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EFFECT OF SPRING GRAVITY BAR ON KNEE JOINT ANGLE IN CHILDREN WITH SPASTIC DIPLEGIA

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ABSTRACT

Objective: to investigate the effect of spring gravity bar on knee joint angle during gait in children with spastic diplegia.**Method**: thirty-six children of both sexes (aged 7-10 years) with diplegic cerebral palsy were enrolled in this study. They were randomly assigned into two groups of equal number: the control and study groups. Evaluation was held before and after 3 successive months of treatment using two dimension of gait tracker video analysis to evaluate knee joint angle during gait cycles. Both groups had received the conventional physical therapy program for one hour / day three sessions per week. The study group additionally received gait training on a spring gravity bar while the control group received the classical gait training program. **Results**: A statistical significant improvement in both groups was noted when comparing the mean value of all measured variables before and after treatment ($p \leq .05$). there were significant differences between the control and study groups with respect to all measured variables which favored the study group when comparing the post-treatment outcomes ($p \leq .05$). **Conclusion**: Adding spring gravity bar to gait training program had a beneficial effect in modulating knee joint excursion in children with spastic diplegia.

INTRODUCTION

Children with spastic diplegia usually walk independently but most have an easily recognised disorder of gait which may include deviations in the sagittal plane such as toe-walking, flexed-stiff knees, flexed hips and an anteriorly tilted pelvis with lumbar lordosis **(Rodda et al., 2004).** Crouch gait, the most prevalent and debilitating gait disorder in spastic diplegia, is characterized by excessive knee flexion in early and/or mid

stance. Muscle weakness, spasticity, contractures, and impaired selective motor control have all been shown to contribute to crouch gait to varying degrees across individuals **(Shdeler et al., 2020).**

Excessive knee flexion in stance was very common, being present in more than 60% of participants in GMFCS levels II to IV, and in more than 45% of those in level I. Odds of having excessive knee flexion in stance increased with increasing age in GMFCS levels I, II, and III.**(Rethlefsen et al., 2016).**Excessive knee flexion throughout stance (i.e. crouch gait) is a major sequela of spastic cerebral palsy (CP) and is sometimes associated with knee pain. Knee pain is hypothesized to result from quadriceps and patellar tendon forces being approximately 2 to 8 times larger in crouch gait than upright gait. **(Pelrine et al., 2019).**

Two-dimensional (2D) video analysis may provide an accessible and affordable means of quantifying postural control deficits that can be implemented across a spectrum of care settings. Angular joint measures during weight lifting obtained using 2D motion analysis software have been shown to be highly correlated to goniometric measures. This system has also been shown to be reliable in quantifying range of motion during reaching and walking/running tasks **(Paul et al., 2016).**

Gait training is often a significant focus of physical therapy intervention, with increased attention to practice in the child's natural environment. Newer methods, which allow partial body weight support and treadmill training, provide an opportunity for increased practice and show promise for improving the gait and functional skills of young children with CP **(Gage et al., 2009).**

Spring gravity bar is a modification of the gravity force system ;which most studies focus on walking on fixed(stable) two gravity bar as :

- In using gravity force system , a lot of vestibular and righting reflexes are used to promote movement. For example: the child stand on the surface of one beam while the therapist holds him at his ankles. He has to balance his body as he receives strong gravitational signals through the vestibular system while his ankles are challenged to find a secure position due to the narrow support **(Cuevas, 2004).**
- Gravity force stimulation program helped the diplegic children to organize sensory information from the visual, somatosensory and vestibular systems (sensory strategies) for postural control thus creating internal neural representation which is necessary for coordinated postural abilities **(Cuevas, 2004).**

- Walking on a narrow beam is a demanding motor skill that requires the control of dynamic stability, defined as the ability to reduce self-initiated or external perturbations via inherent restoring moments to avoid loss of balance. Due to the reduced base of support of the beam and the intrinsic variability of the human, walking tends to become unstable in the medio-lateral (ML) direction **(Chiovetto et al., 2018).**

For this spring gravity bar place spring to two gravity bar to add improve to joint angle as knee joint plus to improvement in balance. Therefore the purpose of this study was to investigate the effect of spring gravity bar on changing excessive knee flexion during gait in diplegic children with crouch gait.

