Accumulative effect of ankle kinesio taping on postural control in children with hemiparetic cerebral palsy

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Background and purpose
Postural control deficit is one of the primary causes of impairments in hemiparetic cerebral palsy, and ankle strategy is one of the muscle synergies to control posture. The purpose of this study was to evaluate the accumulative effect of ankle taping on postural control in children with hemiparetic cerebral palsy.

Patients and methods
A total of 30 children participated in this study, with a mean age of 6.2 ± 0.79 years, mean weight of 25.06 ± 4.43 kg, mean height of 120.6 ± 12.33 cm, and with a degree of spasticity of 1 and 1+ according to the Modified Ashworth Scale. They were divided randomly into two groups: group A and group B. Kinesio taping was applied to the involved ankle joint for children in group B for successive 5 days/week. Rehabilitation exercises were prescribed for children in both groups three times per week for successive 12 weeks. The Biodex system was used to measure dynamic stability indexes. The measurements were carried out before and after the treatment program.

Results
The post-treatment results revealed a significant decrease in stability indexes in group B after 6 weeks of treatment and a significant decrease in stability indexes between the two groups before and after 12 weeks of treatment program ($P < 0.001$).

Conclusion
Ankle taping has an accumulative effect on postural control and it can improve postural control in conjunction with physical rehabilitation for children with hemiparetic cerebral palsy.

Keywords:
cerebral palsy, hemiparesis, kinesio taping, postural control

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Introduction

Cerebral palsy (CP) is defined as a range of nonprogressive syndromes of posture and motor impairments, which is a common cause of disability during childhood. CP results from various insults to different areas within the developing nervous system, which partly explains the variability of clinical findings [1]. CP describes a group of permanent disorders of the development in movement and posture, which cause activity limitation, due to disturbances that occurred in the developing fetal or infant brain. The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication, behavior, epilepsy, and secondary musculoskeletal problems [2].

Hemiplegic CP is a common neurological condition and accounts for more than a third of all CP cases [3]. Children with hemiplegic CP have three types of motor problems: the primary impairments of muscle tone, balance, strength, and selectivity are directly related to the damage in the central nervous system; the secondary impairments of muscles develop contractures and deformities over time in response to the primary problems and musculoskeletal growth; and impairments due to adaptive mechanisms and coping responses that the child develops to adapt to the primary and secondary problems [4]. Hemiplegic spasticity gives rise to difficulties in dorsiflexion and eversion of the foot [3], which result in impairment of posture, balance, and gait control [5,6].

Postural control is vital for all activities of human performance. It refers to the ability to keep the center of gravity within the base of support in various positions [7], and also the ability to maintain or move within a weight-bearing posture without falling, to obtain stability and orientation [8,9]. Postural control has two discrete strategies or synergies: ankle strategy and hip strategy [10]. The ankle strategy involves repositioning the center of mass by moving the whole body as a single-segment inverted pendulum by production of torque at the

ankle, whereas the hip strategy involves moving the body as a double-segment inverted pendulum with counter phase motion at the ankle and hip. Thus, the ankle strategy is used to respond to translations during stance on a flat support surface, whereas the hip strategy is observed during responses to backward translations during stance on a narrow (10 cm) beam [9]. The strategies are present as early as 2 years of age but continue to develop and undergo refinement until 7–10 years of age [11].

Diminishing postural control or balance in children with hemiplegia has been detected as a lack of postural sway twice that of their age, in addition to a reduction in the child's limits of stability, which is the maximal distance that an individual can shift his or her weight in any direction without loss of balance [12]. In CP, foot deformity develops over time and influences the ankle, knee, and hip joint; therefore, foot deformity and malfunction have an impact on the entire postural control and gait pattern [13]. The ankle control mechanism in CP is usually reduced and thus increased hip protraction/retraction synergies (because it requires fewer muscles' efforts) and body transverse rotation for maintaining balance [14].

The Biodex Stability System is a unique dynamic postural control assessment and training system that consists of a movable balance platform that can be set at variable degrees of instability [15]. The child's ability to control his posture is called the stability index; a high stability index is indicative of a lot of movement and therefore less stability, and vice versa. The overall stability index represents the child's ability to balance in all directions; the anteroposterior stability index represents the child's ability to balance in front to back directions; and the mediolateral stability index represents the child's ability to control his balance from side to side [16].

