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Effect of Core Stability Training on Standing and Genu Recurvatum in Children with Spastic Diplegia

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ABSTRACT
Background: Trunk muscles provide the fundamental support for limb movement. They are also necessary for preserving the body's alignment, spinal stability, and carrying out functional activities while standing or sitting.
Purpose: To investigate the impact of core stabilization exercises on standing function and genu recurvatum in spastic diplegic Cerebral palsy (CP) children.
Subjects and methods: Forty diplegic cerebral palsy children, of both genders with ages ranged between 4 to 7 years old were assigned randomly into two groups of equal numbers; control and study groups, each group consisted of 20 children. Children were evaluated with Kinovea software and GMFM-88 before and after 3 months of treatment. The control group underwent a designed physiotherapy program 3 times per week (1 hour per session) while the study group received core stability exercises in addition to the designed program of the control group.
Results: There was significant improvement in GMFM in favor to the study group (p = 0.02) but there was no significant difference between both groups regarding knee angle after treatment (p = 0.5).
Conclusion: For children with spastic diplegic CP, core stability exercises may be a useful strategy to enhance standing function. Physical therapy intervention was found to be beneficial for knee hyper-extension angle.
Keywords: Cerebral palsy, Genu recurvatum, Core stability, Spastic diplegia.

INTRODUCTION

Cerebral palsy (CP) is a non-progressive group of disorders represented by muscle tone, posture, and mobility impairments as a result of permanent brain damage during development [1,2]. It may result in abnormalities in cognitive functions, vision, and speech [3]. The limitations associated with cerebral palsy significantly decrease the quality of life and restrict their engagement in activities appropriate for their age [4]. Cerebral palsy children experience pain, exhaustion, and malfunctioning of organs and systems [5]**.** Almost thirty percent of children suffering from cerebral palsy are unable to maintain their body in an upright position on their own [6]**.** Genu recurvatum is defined as the presence of more than 5° hyperextension of the knee [7], and has been characterized by abnormality of knee in the sagittal plane. It leads to complications including joint pain and osteoarthritis of knee. Moreover, anterior dislocation of knee may occur at the end stage [8]**.**

Genu recurvatum in mid-stance of the gait cycle is a common abnormality of the knee function in spastic cerebral palsy children [9]**.** Trunk control is necessary to move head and extremities freely and properly. Spastic CP children exhibit poor trunk control because of their limited trunk muscle strength, poor position perception, and impaired brain control[10]**.**

Core exercises are exercises aimed at working the abdominal, back and hip muscles that keep the body in balance. These muscle groups are responsible for the development of the coordination of the muscular system, the formation of movement, the correct and proper posture of the skeletal-muscular system, the emergence of the force and its distribution throughout the body [11]**.** It has also been demonstrated that core stability training improves trunk control, gait, and dynamic sitting and standing balance [12]**.**

This study aimed to investigate the impact of core stabilization exercises on standing function and genu recurvatum in spastic diplegic CP children.

PATIENTS AND METHODS

Subjects

Forty diplegic CP children of both sexes participated in the current work. The range of their ages was from 4 to 7 years old. This work was conducted at Abu El-Reesh Japanese Hospital and the Outpatient Clinic of Faculty of Physical Therapy, Cairo University from June 2022 to August 2023.

Children were included in the current study according to the following (a) A diagnosis of diplegic CP with degree of spasticity that ranged from 1 and 1+ according to the Modified Ashworth's scale. (b) (GMCFS) levels 2 and 3. (c) Children could stand with support. (d) Their knee hyper-extension angles ranged from 5 to 15 degrees in Kinovea software. (e) They were able to understand and follow directions.

Exclusion criteria included children that had (a) auditory or visual difficulties. (b) Fixed lower limbs deformities. (c) Surgical intervention in the lower limbs or Botox injection within the last six months.

Methods:

In the present study standing function and degree of knee hyper-extension angle were assessed before and after treatment using GMFM-88 and Kinovea software respectively.

1) ***Gross Motor Function Measure (GMFM-88)***

The Gross Motor Function Measure **(**GMFM) has been used to evaluate motor function for CP children. The GMFM-88 comprises of 88 items that are specifically described, scored using 4-point scale,

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and organized into five developmental areas known as GMFM Dimensions (A-E) [13].

Standing domain was assessed in this work before and after the intervention. The child was allowed to perform a maximum of three attempts in each trial for each item but if the task was completed in the first trial, no further testing of the item was required. The recording sheet of every subject was filled out during evaluation according to manual of GMFM which describes the criteria of each item then the scores of all items were summed to make percent score.

2) Kinovea software

Kinovea software is reliable for measuring the knee extension and flexion as well as other kinematic parameters [14]. Kinovea is utilized for static and dynamic analysis with several applications in physiotherapy, occupational therapy, sports science, ergonomics and anthropometry. It is also appropriate for coaches and physical education instructors. It is easy to use and doesn't require physical sensors during analysis [15].