SUBJECTS AND METHODS

Subject:

Thirty-six children with diplegia CP of both genders (27 boys and 9 girls) were recruited from the faculty physical therapy outpatient clinic , Cairo university and Prof Dr Kamal Shoukry Pediatric rehabilitation center.

Inclusion criteria:

1-Their age extended from seven to ten years.
2-They could walk with limitation or holding on according to GMFCS (level II & III)
3-They can understand and follow instruction.

Exclusion criteria:

1-Children had any recent surgical interference in the lower limb.
2-Children with fixed structural deformities lower limb.
3-Children had any recent botox injection.
4-Children with sever visual or auditory problems.

Data collection procedures

All procedures were performed at baseline (pretreatment) and at the end of 3 successive months of treatment (posttreatment) in a warm, lighted and quiet room.

Materials:

For evaluation:

The participants received baseline and post-treatment assessments after three month training period by using the following tool:

Two dimension (2D), video based gait assessment system:

Two dimension technique is proposed to perform lower limb sagittal plane kinematic analysis using a single video camera. It provides unilateral joint kinematics of hip and knee and ankle in the sagittal plane

along with the estimation of gait events and spatiotemporal parameter. The accuracy of the spatiotemporal parameters estimation was found suitable for clinical use **(Baker, 2006).**

Procedure:

- Adhesive skin markers were applied over the skin on specific sites : greater trochanter , tibial tuberosity and lateral malleolus for right and left side.
- Children were asked to walk along 2m walkway and velocity didn't determine.
- A digital video camera was set up so that it could record from sagittal plane , perpendicular to the center of the pathway and at level of knee.
- The angle chosen for this analysis was knee flexsion/extension.
- The video was transferred from camera to the hardware (laptop) through memory card.
- The tracker software was opened on the laptop.
- Importing a video which analysis.

Intervention

Spring Gravity Bar Features

The spring gravity bar (**figure 1**) comprises the following: (1) two wooden board length (160 cm) and width (15 cm) (2) non skid wooden board (3) wooden board won't break down when child bounce (4) durable spring at every end of board (5) two wooden board connect in the middle (6) Fulcrum in middle of wooden board.

Fig 1: Spring gravity bar.

Physical therapy exercise program:

Children of both groups had received the following exercise program for 1 hour per day, 3 sessions /week for successive 3 months:

(1) flexibility training for iliopsoas, adductor and calf muscles of both lower limbs 3-5 times per session

(2) strength training for hip extensors , hip abductors , hip external rotators , knee extensors and ankle dorsiflexors

(3) standing exercise which include sitting on small bench ask child to stand and standing against wall ask child to squat and standing holding on and ask child to lift on foot on block

In addition to 30 minutes gait training for both groups as follow:

For control group : gait training which include Walking in all directions (forward, backward, and sideways) and obstacles (include rollators , wedges and stepper) were used on the walkway inside and outside the parallel bar and walking on wedges with different height and walking on rollator and walking on stepper and walking on balance board with stepper on it.

For study group: received the same physical therapy program given to the control group for 30 minutes and additionally received gait training on spring gravity bar for 30 minutes, which included the following steps:

(1) therapist provided all instructions and supervision or guarding as needed

(2) therapist place child in front of spring gravity bar

(3) child was asked to place on foot on bar and try to keep balance as much as possible then brought other foot on bar and try to keep balance as much as possible

(4) therapist encourage child to walk on spring gravity bar

(5) child was asked to walk slowly and press spring down during each step with try to keep his balance

(6) at end of bar ; child was asked to stand on bar to maintain balance before descend from it.

