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Efficacy of ankle kinesiotape on balance in children with spastic diplegia

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Abstract

Background: Adequate and efficient standing postural balance is key for functional walking and handling abilities in children with spastic diplegia. This study was designed to evaluate the effect of kinesiotape applied on ankle dorsiflexor muscles on balance in children with spastic diplegia. Thirty children with spastic diplegia of both genders participated in the study: 16 boys and 14 girls between 4 and 10 years old. They were divided randomly and equally into two groups: a control group, in which children received the standard physical therapy program for children with diplegia; and the study group, who received the same physical therapy program as in the control group but after kinesiotape application over the ankle dorsiflexor muscles. Both groups received the treatment program for 1 h, three times per week, for three successive months. Postural stability was assessed through evaluation of three stability index (anteroposterior, mediolateral, and overall) for all children by the Biodex Balance System before and after treatment.

Results: Statistical analysis of results before and after treatment was performed by mixed MANOVA to compare effects both within and between groups on stability indexes, and post hoc tests were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at $p < 0.05$. Before treatment, there was no significant difference in the stability index between both groups ($p > 0.05$). Comparison between both groups post-treatment revealed a significant decrease in the measured variables of the study group compared with that of the control group ($p < 0.05$).

Conclusion: Adding ankle kinesiotaping over dorsiflexor muscles in conjunction with a balance and gait training exercise program for children with diplegia can enhance postural stability and decrease sway. This study suggests that it should be added to the treatment program for children with diplegia.

Trial registration: This study was registered retroactively. Identifier: NCT04243928

Keywords: Kinesiotape, Ankle dorsiflexors, Balance, Spastic diplegia

Background

Cerebral palsy can be classified topographically according to the distribution of motor impairments and tone abnormalities into different spastic categories: diplegia, hemiplegia, quadriplegia, monoplegia, and triplegia [1]. Children with spastic diplegia exhibit weakness of the trunk with increased muscle tone in the lower limbs (compared to the upper limbs). They normally have difficulty in relaxing the spastic muscles and limited ability to voluntary control their active movements, resulting in slow and abnormal patterns of movement [2].

One of the major problems facing children with spastic diplegia is poor balance control that causes difficulties in their ability to change position, leading to increased energy expenditure and causing early fatigue during functional activities and gait [3]. They also have a limited ability to use their lower extremities to adjust posture in the event of external perturbance, leading to frequent falls and difficulty maintaining standing balance independently during regular motor activities [4].

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Furthermore, children with spastic diplegia suffer from poor postural reactions, malalignment of the trunk, and abnormal back geometry, causing low quality of sitting and standing with easy loss of balance, adversely affecting their quality of life and activities during daily life [5].

Proper ankle muscle strength and unrestricted foot range enable diplegia sufferers to select the appropriate strategy to control and regain postural stability, according to the amount and direction of disturbance: tibialis anterior and extensor hallucis longus muscles produce foot dorsiflexion and inversion, the peroneus tertius is responsible for ankle dorsiflexion and eversion, while the extensor digitorum longus produces pure ankle dorsiflexion [6]. Kinesiotape is a common adjunct to therapy, as it is easy to apply, inexpensive, and can be modified according to its purpose. It can be used for different purposes in children with cerebral palsy according to the place and method of application, such as correcting postural malalignment, enhancing the stability of joints, facilitating weak muscles, supporting weak structures, managing spasticity, and for sensory system stimulation [7].

Although tape application on upper limbs and hands has shown significant improvement in almost all of the studies conducted on children, studies involving lower extremity application have sparked debates: some studies demonstrated improvement in gross motor function and trunk and posture control in sitting and standing positions [8], while others reported that kinesiotape is an effective method for spasticity reduction and improving dynamic activities like sit-to-stand, walking and movement patterns, and other normal daily activities [9], but is not effective in enhancing static balance and postural control [10]. Higher levels of balance disturbance, such as level IV and V in gross motor function classification system (GMFCS) showed non-significant differences with tape application [11]. Therefore, the effects initially attributed to kinesiotaping are still controversial, with little scientific evidence to support its clamed effects to increased mechanoreceptor stimulation, facilitating blood flow to painful areas, and its anti-inflammatory or anti-edematous effect due to its action on exteroceptive and proprioceptive receptors [12]. In light of this, this study was conducted to determine the effect of using kinesiotape on ankle dorsiflexor muscles on balance in children with spastic diplegia.

