Original Article | J Adv Med Biomed Res. 2023; 31(147): 323-329

Journal of Advances in Medical and Biomedical Research | ISSN:2676-6264

The Immediate Effects of Spiral Kinesio Taping on In-toeing Gait Pattern in Children with Spastic Diplegic Cerebral Palsy

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Article Info

10.30699/jambs.31.147.323

Received: 2022/10/22;
Accepted: 2023/01/02;
Published Online: 27 Sep 2023;

Use your device to scan and read the article online

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ABSTRACT

Background & Objective: In-toeing is the most common gait pattern in children with spastic diplegic cerebral palsy (CP). Kinesio Taping (KT) has been suggested to improve the function and posture of children with CP. No study has yet evaluated the effects of spiral KT on this gait pattern. The objective of this study was to evaluate whether spiral KT could improve in-toeing in children with spastic diplegic CP.

Materials & Methods: This pre-post designed experimental study was performed on 14 patients with spastic diplegic CP aged between 6 and 10 years at the first level of the Gross Motor Function Classification System. KT was applied spirally with 100% of available tension. Hip, knee, and ankle joint angles in the transverse plane and spatio-temporal parameters including velocity and duration of stride were measured before and immediately after the intervention.

Results: The results showed a significant decrease in hip ($p=0.04$) and knee ($p<0.001$) internal rotation, foot adduction, and abduction ($p<0.001$) in the transverse plane after using KT. Also, significant differences were found for spatio-temporal indices including velocity ($p<0.001$) and duration of stride ($p<0.001$).

Conclusion: Spiral KT with 100% of available tension immediately improved the spatio-temporal indices of in-toeing gait pattern in children with spastic diplegic CP. Hence, clinicians can use the applied method to improve the gait pattern in this group of CP children.

Keywords: Cerebral palsy, Diplegic, In-toeing Gait Pattern, Kinesio Taping, Kinematics

Introduction

Cerebral palsy (CP) describes a group of non-progressive developmental disorders of the foetal or infant brain leading to permanent motor impairment (1). According to recent studies, the prevalence of CP is 2-4 per 1000 live births (2). It has an incidence of 2.06 cases per 1000 live births in Iran (3). So far, fourteen different gait patterns have been identified in patients with CP, such as crouch gait and in-toeing (4). In-toeing is among the most common gait patterns in children with spastic diplegic CP with a prevalence of 64 % (4). Diplegic CP, also known as spastic diplegia, is one of three categories of spastic CP (5).

The most commonly encountered problem amongst children with CP is muscle stiffness. It manifests during infancy and early childhood and is typically diagnosed by the age of three (6). Spastic diplegia mostly affects the lower extremities and sometimes the arms, making them stiff and contracted (7). It causes difficulty crawling and walking (8). In-toeing is a gait pattern in which the lower limbs are deviated toward each other instead of functioning in a more ideal alignment during ambulation (9). The reason for in-toeing is often multifactorial. The commonest causes of in-toeing in spastic diplegic CP are femoral anteversion, hip internal rotation, and internal tibial torsion (10). Dynamic factors such as abnormal muscle tone (spasticity of the hip internal rotators and adductors as well as the medial hamstrings) can also play a major role in the development of in-toeing (11). Failure to immediately manage muscular imbalances leads to permanent increased femoral anteversion (12). The main complaints of this gait pattern include recurrent cramping of the leg muscles particularly during running, uncoordinated movements during physical activity and fatigue-induced pain in the lower extremity muscles (13). Patellofemoral joint impairment (14), abnormal pronation of the subtalar joint (15), hip osteoarthritis (16), and patellar instability are among the long-term consequences of in-toeing (17).

