedures, a signed consent form from the parents assigned to participate in the study was also collected.

Inclusion criteria:

Participants were included according to the following criteria:

- Their age will range from 4 to 8 years.
- Intoeing is caused only by increased femoral anteversion.
- All children are neurologically normal.

Exclusion criteria:

Participants were excluded according to the following criteria:

- Children with tibial torsion.
- Children with metatarsus adductus.
- Children with developmental hip dysplasia (DDH).
- Children with previous operative correction in foot or hip.

I- Randomization:

Thirty-four volunteer children with in-toeing gait diagnoses were among the subjects. The 69 children who were referred or received routine physical therapy treatment at the outpatient clinic of the Damietta Governmental Hospitals, Damietta Governorate, comprised the dataset from which these children were taken. Children who met the eligible criteria (34 children) were enrolled in the current study and allocated into either a control group or a study group of equal numbers (17 children each). Using sealed, opaque, closed envelopes, a person who was not otherwise involved in the research randomly assigned participants (17 children each) to the control or study group.

Study group: Children in this group received a designed physical therapy program for 60 minutes in addition to a home program.

Control group: Children in this group received no treatment, to be treated with the same designed physical therapy program after finishing the same designed program for the treatment group.

The treatment was conducted 3 days/week for 12 successive weeks for the treatment groups. Additionally, a home routine program was conducted for 3 days for the study group.

II- Materials:

A- Materials for subject selection and assessment.

The following instruments were used for subject selection according to the inclusive criteria:

1-Hip external and internal rotation range of motion (goniometer).

ROM assessment using a goniometer is a reliable standard measure, using the ROM assessment to express the anteversion angle and a high correlation between the physical examination and the computed tomography[6].

2- Foot progression angle (FPA).

A standardized technique used to collect foot prints from children using a goniometer, absorbent paper, and water. This method is used to measure foot progression angle. The method appears to be reliable and easy to implement in clinics[7].

A- Materials for treatment :

Physical therapy tools:

The following therapeutic tools were used to conduct the designed physical therapy program for the two groups.

The physical therapy tools included balls, steps, a balance board, mats, a Thera band, and a

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sandbag, in addition to a stepper, separator, and stairs.

III- Methods:

Before beginning the study procedure, each child's name, sex, and age were noted on an assessment sheet.

Methods for evaluation:

All children in both groups were assessed before starting the treatment procedures and after 12 weeks.

1- Range of motion assessment by goniometer

Assessment of the children using the goniometer for internal hip rotation and external hip rotation as follows:

Hip Internal and external rotation ROM using goniometer from prone lying and 90 degrees flexed knees. With a normal range of motion of 45 degrees [8].

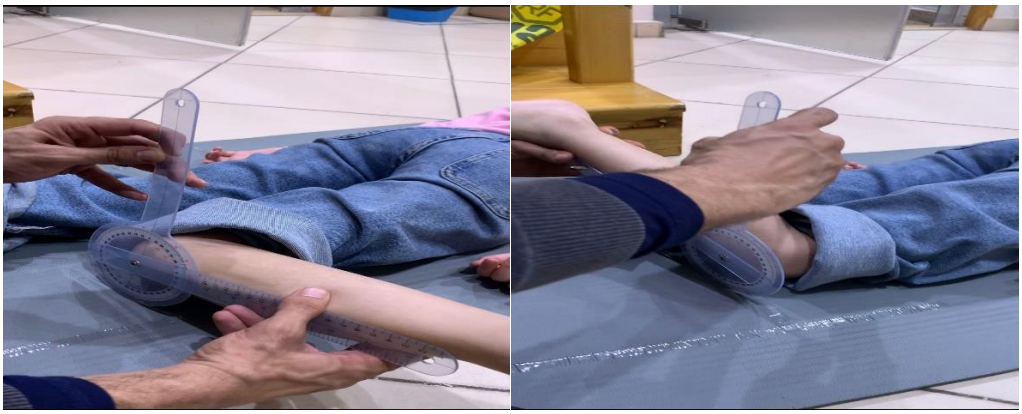

Fig. (1): (A) Assessment of femoral ante-version measured by internal rotation of hip and **(B)** Assessment of femoral retroversion measured by external rotation of hip[9].