The kinesio taping was earlier used in the treatment of orthopedic conditions such as sports injuries, but in recent times it is used in pediatric rehabilitations, as it is defined as a skill that is essential for all those involved in the treatment and rehabilitation of injuries [17]. Kinesio tape is therapeutic in nature and it is considered as a sensory method to support joint function by exerting an effect on muscle function, enhancing activity of the lymphatic system and endogenous analgesic mechanisms, and improving microcirculation [17,18]. Taping a joint increases mechanical joint stability directly but also may increase proprioceptive signals, which are thought to be important in the regulation of the tone of muscles, and thus helps to ensure stability [18,19].

Thus, the aim of this study was to evaluate the effect of ankle taping on postural control, as well as, ascertain whether or not taping has an accumulated effect.

Patients and methods

Patients

A total of 30 children with hemiparetic CP of both sexes participated in the study. They were selected from the Outpatient Clinic of Faculty of Physical Therapy, Cairo University. Children with a mean age of 6.2 ± 0.79 years and having a degree of spasticity of 1 or 1+ according to the Modified Ashworth Scale were included in the study [9,20,21]. In level II of the Gross Motor Function Classification System for Cerebral Palsy [22], they were able to understand and follow verbal commands and instructions included in both test and training. The selected children who had visual, auditory defects and fixed deformity of lower limb were excluded. The children were randomly and equally divided by choosing the day they came: children who visited on Saturday, Monday, and Wednesday were entered in group A (the control group), and those who visited on Sunday, Tuesday, and Thursday were entered in group B (the study group). A specially designed physical therapy program with emphasis on exercise for balance was applied to group A. Group B received the same program with ankle taping for 12 weeks.

Evaluation of postural control

Assessment tool

The Biodex Stability System (Biodex Medical System, Shirley, New York, USA) was used. It has eight stability levels. Stability level 8 indicates a most stable platform surface, and stability level 1 indicates a very low stable platform surface as it consists of platform, which could be tilted up to 20° of surface tilt from horizontal in all directions. The child is made to stand on a foot grid of the platform of the Biodex Stability System to determine the position of foot before testing, with the child holding the hand rails; the display is adjusted so that the child can look straight at it and then the following parameters are recorded:

(1) Height,
(2) Chronological age, and
(3) Platform firmness (stability level).

All children were tested on different stability levels; we chose level 3 (less stable) and repeated it three times for each trial for 2 min. The mean of the three trials was calculated and recorded. The sites of feet and heels of each child were recorded by asking him or her to stand on both feet with no support and instructing him or her to achieve a centered position on a slightly unstable platform

by shifting his or her feet position until the cursor (which represents the center of the platform) is in center on the screen grid while standing in a comfortable and upright position. The child was instructed to keep his or her balance without moving his or her feet on the unstable platform and then feet, ankles, and heels coordinate from the platform were recorded. At the start of the test, the platform advanced into an unstable state, and the child was instructed to focus on the screen and maintain the cursor in the middle of the bullseye in the screen. At the end of each test, a printout report was obtained. This report included information on the overall stability index, mediolateral stability index, and anteroposterior stability index. The mean values of the three trials of stability indexes were calculated for each child individually before ankle taping, with ankle taping, and after taping.

Taping technique

The tape was elastic (Kinesio Tex Tape) with 5.0 cm width ×5 m length (2.0 inch × 16.4 feet) (Suzhou Med Sport Products Co. Ltd., China).

Prerequisites

(1) The lower leg and the ankle of the involved limb were cleaned using organic solvent (alcohol pads) every time before applying the tape.
(2) The distance from the forefoot at the level of metatarsal head along with the dorsal aspect of the lower leg at the level head of the fibula with the ankle at maximum dorsiflexion was measured with the tape.
(3) The girth of the leg and the foot was measured at the level of the head of the fibula, ankle joint, and the metatarsal heads.

Application

(1) One tape was applied longitudinally: the tape was cut with appropriate length third (two-thirds) of the measurement taken by tape measurement of lower leg and it was applied along with the dorsal aspect of the lower leg just below knee joint (proximally) with (25–50%) tension while keeping the ankle in maximum dorsiflexion (that is only during the application of the tap) eventually that provided some degree of maintained ankle dorsiflexion (80–90°), ending at dorsal aspect of the leg below knee with two inches no tension.
(2) Two tapes were applied diagonal of the lower leg, was backed in the center and placed on the plantar surface of the midfoot, with no tension (between the calcaneus and the metatarsal heads) and the ankle in dorsiflexion. The tape may be applied with tension diagonally over the anterior ankle. The tape may be applied with increased tension on the medial side (if the foot pronated) or the lateral side (if the foot supinated).
(3) Three transverse tapes were applied: one was at the level of the metatarsal heads, the second was at the level of ankle joint, and the third was at the level of the head of the fibula (Fig. 1).