Methods

Subjects

Ethical committee approval (from faculty of physical therapy Cairo University with number P.T.REC/012/001799) and signed written consent forms were obtained before starting the study. The parents of all children accepted their child's participation in the study and agreed to publication of the treatment results.

Eligibility criteria

A total of 50 participants with spastic diplegia were recruited into the study. Nine of them did not meet the inclusion criteria, six declined to participate in the study, while five children were excluded as their parents were unable to attend the assessment and treatment sessions.

A total of 30 children of both genders (16 boys and 14 girls) with spastic diplegic cerebral palsy participated in the study. They were selected from the pediatric outpatient clinic (Faculty of Physical Therapy, Cairo University). Their age ranged from 4 to 10 years, and they had spasticity of grade 1 or 1+ according to the Modified Ashworth Scale (MAS) [13]. Children at level I and II [14] of the GMFCS for cerebral palsy were eligible for the study. All subjects were taller than 1 m to be able to observe the screen of the Biodex, and children were able to understand and follow simple verbal instructions. Subjects who had visual or auditory problems that limited movement or had hypersensitivity to the tape were excluded and were divided randomly into two groups (control and study) of equal number (15 patients). The control group received a regular therapeutic exercise program designed for children with diplegia. The study group received the same therapeutic exercise with the addition of kinesiotape applied to the ankle dorsiflexors of both lower limbs.

Randomization

The 30 children were randomized before data collection by means of the SPSS program (IBM, Armonk, New York, USA), generating two random groups. To avoid bias, assessment was done by one researcher, while intervention was carried by two other researchers, and the results were analyzed by a statistical analyst who was not included in the research. Each child had a specific identification number, which were distributed randomly into two groups. Individual and numbered index cards were secured in closed envelopes. Each participant was given a hand-picked envelope and was distributed according to their groups (Fig. 1).

Procedure

Weight and height of all participants were measured using a standard weight and height scale (ZT-120 model). The MAS and GMFCS were used for selecting children who were eligible for the study, and the Biodex Balance System was used for evaluation of postural stability indexes before and after treatment for children of both groups.

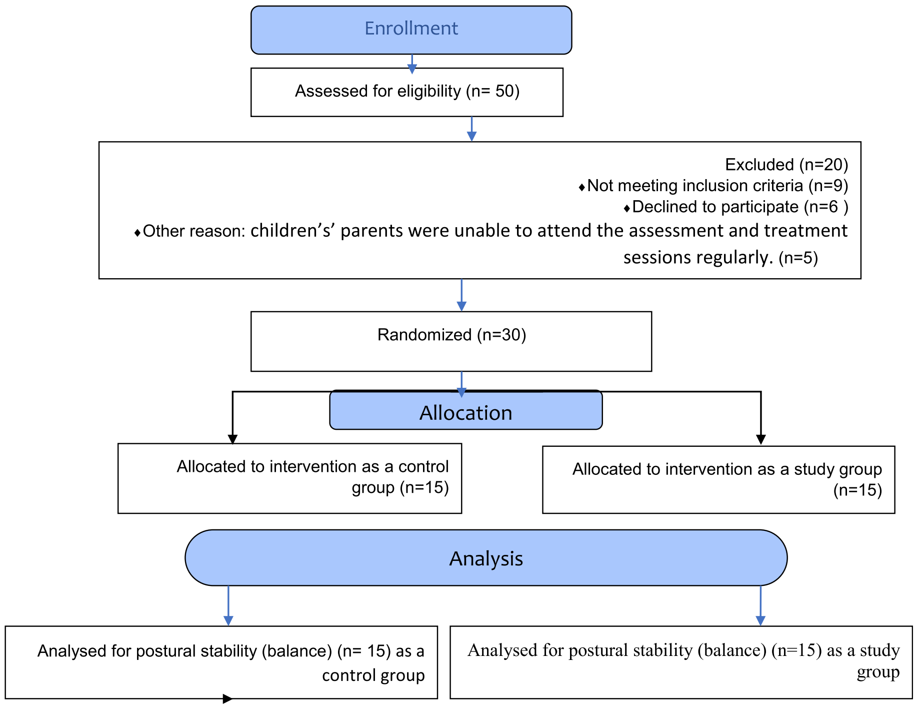

Fig. 1 Participants' flow chart. (consort flow 2010)