2- FPA (foot progression angle) assessment

- Footprint data were attained using 4 m lengths of white paper with an 80 cm width. The paper was outlaid over a 4 m-long walkway.
- A box containing red powder was positioned at one end of each chair that was positioned at the paper's ends.
- The child was instructed to put his or her feet in the box and then shake off any remaining powder gently.
- After removing the powder box, the child was informed to get up of the chair and step directly toward the end, starting with the right foot, looking forward, then sit in the chair at the other end.
- After that, each foot print is treated with artist fixative spray, and the trial number is written on the paper. A piece of sticky, clear contact plastic was placed on each footprint once it had dried.
- To make repeating measurements easier, all experiments were laminated. Each trial yielded two left and two right footprints, which were then utilized to compute the FPA in order to exclude phases of acceleration and deceleration.
- A water-soluble pen was used to ensure that marks can be erased completely with no cavities on the laminated surface.
- A ruler of stainless steel was used to draw the lines and measure the lengths, then a transparent plastic protractor was used to

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measure angles, allowing measurement increments to 0.5◦

- Over the footprint, a translucent grid made of parallel lines was placed. The medial side of the foot and the hallux apex were the grid's longitudinal borders. Measuring the distance between the paper's border and the grid's top and bottom will ensure that the grid is positioned parallel to the paper.
- The lines were drawn using the grid. Define the hallux apex in (A). Parallel to line (A), an identical line (B) was drawn at the rear of the heel. Both ends of the grid's longitudinal edge, which runs parallel to the medial side of the foot, were marked. The two spots that were joined to create the line of progression (LOP) when the grid was removed (Figure 2).
- FPA is produced by the angle formed by the line of progression and the bisector line of the foot, which is the line that intersects from the heel center through the second toe.

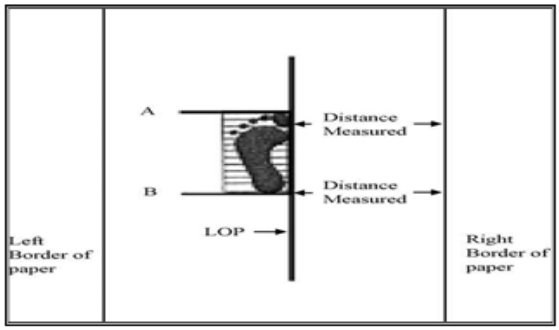

Fig.(2): Transparent paper placement (line of progression). Adopted from[10].

Methods for treatment:

- Strengthening exercise program (hip external rotators) [11].
  a) Calm shell.
  b) Lateral slides.
  c) Monster walk.
  d) Pseudo-running exercise, using thera band and sandbag.
  e) Walking sideways.
  f) Frog hops (with hands on the floor between feet and toes turned out).
  g) Step ups (on stairs/boxes; forward and sideways).
  h) Penguin walks (walk on the heels with toes in the air and feet turned outward).
  i) Kicking a ball with the outer side of their foot.
  j) Balancing on one foot.
  k) Crab walking.
  l) Ring sitting or crisscross sitting.
  m) Squatting (especially sumo squatting with feet pointed out) .
- Stretching exercise program (hip internal rotators). Child Lying Supine. Place the ankle of one leg on the opposite knee, then push the knee gently downward[12].
- Ring sitting positioning program.
  Classically, parents of incoming children reported that their children prefer a W-shaped sitting position, rather than the cross legged sitting position[2].

Treatment includes patient education, daily activities, and specific corrections based on activities. The education means that to educate the child and parents about how the impaired movements, prolonged positions, and repetition of those movements may be related to the musculoskeletal condition. Then, how to correct these movements and positions during all daily activities, especially those that cause symptoms[13].

RESULTS

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The results of the present study are demonstrated in the following tables and figures.