In-toeing can be modified using surgical interventions, assistive orthotic devices, and physiotherapy (13). Chang and colleagues showed that a customized external strap orthosis improved gait performance and corrected leg alignment in a group of CP children with in-toeing (18, 19). Abd El-Kafy evaluated the clinical impact of an orthotic intervention composed of a static ground reaction ankle foot orthosis combined with the Thera-Togs strapping system on the gait pattern of spastic diplegic CP children in Gross Motor Function Classification System (GMFCS) levels I and II. The orthotic intervention improved the gait more than conventional treatment with or without Thera-Togs (19). An alternative for orthotic device is Kinesio Taping (KT), which is reported to be able to modify joint alignment (20).

KT is an increasingly popular adjunct therapy because it is an accessible, non-invasive and inexpensive method for therapists (21). Over the last few years, KT has been used to improve functional mobility, balance, and posture in children with CP (22, 23).

With a general look at the articles and given the impact of this intervention and the gaps in the studies, the objective of this study was to evaluate the immediate effects of KT on gait spatio-temporal parameters. We hypothesized that re-aligning femoral and tibial internal rotations using KT might improve in-toeing in this patient group.

Materials and Methods

This pre-post designed experimental study (IRCTID: IRCT2017020428447N2) was conducted in the motion analysis lab, School or Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran from January to May 2017. The study was approved by the local medical ethics committee of vice chancellery of research, Shiraz University of Medical Sciences, Shiraz, Iran and was in accordance with the standards of the Helsinki declaration (Ethics number: IR.SUMS.REC.1395.170). Written informed consent was obtained from the parents of the participants prior to the commencement of the study procedures. The participants were recruited from two rehabilitation centres affiliated with Shiraz University of Medical Sciences, Shiraz, Iran through a convenience sampling method. Based on a pilot study on 5 spastic diplegic CP children, 14 participants were required to be confident of observing a 6-degree change in hip internal rotation as the primary outcome measure, with 80% power and alpha level of 0.05.

The inclusion criteria were children with a diagnosis of spastic diplegic CP categorized in level I of the GMFCS, in-toeing gait pattern, aged 6 to 10 years old, and an ability to follow verbal commands. Exclusion criteria were having orthopaedic surgery or botulinum toxin injections in the preceding 6 months, history of lower limb fracture, infections and any other conditions that might impact the anatomical structures, and subluxation or dislocation of the lower limb joints (11).

Outcome measures

The primary outcome measure was the degree of internal rotation of the hip, and the secondary one included the degrees of internal rotation of the knee and ankle, and spatio-temporal parameters of gait.

Data of Ground reaction force (GFR) were collected using a single force platform (Kistler Instrument, Winterthur, Switzerland) with a sampling rate of 240 Hz. Kinematic data were recorded by an eight-camera motion analysis system (Proreflex, Qualisys Track Manager Ltd., Gothenburg, Sweden) with a sampling rate of 120 Hz.

For measuring anthropometric data and building a model with six degrees of freedom, 39 retro-reflective calibration markers were fixed bilaterally to pre-determined landmarks of the pelvis and lower limbs, attached to the skin using adhesive tape. Landmarks were placed on the posterior superior iliac spine (PSIS), anterior superior iliac spine (ASIS), sacrum (between the two PSIS), greater trochanter, middle third of the thigh (cluster markers), lateral femoral epicondyle, medial femoral epicondyle, middle third of the shin (cluster markers), lateral malleolus, medial malleolus, middle of the calcaneus bone, the head of the first metatarsus, and the base and head of the fifth metatarsal bone. Each subject was evaluated twice a day, before and after applying KT. The time interval between the evaluations was 30 minutes (20) chosen to allow for maximum KT adhesion to the skin. Before commencing the gait analysis, the camera system was calibrated using a reference structure and a wand to provide the cameras with calibration locations.

Intervention method:

Corrective KT was applied bilaterally with 100% tension, based on Kase' method, starting from the inside of the foot (navicular bone prominence), through the leg and the upper ankle and extended spirally around the limb from the inside of the leg to the posterior part of the leg and thigh and ultimately terminating on the iliac crest. To optimise correction, we applied the KT in three layers with 70% overlap (20).