Biodex balance system

The Biodex Medical System (Biodex, Inc., Shirley, New York, USA; Biodex, Version 1.08) was used to evaluate postural stability before and after treatment for children in both groups, as it emphasizes a patient's ability to maintain center of balance. It is a multi-axial valid and reliable device that objectively measures and records the ability of the subject to maintain stability and balance under dynamic stress. The Biodex Balance System is a comprehensive objective testing tool designed for screening, assessing, and identifying patients with core balance issues. It helps in the evaluation of the neuromuscular control by quantifying their abilities to maintain dynamic postural stability on a movable surface by numbers that detect the amount of postural sway in different directions [15]. The patient's score on this test assesses deviations from center; thus, a lower score is more desirable than a higher score. The system consists of a movable platform which has been set at variable degrees of instability from level 8 (the most stable) up to 4 (less stable). This system is integrated with computer software for results reporting [16].

Procedure for evaluation Simple, clear instructions about the device were given to the children and their parents before starting the assessment. Data about each patient (age, gender, weight, height) was introduced to the device, as well as the level of platform stability (starting with stability level 8, then moving to stability level 4).

Children were allowed to stand on the platform of the device with an adequate base of support, and foot position was recorded each time to be used in the assessment. They were advised to keep their back straight and look forward at the screen of the device (for safety, the arm support was positioned around the child without contact and the physical therapist was standing behind the children without giving support). Instructions were given to the children to maintain their foot position and look at the screen during assessment. The average (of three records of the stability indices) was calculated.

The subject's ability to control the angle of platform tilt was measured by the system through a stability index. This index represents the variance of the platform displacement, in degrees, from level of greatest stability to level of least stability. A high number signifies greater motion, indicating a balance problem. Data regarding the balance of the tested subject was introduced to the system [16], including the antero-posterior stability index (APSI) (representing the child's ability to regain balance when displacement occurs in the front and back directions) and the mediolateral stability index (MLSI) (representing the child's ability to adjust their balance from side to side). The overall stability index represents the child's ability to keep balance in all directions [17].

Intervention

Physical therapy treatment program

All children received a physical therapy program for 1 h, three times per week, for three successive months. Both groups received the same physical therapy treatment program designed specifically for diplegic children as follows: (1) flexibility exercises (for 15 min) to maintain the length and the elasticity of the muscles; (2) balance exercises (20 min) consisting of (a) starting from a half kneeling position and then reaching with one hand in the oblique direction; (b) standing position on the mat on one limb for 30 s while trying to be erect as possible, then repeating on the other limb; (c) standing with one limb on a balance board and the other on the mat, then lifting the leg on the mat to the balance board; (d) squatting from a standing position, then standing again; (3) gait training (15 min), including sideways, forward, and backward walking between parallel bars, as well as gait training using a stepper; and (4) ascending and descending stairs (10 min).

Application of kinesiotape for the study group

Preparation The skin over the lower legs and ankles was cleaned by organic solvent (alcohol pads) for infection control every time before application of the tape. The distance (along the dorsal aspect of the lower leg) from the tibial plateau to the level of the metatarsals of the forefeet was measured by measuring tape. Kinesiotape (Kinesio Tex® Tape, 5 cm width) was cut to two-thirds the length of the measurement recorded. The strips were prepared for each child individually.