Our study aimed to investigate the effect of a specially designed physical therapy program on the in-toeing gait caused by excessive femoral anteversion in typically developed children, and we applied our study to 34 patients who were divided into two groups: the study group (n = 17) and the control group (n = 17), with the same inclusion and exclusion criteria.

I- General characteristics of the study groups:

Based on demographic information regarding age in "years" and sex, there is no statistically significant difference between the treatment group and the control group, as indicated by the p-value (P > 0.05) as shown in (Table1).

Table (1): Comparison between study group and control group according to demographic data.

Demographic data	Study Group (n=17)	Control Group (n=17)	Test value	p-value	Sig.
Age "years"					
Mean±SD	6.01±1.12	5.89±0.93	0.122	0.729	NS
Range	4.2-7.8	4.3-7.2			
Sex					
Female	9 (52.9%)	10 (58.8%)	0.119	0.942	NS
Male	8 (47.1%)	7 (41.2%)			

Using: t-Independent Sample t-test for Mean±SD;

Using: x^2: Chi-square test for Number (%) or Fisher's exact test, when appropriate

NS: Non significant; S: Significant; HS: Highly significant

II- Pretreatment comparison of lower limb parameters of the both groups:

The pretreatment comparison of lower limb parameters is determined in (Table 2). The results showed non-statistically significant difference between the two groups regarding FPA, hip external and internal rotation with p-value (p< 0.05).

Table (2): Pretreatment comparison between study group and control group according to foot progression angle, external and internal hip rotation.

Parameter	Study Group (n=17)	Control Group (n=17)	Test value	p-value	Sig.
Foot progression angle					
Mean±SD	-2.06±1.15	-2.29±1.17	0.836	0.406	NS
Range	-4_0	-5_-1			
External hip rotation					
Mean±SD	32.79±3.83	30.06±3.66	1.512	0.104	NS
Range	25-40	22-35			
Internal hip rotation					
Mean±SD	71.18±3.06	72.44±3.88	-1.493	0.140	NS
Range	65-78	65-79			

III- Posttreatment comparison of lower limb parameters of the both groups:

The post treatment comparison of lower limb parameters is determined in (Table 2). The results showed highly statistically significant difference between the two groups regarding hip external and internal rotation with p-value (p<0.001) and statistically significant difference between the two groups regarding foot progression angle with with p-value (p<0.001).

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Table (3): Posttreatment comparison between study group and control group according to foot progression angle, external and internal hip rotation.

Parameter	Study Group (n=17)	Control Group (n=17)	Test value	p-value	Sig.
Foot progression angle					
Mean±SD	-1.12±0.48	-1.68±0.91	3.165	0.002	S
Range	-2_0	-3_0			
External hip rotation					
Mean±SD	36.74±3.20	32.62±2.47	5.932	0.001	HS
Range	30-41	29-38			
Internal hip rotation					
Mean±SD	66.47±2.89	71.56±3.72	-6.296	0.001	HS
Range	60-71	65-78			

IV- Amount of change comparison of lower limb parameters of the both groups:

The results showed statistically significant difference between the amount of change between the study group compared to control group regarding foot progression angle , hip external and internal rotation . as showed in table (4).

Table (4): Comparison between amount of change of lower limb parameters of both groups.

Amount of change	Study Group (n=17)	Control Group (n=17)	Test value	p-value	Sig.
Foot progression angle					
Mean±SD	0.94±0.21	0.62±0.18	2.674	0.019	S
Range	0-3	0-2			
External hip rotation					
Mean±SD	3.94±0.60-	2.56±0.47-	2.556	0.013	S
Range	0-10	0-8			
Internal hip rotation					
Mean±SD	-4.71±0.45	0.88±0.30	-10.04	0.001	HS
Range	-8_-1	-4_1			

V- Pre and post-treatment comparison of lower limb parameters of the both groups:

Study Group (n=17)

This table shows highly statistically significant improvement in post-treatment compared to pre-treatment according to foot progression angle "FPA" , hip external and internal rotation with p-value ($p<0.001$).