Following multiple practice trials, we asked the subjects to walk barefoot with a self-selected gait velocity. Three successful trials before and after the intervention were recorded for the final analysis. The force plate was used to record the moment of the first and last foot contact with the floor. The trials in which the child's dominant foot was correctly placed on the force platform were concerned for further analysis. Dominant leg was determined based on the leg kicking a ball.

Data were synchronously recorded using QTM software (Qualisys Track Manager Ltd., Gothenburg, Sweden). Modelling and subsequent analyses were carried out with Visual 3D software (C-Motion, Inc., Rockville, MD, USA). Raw data were filtered by a fourth order low-pass Butterworth filter using a cut-off frequency of 6 Hz and 15 Hz for kinematic and kinetic data, respectively. The lower extremities were modelled as a rigid, linked-segment system. The standard Newton-Euler method was applied to calculate the knee joint angle. GRF was normalized to the child's weight (N/kg).

The minimum and maximum degrees of rotation of the hip, knee and foot in the transverse plane were recorded during the stance phase with and without KT, as were time-spatial parameters including velocity and duration of stride. Gait velocity was calculated by dividing the x-axis coordinates of the marker mounted on the sacrum (midpoint between the left and right PSIS) by the recorded time **(24)**.

Data were analysed using SPSS (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp., USA). Normality of the data was confirmed using the Shapiro-Wilk test. Paired t-tests were used for comparing pre- and post-intervention data. Results were expressed as mean ± standard deviation (SD). The significance level was set at $P < 0.05$.

Results

Fourteen children with spastic diplegic CP participated in the study. Demographic data of the participants is summarised in Table 1. A statistically significant difference was observed in the spatial and temporal indices before and after the intervention. Gait velocity increased by 9 cm/s and stride duration increased by 0.20 seconds, indicating an improvement in temporo-spatial parameters of the gait. Internal rotations of the hip, knee, and ankle decreased after applying KT (Table 2).

Figure 1 is a representative cycle of one of the participants. It represents the changes of internal/external rotation angles of the dominant lower extremity during the stance phase of gait before and after the application of KT.

Table 1. Demographic data of the participants

Variable		(number/ mean ± SD)
Sex	**Male**	8
	Female	6
Age (years)		7.92 ± 1.14
Height (centimeters)		124.21 ± 7.82
Weight (kg)		24.77 ± 10.83