The tape was applied for 5 days and then removed for 1 day to allow skin perspiration. This process was repeated for successive 12 weeks. The child was instructed to avoid vigorous activities for 30 min, which is required for the glue to become fully activated [23].

Physical therapy program

The physical therapy program was used for the treatment of the children in both groups. The selected exercise program emphasized on exercise for postural control, which is based on the neurodevlopmental technique (NDT) approach, for 2 h, three times per week, for successive 12 weeks.

Results

A total of 30 children participated in this study and were classified into two groups: group A included nine boys and six girls, and group B included seven boys and eight girls. They were homogenous in their age, height, and weight (Table 1).

The collected data included the overall stability index, the anteroposterior stability index, and the mediolateral stability index before and after treatment program with taping at 12th week and without taping after removal of taping in group A and group B (Table 2).

Accumulative effect of taping was obtained by comparing the mean values of stability indexes of the

Figure 1

Steps of application of tape straps: (a) longitudinal tape, (b) diagonal tape, and (c) transverse tapes.

study group before the taping, after 6 weeks of taping with taping, and after 12 weeks of taping with taping (Tables 3 and 4).

Discussion

The 30 hemiparetic cerebral palsied children who participated in this study were chosen from the Outpatient Clinic, Faculty of Physical Therapy, Cairo University. Hemiparetic CP is a defect in balance during standing secondary to ankle plantar flexion problem with inversion or eversion problem [24].

The results of treatment showed that all hemiparetic children had some degree of posture problems, which was attributed to neuromuscular and biomechanical defect, and improvement in posture control was related to the designed physical therapy program and ankle taping. The results of the present study showed significant improvement in all measuring variables of both groups when comparing their pretreatment and post-treatment values. However, more improvement was noticed in the study group with and without taping compared with the post-treatment values of both groups after 3 months of treatment. Improvement with significant difference was also noticed in the study group with taping.

This significance in the post-treatment mean values might be attributed to the effect of the exercise program (based on NDT), which emphasized on the following:

Table 1 Demographic data of children in both groups (A and B)

Characteristics	Mean ± SD	*t*-Value	*P*-value
Age (years)			
Group A	6.06 ± 0.82	0.45	0.65 (NS)
Group B	6.2 ± 0.79		
Weight (kg)			
Group A	23. 6 ± 3.83	0.97	0.34 (NS)
Group B	25.06 ± 4.43		
Height (cm)			
Group A	116.8 ± 11.73	0.86	0.39 (NS)
Group B	120.6 ± 12.33		

Table 2 Mean values of the overall, anteroposterior, and mediolateral stability indexes before treatment, after treatment with and without taping between groups A and B

Items	Mean ± SD			Comparison		Significance
	Group A	Group B		*T*-value	*P*-value	
Overall stability						
Before	2.84 ± 0.31	2.85 ± 0.4		0.1	0.92	NS
After	2.64 ± 0.29	With tape	2.04 ± 0.29	4.7	0.0001	S
		Without tape	2.31 ± 0.31	2.43	0.02	S
Anteroposterior						
Before	2.38 ± 0.41	2.3 ± 0.53		0.45	0.65	NS
After	2.12 ± 0.45	With tape	1.54 ± 0.55	3.6	0.001	S
		Without tape	1.78 ± 0.41	2.12	0.04	S
Mediolateral						
Before	2.12 ± 0.64	1.86 ± 0.65		1.06	0.29	NS
After	1.88 ± 0.63	With tape	1.22 ± 0.53	3.23	0.003	S
		Without tape	1.44 ± 0.63	2.1	0.04	S

S, significant.

Table 3 Mean values of the overall, anteroposterior, and mediolateral stability indexes, before treatment, after 6 weeks of taping, and after 12 weeks of taping in group B

Stability index	*X* ± SD	SS		MS		*F*	*P*	Significance
		Within	Between	Within	Between			
Overall stability index								
Before taping	2.85 ± 0.4	4.9	6.46	2.45	0.46	128.44	0.0001	S
After 6 weeks of taping	2.5 ± 0.43							
After 12 weeks of taping	2.04 ± 0.38							
Anteroposterior stability index								
Before taping	2.3 ± 0.53	4.36	8.9	2.18	0.63	105.68	0.0001	S
After 6 weeks of taping	1.98 ± 0.45							
After 12 weeks of taping	1.54 ± 0.42							
Mediolateral								
Before taping	1.86 ± 0.65	3.2	13.16	1.6	0.94	43.11	0.0001	S
After 6 weeks of taping	1.62 ± 0.59							
After 12 weeks of taping	1.22 ± 0.47							

MS, mean square; S, significant; SS, sum of square.