Statistical analysis

The results were expressed as mean (standard deviation). Data was analyzed using the Statistical Package for Social Sciences (SPSS computer program version 25). Paired t-test was used to compare between the mean values of all measured parameters pre and post-treatment in each group. While the comparison between both groups pre and post treatment was carried out by using an unpaired t-test. A probability of $P \leq 0.05$ was considered to be statistically significant.

RESULTS

Table 1: represents general characteristics of age, weight, and height of children in study and control groups.

Items	Study groups, mean (SD)	Control groups, mean (SD)	Comparison value [a]	P value
Age (years)	7.83 (1.8)	7.83 (1.8)	00.00	1.00*
Weight (kg)	27.2 (10.56)	24.27 (7.71)	22.07	0.524*
Height (cm)	99.9 (45.69)	109.98 (16.87)	10.08	0.536*

*Non-significant [a] From unpaired test

Table 2: represents Comparison between pre and post mean values of right knee angles in both groups :

Angles of right knee degree		Stance phase					SWING PHASE		
		IC	LR	MS	TS	P Swing	ISW	MSW	TSW
pre	mean difference	2.45	5.50	6.23	3.55	5.25	3.46	.141	.475
	T- value	.489	1.8	1.65	.737	1.17	1.137	.029	.087
	P- value	.634	.098	.127	.477	.266	.28	.977	.932
	Significant	NS							
post	mean difference	1.48	7.13	2.05	5.93	7.15	9.3	5.65	.99
	T- value	.355	1.73	.539	1.83	1.22	1.49	1.35	.355
	P- value	.011					.016	.002	.007
	Significant	S							

Table 3: represents Comparison between pre and post mean values of left knee angles in both groups :

Angles of left knee degree		Stance phase					SWING PHASE		
		IC	LR	MS	TS	P Swing	ISW	MSW	TSW
pre	mean difference	1.00	10.49-	8.98	.42	6.32	2.66	4.15	7.38
	T- value	.254	2.87	1.99	.171	1.44	11.08	16.41	16.67
	P- value	.804	.075	.072	.867	.175	.500	.472	.108
	Significant	NS							
post	mean difference	3.08	7.72	6.85	1.48	2.57	1.02	.533	.858
	T- value	.944	1.993	2.568	.701	.734	0317	.149	.261
	P- value	.026	0.007	0.003	.0001	0.00	.001	.000	.0001
	Significant	S							

DISCUSSION

This study was conducted to evaluate the effect of spring gravity bar program in addition to conventional physiotherapy program on knee flexion in crouch gait in children with spastic diplegia . The results concluded that spring gravity bar program can be added to conventional

physical therapy program to improve knee joint angle of crouch gait in children with spastic diplegia.

Children with spastic diplegia develop abnormal muscle tone and involuntary motor control that may affect their ability to play , this was consistent with the reporting of **Ju y-h et al., (2012)** who reported that Children with spastic diplegic CP, which is characterized by increased muscle tone, paresis, and involuntary motor control, and by more severe involvement of the lower extremities than of other parts of the body, usually have difficulty in maintaining balance in an upright posture because of the posture's unstable condition of a high center of mass and a small base of support.

Children with spastic diplegia suffer from poor activates of daily living due to lack of sensory integration which is a necessary component for motor control and movement performance , and this comes in agreement with the findings of **Girolami et al.,(2011)** Children with diplegic CP encounter difficulties in sensory processing and integration which influence the achievement of mature postural control, consequently, they have balance impairments in altered sensory environments, and tend to depend excessively on visual input to maintain posture and to position their limbs during gait.

In this study work with pattern of spastic diplegic gait described by **Rise and Schwartz (2018)** Crouch gait was defined as excessive knee flexion coupled with excessive dorsiflexion in stance for a limb (i.e. true crouch gait). As such, the objective criteria used to identify crouch gait was mean knee flexion in stance angle more than 24.7° (>2SD from normal) and mean ankle dorsiflexion in single support angle more than 7.3° (more than normal).