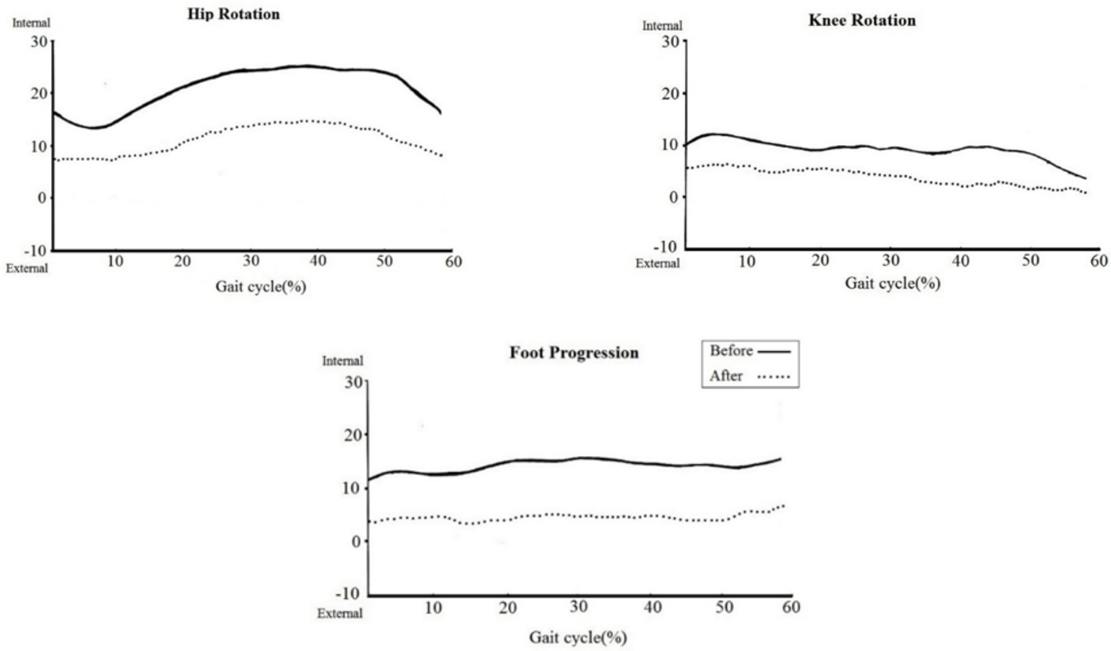

Figure 1. Joint angles obtained from gait analysis, from the dominant side of one participant

Table 2. Comparison of the outcome measures pre- and post-intervention

Variable	Pre-mean ± SD	Post-mean ± SD	P-value
Velocity (cm/s)	68.21 ± 0.04	77.57 ± 0.05	.001<
duration of each stride (s)	0.54 ± 0.04	0.56 ± 0.03	.001<
Hip int. rot (degrees)	20.92 ± 8.04	12.27 ± 10.45	.04

Variable	Pre-mean ± SD	Post-mean ± SD	P-value
Knee int. rot (degrees)	11.99 ± 9.54	7.99 ± 9.89	.001<
Foot adduction (degree)	13.69 ± 7.16	7.76 ± 7.25	.001<
Foot adduction (degree)	8.36 ± 7.34	0.94 ± 7.41	.001<

Discussion

The aim of this study was to evaluate the immediate effects of spiral KT on in-toeing gait parameters in children with diplegic spastic CP. The results revealed significant improvements in the kinematic measures of the hip, knee, and ankle joints in the transverse plane. The spatio-temporal parameters, like velocity and stride time, showed significant improvement after spiral application of KT.

Children with CP present deficits in sensory pathways such as decreased perception of tactile and proprioceptive stimuli **(25)**. The beneficial effects of KT may be attributed to mechanisms such as tactile-proprioceptive stimulation, realignment of muscular fascia, and the provision of a foundation for normal firing and recruitment patterns **(26, 27)**. KT may influence the cutaneous receptors of the sensory motor system, leading to improvements in coordination and voluntary control **(28)**. By providing somatosensory stimulation, KT is likely to activate the gamma motor neurons, in turn regulating the modulation of type Ia afferent fibres **(25)**. We applied spiral KT with full tension over the lower extremities of children with diplegic CP. This could be considered as functional correction, according to Kase **(20)**, and is believed to act by assisting desired motions or limiting non-desired motions. Increased stimulation of mechanoreceptors acts as a preload during the end of motion positions **(20)**.

The study participants were classified as GMFCS level II. KT has been claimed to be mostly beneficial for CP patients at GMFCS levels I and II and also to dynamic activities **(29)**. A review of the literature demonstrated that the impact of KT on gross and fine motor function and dynamic activities was greater than that on postural and static activities **(29)**. There is insufficient evidence on the effects of KT on the outcomes pertaining to motor functions such as gait pattern **(30)**. Some studies investigated the effects of KT on gait parameters in children with CP. They used KT locally either over specific muscles or joints. Kemer and colleagues evaluated the effects of KT Over gluteal muscles on activity and participation in Children with Unilateral CP **(31)**. They found that KT combined with conventional physiotherapy could improve several parameters including cadence, functional mobility, gait and pelvic symmetry, functional mobility, gross motor function, balance, and participation in the medium term in children with unilateral CP. The dorsiflexion range at the heel strike phase of gait increased after three months of taping. Jung and colleagues evaluated the effects of KT on gait parameters in four children with diplegic spastic CP at GMFCS levels I and II **(32)**. KT was applied to the tibialis anterior, rectus femoris, and gluteus maximus muscles using I- and Y-shaped patterns with 50-70% of the available tension. They concluded that KT provided beneficial effects on gait parameters such as gait velocity, step length, stride length, and single support time. Ozmen and colleagues evaluated the effects of KT on gait performance and balance in children with hemiplegic CP. They applied KT over the gasterocnemius and tibialis anterior muscles with 25% of the available tension using Y-shape and I-shape cuts, respectively. They concluded that facilitating dorsiflexion may contribute to the correction of equinus gait and improvement of gait pattern **(33)**. Tsimerakis et al. reported positive results for the application of KT in children with CP in terms of increasing the function of the trunk and lower limbs **(34)**.