Procedures Kinesiotape strips were applied longitudinally with 25–50% tension. The upper end of the tape was applied over the tibial plateau (proximally) and the lower end on the forefoot (distally), while the ankle was in maximum dorsiflexion (just at the time of application) [18]. The tape was applied once per week, usually at the first session, and maintained for 5 days. It was then removed 1 day before physical therapy session to allow skin perspiration. It was designed to accommodate thickness and elasticity of skin, and could be worn comfortably 3 to 5 days per week at a time. Instructions were given to subjects' mothers to remove the tape a day before the session to give the skin some rest. Vigorous exercises were avoided for at least 15 min after application of the tape, allowing the glue to fully activate [19].

Sample size Sample size calculation was performed prior to the actual study based on results of a pilot study on five subjects using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universität Kiel, Germany), resulting in a calculated appropriate required sample size of 30. The primary outcome measure was OASI, and calculations were made using $\alpha = 0.05$, $\beta = 0.2$, and with large effect size.

Statistical analysis Descriptive statistics and unpaired *t* tests were conducted for comparison of age, weight, height and BMI between both groups. A Mann–Whitney test was conducted for comparison of GMFCS between groups, while chi-squared tests were carried out for comparison of sex and spasticity grade distribution between groups. Normal distribution of data was analyzed using the Shapiro-Wilk test for all variables. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. Mixed MANOVA was performed to compare effects on APSI, MLSI, and OASI within and between groups. Post hoc tests using the Bonferroni correction were carried out for subsequent multiple comparisons. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the Statistical Package for Social Studies (SPSS) Version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics

Table 1 shows the characteristics of the subjects in the study and control groups. There was no significant difference between the groups in age, weight, height, BMI, and GMFCS ($p = 0.6$). Also, there was no significant difference in sex and spasticity grades distribution between groups ($p = 0.7$).

Effect of treatment on APSI, MLSI, and OASI

Mixed MANOVA revealed that there was a significant interaction between treatment and time (F (4,6) = 30.47, $P = 0.001$). There was a significant main effect of time on treatment (F (3,26) = 112.17, $P = 0.001$). There was

Table 1 Basic characteristics of participants

	Control group	Study group	*p* value
Age, mean ± (SD), years	7.06 ± 1.03	7.1 ± 1.25	0.93
Weight, mean ± (SD), kg	20.26 ± 2.71	21.4 ± 3.06	0.29
Height, mean ± (SD), cm	113.26 ± 13.48	112.13 ± 16.47	0.83
BMI, mean ± (SD), kg/m^2	16.08 ± 2.64	17.8 ± 5.6	0.3
GMFCS, median	2	2	0.69
Sex, *n* (%)			
Girls	8 (53%)	6 (40%)	0.46
Boys	7 (47%)	9 (60%)	
Spasticity grades, *n* (%)			
Grade 1	10 (67%)	9 (60%)	0.7
Grade 1+	5 (33%)	6 (40%)	

SD standard deviation, *p value* level of significance no significant main effect of treatment on time (F (3,26) = 0.87, P = 0.46).

Within group comparison

There was a significant decrease in APSI, MLSI, and OASI post-treatment compared with the respective pre-treatment values in the control group (p = 0.003). Also, there was a significant decrease in APSI, MLSI and OASI post-treatment compared with the respective pre-treatment values in the study group (p = 0.001). The percent of decrease in APSI, MLSI and OASI in the control group was 6.7%, 7.69%, and 8.04% respectively, while the same decreases in the study group were 23.56%, 23.33%, and 25.88% respectively. OASI demonstrated the most improvement in both groups (p = 0.009) (Table 2).

Between groups comparison

There was no significant difference in APSI, MLSI and OASI between both groups pre-treatment (p > 0.05). Comparison between both groups post-treatment revealed a significant decrease in APSI, MLSI, and OASI in the study group compared to the control group (p = 0.001) (Table 2).

Discussion

This study was conducted to investigate the effect of applying kinesiotape over ankle dorsiflexors on improving postural stability and balance in children with spastic diplegia. Improvements were recorded for both treatment groups (with and without kinesiotape) in the three stability indexes assessed (APSI, MLSI, and OASI). Higher percentage of improvement was noticed in the study group (physical therapy with kinesiotape applied) regarding all measured variables when compared to the control group (physical therapy with no kinesiotape).