The pretreatment results of our study may be contributed to weakness of muscles around joints which lead to reduces range of motion , this comes in agreement with the finding of **Thompson et al., 2011** who found that children with spastic CP have smaller and weaker muscles than healthy children. Muscle strength correlates with gait and motor function and strength is more highly related to function than spasticity. Spastic muscles respond positively to strength training and strength gains have been shown to be similar or greater than those reported in the healthy population.

The post treatment mean values of measured variables showed significant improvement toward study group that may be attributed to the effect of spring gravity bar program which appeared in abilities of child to develop normal gait pattern with greater precision and ease of movement. Spring gravity bar program improves joint angle of hip and knee toward extension especially during stance phase of gait cycle and that may be due to effect of vestibular stimulation during walking on

spring gravity bar. Development of antigravity muscle strength could resulted in improve balance that lead to improve of postural alignment. This agreement with **Unayik & Kahiyan (2011)** Reported that vestibular system is important in the achievement of normal motor development and treatment approach to cerebral palsy child should consist of physiotherapy programs toward the development of postural reactions, proprioceptive and vestibular stimulation for the development of visual-motor coordination and normalization of muscle tone.

The result of study group showed that there was significant reduction in hip and knee flexion especially loading stance, mid-stance and terminal stance phases in both lower limb and that lead to improve gait pattern. These improvement may be result from vestibular stimulation by bouncing on spring gravity bar , develop resistance exercise to strength extensor muscles of lower limb by press on spring and develop balance by decrease base of support by walking on narrow bar of spring gravity bar.

The findings of our study is confirmed by the study of **Cuevus (2004)** which concluded that GFS provokes central nervous system to produce new antigravity postural control reactions by providing the less possible external support. It poses a physical challenge to the child's brain which would create the appropriate internal response. It has strong impact on the sensory system of the child helping normalize the system through exercises that send strong messages to the brain to regulate the tactile, proprioception and vestibular components.

This agreement with **Germain et al., (2019)** who reported that rebound therapy enhances cardiovascular and pulmonary functions, modulates of muscle tone, improves kinesthetic awareness and also improves postural control. It helps the children with CP to improve their postural balance and enhances their muscular tone , resultantly improving their motor performance.

CONCLUSION

From the previous discussion of the results of this study, it can be suggested that using of spring gravity bar can be effective in improving the gait pattern through improving knee joint angle in children with spastic diplegia.

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دراسة تاثير العلاج بالمشى على شريط الجاذبية الزنبركى على مفصل الركبة اثناء المشى عند الاطفال المصابين بالشلل التقلصى المزدوج

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يهدف هذا البحث الى تقييم تاثير العلاج بالمشى على شريط الجاذبية الزنبركى على مفصل الركبة اثناء المشى عند الاطفال المصابين بالشلل التقلصى المزدوج بعد المشاركة فى برنامج العلاج الطبيعى الذى يتكون من برنامج من التمرينات العلاجية المختارة و برنامج شريط الجاذبية الزنبركى ثلاث مرات فى الاسبوع لمدة ثلاث اشهر. ستة وثلاثون طفلا مصابا بالشلل التقلصى المزدوج من كلا الجنسين . تتراوح اعمارهم بين السابعة و العاشرة من العمر، تم اختيارهم من العيادة الخارجية بمستشفى الاطفال بجامعة القاهرة و مركز كمال شكرى لاعادة التاهيل . و قد تم تقسيمهم بشكل عشوائى الى مجموعتين متساوتين ف العدد(مجموعة الدراسة و مجموعة الضابطة) . اظهرت نتائج هذه الدراسة تحسنا ذا دلالة احصائية فى المتغيرات المقاسة لمجموعه الدراسة و الضابطة عند المقارنة قيم المتوسطات قبل و بعد العلاج . وفى الختام تشير النتائج الى انه يمكن تضمين التدريب على المشى على شريط لبجلذبية الزنبركى كطريقة علاجية بديلة لتعزيز المشى و الوظيفة الحركية لدى الاطفال المصابين بالشلل التقلصى المزدوج.

الكلمات الدالة: التقلصى المزدوج ، شريط الجاذبية الزنبركى ، تحليل ثنائى الابعاد.