Table 4 Mean values of overall, anteroposterior, and mediolateral stability index before taping, after 6 weeks of taping, and after 12 weeks of taping in group B

Comparisons	Mean difference	*t*-Value	*P*-value	Significance	Percentage of improvement
Before taping vs. 6 weeks after taping					
Overall stability	0.35	7.0	<0.001	S	12.28
Anteroposterior	0.23	6.09	<0.001	S	10
Mediolateral	0.24	3.4	<0.01	S	12.9
Before taping vs. after 12 weeks of taping					
Overall stability	0.8	15.98	<0.001	S	28.07
Anteroposterior	0.76	14.47	<0.001	S	33.04
Mediolateral	0.64	9.18	<0.001	S	34.4
After 6 weeks of taping vs. after 12 weeks of taping					
Overall stability	0.45	8.98	<0.001	S	18
Anteroposterior	0.44	3.38	<0.001	S	22.22
Mediolateral	0.4	5.77	<0.001	S	24.69

S, significant.

facilitation of normal patterns of postural control (righting and equilibrium reactions); providing postural adaptations and alignment to improve equilibrium in all positions; developing a greater variety of normal movement patterns particularly in the trunk and lower extremities; and, finally, reinforcement of posture and the effect of postural correction exercises and balance exercises to regain symmetry through stretching of shortened muscles and strengthening exercises for weak muscles. Hemiparetic children have problem in motor control so directed physical therapies to restore a balance by restoring even a limited degree of ankle control with balance training could restore unassisted gait and/or postural balance to many children [25].

Ankle taping might provide feedback to the child as the tape keeps the ankle at right angle while the spasticity in calf muscles pulls the ankle to plantar flexion. This pulling results in stretching of the tape, thus causing mild pain. The child tried to resist the force of stretching by tape by keeping ankle at right angle and overcome the pain caused by the calf pull; this process increases the ankle range of motion and so the taping prevents further sprains by enhancing proprioceptive acuity [19]. This is believed to be achieved through the activation of the skin proprioceptive receptors, which offers additional awareness of the foot position and the direction of motion [26].

The improvement in balance in the study group may be due to the effect of taping on the proprioception of the ankle among injured athletes who suffered from at least one unilateral grade I or II ankle inversion sprain. The angle-reproduction test in two movement planes (inversion and plantar flexion) and four target angles (10 and 30° of plantar flexion, and 5 and 20° of inversion) was applied to all participants under two conditions: without the application of tape, and with the application of ankle taping technique. The results of this study concluded that the tape improves ankle position awareness of the participants and thus their proprioceptive ankle capability when tested in non-weight-bearing position [27].

The stability indexes decreased in the study group compared with the control group, which means that balance was improved and may be due to stability provided to involved ankle by taping. Taping is considered one of the most popular methods of supporting a weakened ankle from undergoing further instability by applying external support, which enhances the child to use ankle strategy more than using the hip strategy, as normally postural muscles activated in a distal–proximal sequence from the ankle towards the hip, whereas in children with hemiparesis the proximal muscles contracted (hip muscles) in advance of the distal muscles during backward sway perturbations and during forward sway to keep postural stability [28].

The ankle taping could be an alternative to the standard ankle foot orthosis in hemiparetic CP [9–29] . Adhesive tape has long been used to provide external support for the ankles of athletes; a variety of taping techniques are highly effective in supporting both ligamentous and musculotendinous conditions related to the ankle joint, so that the kinesio taping method gives the practitioner the opportunity to actually give support while maintaining full range of motion, enabling the individual to participate in physical activity with functional assistance [30].

With the application of proper taping techniques, the child can rapidly resume normal competitive activity and/or intense training [23]. The postural stability and functional ability may be improved due to functional ability reduction in Biodex dynamic balance test values due to application of the selected physical therapy program in addition to the taping technique. This clearly demonstrated the effect of ankle taping on improvement of the child's ability because it gives some degrees of movement and so it enhances a pattern of stability and mobility as more

immobilizing or assisting the ankle with an orthotics, tends to inhibit neurorehabilitation, that depends on active neuromuscular efforts [31].