Table 2 Mean APSI, MLSI, and OASI pre- and post-treatment of the control and study groups

	Control group	Study group	MD	*p* value
	x̄ ± SD	x̄ ± SD		
APSI				
Pre-treatment	1.79 ± 0.31	1.74 ± 0.47	0.05	0.71
Post-treatment	1.67 ± 0.29	1.33 ± 0.38	0.34	0.01
MD	0.12	0.41		
% of change	6.7%	23.56%		
	***p* = 0.003**	***p* = 0.001**		
MLSI				
Pre-treatment	1.82 ± 0.35	1.8 ± 0.51	0.02	0.9
Post-treatment	1.68 ± 0.34	1.38 ± 0.36	0.3	0.03
MD	0.14	0.42		
% of change	7.69%	23.33%		
	***p* = 0.001**	***p* = 0.001**		
OASI				
Pre-treatment	2.24 ± 0.2	2.28 ± 0.54	− 0.04	0.79
Post-treatment	2.06 ± 0.21	1.69 ± 0.45	0.37	0.009
MD	0.18	0.59		
% of change	8.04%	25.88%		
	***p* = 0.001**	***p* = 0.001**		

x̄ mean, *SD* standard deviation, *MD* mean difference, *p value* probability value

Tension provided by the tape may cause neuromuscular and proprioceptive stimulation, which has a major role in maintaining posture and stability. It enhances proprioceptive feedback to the brain and facilitates correcting posture and movement, even after the removal of the tape, which in turn improves functional performance through the enhancement of muscle activity [20]. Proprioception is improved by providing constant cutaneous afferent stimulation of the skin, which improves joint function, stimulates sensory receptors, decreases pain (as a result of a reduction in neurological activation), enhances blood and lymph circulation to the taped area, and improves muscle function [21].

Improvement in the postural stability indexes in the study group may be attributed to the stretch effect of the tape on the skin over the treated area, which provides a pulling force on the skin and creates more space by lifting the fascia and soft tissue, in turn improving the mechanoreceptors' sensitivity and increasing the number of motor units recruited [22]. In conjunction with a rehabilitation exercise program, kinesiotape allows functional movement of joints while giving extra support and protection over the taped area that can enhance recovery and early resumption of activity without the risk of reinjury [23].

The significant improvement that was recorded after treatment in the study group may be attributed to the effect of ankle taping on ankle stability, which facilitates a precise, smooth, and homogenous pattern of movement. This was previously demonstrated in Alhusaini et al., who reported that greater support around the ankle by external ligaments and muscles can be achieved by various taping techniques, enhancing the ability of a child to return to normal daily activities [24].

When comparing the pre- with the post-treatment results in the study group, there was significant improvement in the subjects' capability to control their postural stability in different directions when exposed to balance disturbance. The benefit of adding kinesiotape to a physical treatment program in children with diplegia was asserted previously by Ragab, who studied the role of ankle taping on balance in children with hemiparetic cerebral palsy. That study concluded that using the tape in conjunction with a rehabilitation treatment program for children with hemiparetic cerebral palsy improved their ability to maintain stable postures [25].

The significant improvement of balance in the anteroposterior direction of the study group may be explained by the positive effect of ankle kinesiotape on forward-backward control of balance by facilitating dorsiflexor muscle function, helping children with diplegia to control the displacement of center of mass and keep balance by using ankle strategies. Normally, balance is maintained through small movements in about four actions that occur at the ankle joint: dorsiflexion, plantar flexion, inversion, and eversion. Ankle joint plantar flexion is a core control mechanism in standing which includes the gastrocnemius, soleus, and the tibialis anterior. Dorsiflexion serves the function of balance control in response to displacement of the body from front to back and plays an important role in maintaining balance during standing and walking [26].