Few previous studies have investigated the effects of orthotic devices on correcting rotational deformities of the lower limbs in children with CP. Abd El-Kafy found improvements in cadence, stride length, and gait speed of spastic diplegic children when using spiral strapping in combination with a solid ground reaction ankle foot orthosis **(19)**. Chang and colleagues assessed the immediate effects of a customised external strap orthosis on gait parameters in a group of children with mild CP **(18)**. Induction of external rotation at the lower limbs following the application of customised external strap orthosis improved the gait velocity, cadence, and stride length of the participants. Twister wraps have been shown to be effective in improving spatio-temporal parameters of the gait (stride length, cadence, and velocity) and correcting in-toeing gait pattern in children with diplegic CP **(35)**.

In agreement with the findings from studies using corrective orthoses, our study showed that spiral KT with 100% of available tension was sufficient to improve the spatio-temporal gait parameters and correct the lower limb alignment. To the best of our knowledge, this is the first study on evaluation of the immediate effects of KT using a spiral application pattern over the lower extremities in spastic diplegic children with CP. Our method, however, has some advantages over corrective orthoses. First, parents or caregivers could easily learn how to apply KT. Donning and doffing of orthoses is usually time-consuming, while KT can be applied quickly. Orthoses are often expensive, while KT is relatively low-cost. KT could easily be reapplied several times if the child feels uncomfortable, whereas any reported discomfort derived from wearing orthoses requires referral to an orthotist for revaluation. Another advantage of KT is its invisibility, as it can be applied under clothes, and is very light in comparison to many prefabricated and custom-made orthoses. Our study had some limitations. First, we only investigated the immediate effects of KT. As such, future studies are warranted to evaluate the short term and long-term effects of this pattern of KT application. Second, these results can only be generalized to patients with diplegic spastic CP in GMFCS level II. The effects of this pattern of KT application are yet to be assessed in other types of spastic CP, or among patients with CP with different GFSCS levels. We did not simultaneously evaluate electromyography (EMG) activity in the muscles alongside the kinetics of the lower extremities. Such data may provide a clearer picture of the possible mechanisms involved in the effects of KT application. Moreover, the lack of a control group was another limitation of this study.

Conclusion

Applying KT in a spiral pattern over the lower extremities with 100% of the available tension immediately improved the spatio-temporal parameters of the gait including gait velocity and stride time, while decreasing the internal rotation of the hip, knee, and ankle joints in the transverse plane in children with spastic diplegic CP. Given the advantages of KT, clinicians may consider its use to improve gait with similar effects to those of corrective orthoses. Achieving more normal gait patterns using KT provides children with CP with more opportunities and self-confidence when taking part in social activities such as playing with other children and cultivating social skills.

Acknowledgments

None.

Conflict of Interest

All authors will disclose any financial and personal relationships with other people or organisations that could inappropriately influence (bias) the work.

Funding

The study was financially supported by the Vice Chancellor of Research, Shiraz University of Medical Sciences, Shiraz, Iran (Grant number: 95-01-06-11846).

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