Table (5): Comparison between pre and post treatment parameters of the study group.

Study Group	Pre Treatment	Post Treatment	Amount of change	t-test	p-value	Sig.
Foot progression angle	-2.06±1.15	-1.12±0.48	0.94±0.21	-6.451	0.001	HS
Hip external rotation	32.79±3.83	36.74±3.13	3.94±0.60	-9.246	0.001	HS
Hip internal rotation	71.18±3.06	66.47±2.89	-4.71±0.45	14.825	0.001	HS

Control Group (n=17)

This table shows statistically significant improvement in control post compared to pre-control according to foot progression angle "FPA" with p-value ($p<0.05$). but insignificant difference between pre and post, external and internal hip rotation with p-value ($p>0.05$).

Table (6): Comparison between pre and post treatment parameters of control group.

Control Group	Pre Treatment	Post Treatment	Amount of change	t-test	p-value	Sig.
Foot progression angle	-2.29±1.17	-1.68±0.91	0.62±0.18	-2.372	0.018	S
Hip external rotation	30.06±3.66	32.62±2.47	2.56±0.47	-1.185	0.127	NS
Hip internal rotation	72.44±3.88	71.56±3.72	-0.88±0.30	1.200	0.343	NS

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DISCUSSION

The study was conducted to distinguish the role of a specially designed physical therapy program on the in-toeing gait caused by excessive femoral anteversion in typically developed children in the age range of 4 to 8 years. We hypothesized that the physiotherapy program will have no effect on improving the in-toeing gait caused by increased femoral anteversion in children between 4 and 8 years old. Thirty-four children were selected for this purpose from the government hospitals in Damietta Governorate. Ages of the participants ranged from 4 to 8 years for both sexes. Two equal-sized groups of subjects (control and study) were formed. Every group consists of seventeen children.

The present study, conducted with thirty-four children, presented with a toe gait and referred to physiotherapy clinics as a conservative approach for managing that problem. Despite the lack of scientific evidence that supports the physical therapy effect on the in-toeing gait in typically developed children, which is caused only by the increased femoral anteversion, that lack of evidence was the first precursor of this study. Evaluating the exact role of physical therapy on the correction of the in-toe gait in typically developed children represents the significance of this study.

A three-dimensional importance were the causes for conducting the present study. First, conservative treatment options should be correctly and properly evaluated. This agrees with that in toeing gait are expected to be corrected conservatively[1].Besides, the nature of the problem, which is the progressive physiological resolution of the excessive femoral anteversion throughout the growing process, especially when the child masters the art of walking with ranges of 50–60 degrees to reach 15 degrees at the age of 15 years, with most of this resolution happening in the age range of 4 to 8 years[6].

The second dimension is that other conservative approaches such as shoe modification, wedges, shoe plates, and cluster cables have weak supporting evidence. However, these approaches are the most commonly used approaches. It is hard to have definite knowledge about the effectiveness of the conservative treatments for in-toe gait after reviewing 35papers[5].

The third dimension is that the only definite treatment for the in-toeing gait is the surgical intervention. However, surgical procedures, which are de-rotational osteotomies, are limited for children with severe anteversion aged above 8 years. Surgical treatment is limited for children after the age of 8 with a femoral anteversion angle exceeding 50 degrees, internal rotation more than 85 degrees, and external rotation more than 10 degrees[14, 15, 16].

Besides, surgical correctional osteotomies have been reported to have common complications. Surgical correctional osteotomies are considered a treatment after the age of 8 to 10 years with different locations and fixation techniques; however, serious complications are common. Proximal osteotomies are reported to have a higher risk of complications such as peroneal nerve injury and compartment syndrome[17].

Common complications of correctional osteotomies were reported in many papers. A total of 95 children had derotational subtrochanteric osteotomy with plate fixation for excessive femoral anteversion. All of 83 osteotomies healed, while 13 had serious complications. A recommendation for more conservative treatment options in regard to surgical options, based on the common complications in surgical options and the nature of spontaneous resolution of the problem[16].