Significant improvement of balance in the study group after kinesiotape application may be due to increased sensory awareness via stimulation of skin receptors and modification of sensory input to improve the motor output. This possibility is supported by Blanch et al. who stated that taping causes skin stretching, which stimulates the underlying sensory receptors that modify and integrate the different sensory inputs to the central nervous system and reflectively improves the execution of movement. Also, it prevents further sprain by enhancing proprioceptive acuity, believed to be achieved through the activation of the different skin receptors, which offers additional awareness of the perception of foot position and the direction of the movement [27].

The observed significant decrease in postural sway in the anteroposterior and mediolateral direction during balance disturbance in the study group after treatment, as well as the increased capability to use the appropriate sensory feedback to select the correct motor output for balance control, agree with the concepts presented by Matsusaka et al., who compared the effect of adding adhesive tape on the ankle around the lateral malleolus on both posture sway and balance. This study showed earlier improvement in balance and decrease of sway in the group with taping, suggesting increased afferent sensory input from receptors stimulated by traction caused by the tape as a cause of the improvement [28].

Increasing support around the ankles with enhancement of muscle stimulation by the tape led to improvement of balance control as well as decrease of sway in the study group, in agreement with Miller and Othmotherly, who stated that the application of kinesiotape provides adequate support to the weak muscles and ligaments while maintaining full joint range of motion in the surrounding area, enabling the individual to participate in functional physical activities. In addition to other therapeutic modalities such as hydrotherapy, massage, and electrical stimulation, kinesiotaping could be used to improve the quality of life [29].

Searching for durable, soft, long-lasting, and effective therapeutic tools is especially an issue of concern when designing a rehabilitation program for children. The kinesiotaping treatment modality enables the individual to receive the therapeutic benefits throughout the day. Kinesiotape could possibly replace some external supporting devices that are commonly used in children with cerebral palsy children. Previously, Feuerbach et al. [30] and Cools et al. [31] reported that ankle taping could replace the standard ankle foot orthosis in children with hemiparesis. They can gain more ankle stability and better alignment positioning through the use of some techniques of taping.

Limitations

A larger sample size would help to generalize the results in the diplegic population. Also, adding a functional scale (for example balance scale) to evaluate the impact of kinesiotaping on enhancing postural control, stability, and quality of life would be preferred. Moreover, a follow-up period should be added to evaluate the long-lasting effects of kinesiotape on postural stability.

Implication on physical therapy

When balance is impaired, there is an increased demand on conscious effort to compensate abnormal sensations and guard against falling. This effort in turn leads to common secondary symptoms, such as fatigue and the inability to focus attention on other cognitive tasks.

Conclusion

The results of this study suggest ankle kinesiotape can increase the efficacy of balance exercises, improving balance control and postural stability in children with spastic diplegia. Moreover, balance exercises alone are beneficial, but to a lesser extent than when done after applying kinesiotape.

Abbreviations

APSI: Antero Posterior Stability Index; GMFCS: Gross Motor Function Classification System; MAS: Modified Ashworth Scale; MLSI: Medio Lateral Stability Index; OASI: Over All Stability Index; ROM: Range of motion

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Authors' contributions

All people named as authors meet all four criteria of the ICMJE. I declare that the manuscript has been read and approved by all the authors, that the requirements for authorship as stated earlier in this document have been met, and that each author believes that the manuscript represents honest work. Nahla-SS and NM evaluated the children balance by the Biodex balance system before and after the treatment. SS and NM applied the treatment program for children of both groups under the supervision of EH, SS, and NM wrote the paper and it was revised by EH. All authors read and approved the final manuscript.

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Availability of data and materials
The data collected and/or analyzed during the study are available from the corresponding author on reasonable request and after institutional approval.

Ethics approval and consent to participate
Ethical committee approval (from Faculty of Physical Therapy Cairo University by number P.T.REC/012/001799) and signed written consent forms were obtained before starting the study. The study aims and procedures were explained to the children and their parents. The parents of all children accepted their child's participation in the study and agreed to publication of the treatment results.

Consent for publication
Children and their parents received verbal information about the study and parents gave written consent to participate, before the beginning of the study. The safety and confidentiality were assured, and all the procedures of evaluation and treatment were carried out in compliance with laws and institutional guidelines.

Competing interests
The authors declare that they have no competing interests.

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