The taping technique of ankle joint might aid in realignment of the ankle at mid-position, which enhanced proper body alignment with the least expenditure of muscle energy and postural tone. The taping technique had some proprioceptive influence such as cutaneous stimulation, which enhances hemiparetic children's awareness to maintain their ankle and foot in an upright position, resulting in effective postural control and good body alignment. The significant improvement in the balance of group B may be attributed to the ability of the child to have a new posture strategy under exercise with the application of the ankle taping technique. The concept of new posture strategy was presented by testing the effect of balance training on postural sway with and without the application of a nonelastic adhesive tape to the skin around the lateral malleolus on 22 participants with unilateral ankle stability who were randomly assigned into two groups. The training was performed for 10 min a day, five times per week, for a period of 10 weeks. The study showed a significant improvement in both groups, but it improved 2 weeks earlier in the group with taping. This improvement could be due to an increased afferent input from receptors stimulated by traction of the nonelastic adhesive tape [32].

The treatment plan in the study group depended on balance exercise with tape application on ankle joint, which might aid in repositioning the joint in mid-position and prevent dropfoot during gait. The involved lower limb in hemiparetic CP generally experiences profound loss of sensory and motor function. The inability to dorsiflex the ankle leads to drop foot, which can manifest as ankle equinus or equinovarus due to decreased flexibility in the gastrocnemius or soleus muscle groups that weakens the ankle dorsiflexion and the ankle eversion muscles, as well as increased ankle stiffness [33]. To compensate for decreased dorsiflexion, the subtalar and midtarsal joints may be overused, resulting in a severely pronated foot. Kinesio tape has been suggested to provide proprioceptive input in the acute phase of the injury process for lateral ankle sprain. Increased mechanical stability, however, may have some proprioceptive influences due to tape application, enhanced awareness of foot and ankle position, and subjective parameters of comfort after tape application may possibly explain a positive effect of the tape on functional ankle performance [34].

A significant improvement in posture control was noticed in group B with decreasing of measuring variable degrees, as there are changes in the onset of muscle activity in the ankle with tape. This study supposes that cutaneous stimulation and traction on the skin or the pressure of the tape provides cutaneous sensory cues, thus providing additional proprioceptive input to the central nervous system [30].

In the current work, in the study group, treated with ankle taping from the first session, balance measurement was taken before the start of the treatment and then after the treatment period (12 weeks) with the tape and then taken again after 1 week after removing the tape. The results showed that balance with tape was better compared with that after removal of the tape. The tape has supportive characteristics in addition to elastic characteristics, so the tape provides support and protection while allowing functional movement. When used in conjunction with a comprehensive rehabilitation program, tape or wraps can allow early resumption of activity without the threat of reinjury [35].

These findings were also supported by Yasukawa *et al*. [36], who conducted a research on 15 children, who were receiving rehabilitation services at the Rehabilitation Institute of Chicago; this was the initial rehabilitation following an acquired disability. Children's upper-limb function was compared over the three assessments using analysis of variance. They proved that the use of kinesio taping in conjunction with the child's regular therapy program may favorably influence the cutaneous receptors of the sensorimotor system, resulting in subsequent improvement in voluntary control and coordination of the upper limb.

The post-treatment results of group B were contradicted by Hubbard and Kaminski [37], who stated that, in contrast to findings on joint position sense, the application of tape does not improve perception of passive motion in the plantar flexion–dorsiflexion or inversion–eversion plane in recurrent ankle sprain. In fact, detection of passive motion in the inversion–eversion plane is significantly worse with the ankle taped compared with that in the untaped condition. Walters [38] proposed many studies that compared taping versus bracing of the ankle. Prospective studies have met with difficulty in controlling all of the variables associated with ankle injuries (e.g. playing surface, shoe wear, individual inherent stability, and intensity of competition on both a team and individual level). Most of these studies had shown that braces are slightly more effective compared with taping, but that both are better compared with no support.

The study was limited to children who were uncooperative or who removed the tape before 3 days of application, and who had hypersensitivity to the tape.

Conclusion

The results of the present study suggest that ankle taping can improve posture control in hemiplegic cerebral palsied children when it is combined with physical therapy program. Moreover, with prolonged period of tape application the effect on postural control increased and so we recommend application of taping for more than 3 months and evaluate its impact on other functional capabilities.

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Conflicts of interest

There are no conflicts of interest.

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