Clinical gait analysis using the FPA can be used to describe the intoeing gait[18, 19]. Using the foot prints for infant evaluation using absorbent

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paper and goniometers is reliable and easy to apply in clinics. The techniques for evaluation[7].

The physical therapy designed in this study is based on strengthening exercises for the external hip rotator muscles and stretching exercises for the hip internal rotator muscles. Physical therapy is one of the conservative approaches for subjects with intoeing, as internal hip rotator stretching may decrease the foot progression angle and then reduce the intoeing.

The strengthening exercise program for hip external rotators used (calm shell, lateral slides, monster walk, and pseudo-running exercise, using Theraband and sandbag). As well, a stretching exercise program for hip internal rotators. Besides, a ring-sitting positioning program is used to counter the usually habituated w-shape sitting exhibited by entering children and educate the child and parents about the impaired movement and prolonged positions that relate to the problem and how to correct the impairments in daily activities.

Thirty-four children with in-toeing gait were divided into two equal groups in order to evaluate the study hypothesis. The intervention group received the designed physiotherapy program, while the control group did not receive any treatment at all (they will receive the program after the control group's treatment is completed). For a total of twelve weeks, the therapy was administered three days a week.

The main results of the current study showed that within-group comparison showed a statistically significant amount of change in internal rotation and external rotation range of motion of hip joint and foot progression angle in the treatment group compared to the control group. There was highly statistically significant improvement in post-treatment compared to pre-treatment according to the internal and external rotation range of motion of the hip joint and foot progression angle in the treatment group. While slight improvement in post-control compared to pre-control according to internal and external rotation range of motion of hip joint and foot progression angle.

Comparison of the result of the study with other studies is hard to do as there is a lack of evidence to inform the effect of a physical therapy program on the intoeing gait in typically developed children. There is not enough evidence to exactly determine the non-surgical treatment options for in-toeing gait in children. The evidence body that exists is small (n = 5) and of different quality, which means that recommendations based on this evidence should be interpreted [20].

A comparison can be made between the results of this study and the results of surgical osteotomies after follow-up.. Twenty-one patients underwent surgical procedures on thirty-five lower extremities. The patients ranged in age from 8 to 18 years, on average 13.3. The follow-up time was, on average, sixteen months (6–36 months). 40.8° was the average femoral anteversion angle (28°–53°). Hip external rotation improved significantly, going from 30° to 51.8° ($p < 0.0001$). The mean foot progressing angle improved as preoperatively rotated (-15.2°) to postoperatively rotated (- 7.7°). Complications ranged from persistent knee pain to non-union osteotomy leading to plate failure and were suffered from five patients[28].

The following data represent the comparison between the same parameters of pre- and post-treatment in our recent study and pre- and post-operative subjects. For recent study, the pretreatment, hip internal rotation were (71.18±3.06) and post treatment were (66.47±2.89), pretreatment, hip external rotation were (32.79±3.83) and post-treatment were (36.74±3.13), and pre-treatment, foot progression angle were (-2.06±1.15) and post-treatment were (-1.12±0.48).

While the pre-operative hip internal rotation was (71.2 ± 12.9) and post-operative was (47.4 ±

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8.8), the pre-operative hip external rotation was (30 ± 13.5) and post-operative was (51.8 ± 11.2), and the pre-operative foot progression angle was −15.2 ± 9.7 (−35–0) and post-operative was (−7.7 ± 6.1).

From the previous data, higher significant improvement was shown in the pre- and post-operative in relation to the pre- and post-physical therapy treatment, however. Both of them have the same statistical significance. Otherwise, the physical therapy study did not have any complications, but complications reported in the post-osteotomy study. It can be concluded that the physical therapy program is an effective conservative approach for correcting the in-toeing gait caused by increased femoral anteversion in the age of 4 to 8 years, and we recommend using the designed physical therapy program for a longer period of time than used in our recent study, which was assumed to have more effect and higher statistical significance.

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Declaration of conflicting interests

Concerning the research, writing, and/or publication of this work, the authors have declared that they have no potential conflicts of interest.

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