It is used to make 2-D analysis of the knee joint hyper-extension angle from lateral view while patient standing. The camera was placed on carrier with a height of 30 centimeters from the ground and 1.5 meters away from the child. Circular marks were placed on the greater trochanter, lateral articulation of knee and lateral malleolus. The child was instructed to stand on one limb while lifting the other then photos were captured from lateral view for the extended limb. The results of the recorded images were transferred to a computer to be analyzed by Kinovea. The angle of the knee was measured between femoral and tibial axes.

Treatment procedures:

The participants were allocated into 2 equal groups randomly:

Group A (control group) included twenty children who underwent a selected physiotherapy program depending on neurodevelopmental approach. Over a period of three successive months, it was applied for one hour each session, three times a week.

It consisted of following tasks: (1) Exercises to facilitate equilibrium and righting reactions, using physioballs [16]. (2) Strengthening exercises performed for back extensor and abdominal muscles [17]. (3) Active exercises for knee flexors muscles [18]. (4) Muscle stretching for lower limb muscles; adductors, hip flexors and plantar flexors [19]. (5) Exercises that improve standing balance including step-standing, kneeling, half-kneeling, single-limb support, and standing on a balancing board. (6) Gait training involved using a stepper, walking in parallel bars and climbing stairs [20].

Group (B): Children in the experimental group underwent core exercises for 30 min along with the designed physiotherapy program of group (A) for 30 min.

When children couldn't complete the training exercises on their own, the therapist assisted them in maintaining the trigger posture, and helped the children to complete the training with the maximum effort through instructions, then gradually reduced the auxiliary until the children could complete the training action independently [21]. The core stability program included 3 levels. Each level was performed for 4 weeks [22].

- **The simple level (1)**:
  (1) Draw-in abdominal muscles from supine lying position. (3 sets, 20 repetitions per set).
  (2) Knees to the chest with abdominal draw-in (three sets and 10–20 repetitions per set).
  (3) Supine twist (3 sets and10–20 repetitions/set).
- **The (medium) level (2)**:
  (1) Pelvic bridging exercises (3 sets and 3–5 repetitions/set).
  (2) Supine hip twist on physioball (3 sets and 10–20 repetitions/set).
- **The (difficult) level (3)**: BOSU ball was used as a graduation from stable to unstable surface to increase core and limb muscles activation.

The supine exercises:

(1) Abdominal draw-in exercise on BOSU ball.
(2) Pelvic bridging exercise using BOSU ball.

The prone exercises:

(1) Quadruped exercise on BOSU ball.
(2) Quadruped position with unilateral upper limb reaching using BOSU ball.

Ethical approval:

This work was approved by the Ethical Committee of Faculty of Physical Therapy, Cairo University. Before starting the study, each participant's parent provided signed informed consent. This investigation was conducted according to the Code of the World Medical Association (Declaration of Helsinki) for studies including humans.

Statistical analysis

Quantitative data were presented as mean and standard deviation (SD). An unpaired t test was used to compare the knee angle and GMFM between the groups. A paired t test was used to compare each group's pre- and post-treatment data. The level of significance for all statistical tests was set at $p < 0.05$. Qualitative data were presented as frequency and percentage and were compared by chi^2 test. The Statistical Package for the Social Sciences (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used for all statistical analysis.

RESULTS

Subject data:

Table (1) illustrated participant data of study and control groups with no significant difference between groups in age, GMFCS, sex and distribution of spasticity.

Table (1): Comparison of participant data between both groups:

	Control group Mean ±SD	Study group Mean ±SD	p-value
Age (years)	5.22 ± 1.06	5.55 ± 1.13	0.35
GMFCS	3 (3-2)	3 (3-2)	0.79
Sex, n (%)			
Girls	8 (40%)	٩(٤٥%)	0.74
Boys	12 (60%)	1١ (٥٥%)	
Spasticity, n (%)			
Grade I	9 (45%)	10 (50%)	0.75
Grade I+	11 (55%)	10 (50%)	

SD, Standard deviation, GMFCS: Gross Motor Function Classification System.

Effect of intervention on GMFM and knee angle:

Comparison within group

Both groups showed a significant increase in GMFM and a significant decrease in knee angle after treatment compared to the pretreatment. The percent change in GMFM and knee angle in the control group was 11.48 and 12.33%, respectively, but in the experimental group it was 26.34 and 18.03% (Table 2).

Comparison between groups

There was no significant difference between groups before therapy. A post-treatment comparison between groups demonstrated a significant increase in GMFM in the study group compared to the control group, but no significant changes in knee angle between groups (Table 2 and figures 1 & 2).

Table (2): Mean GMFM and knee angle before and after treatment for both groups:

	Control group Mean ±SD	Study group Mean ±SD	MD	t-value	p-value	Sig
GMFM						
-Pre treatment	21.35 ± 6.05	22.40 ± 5.36	-1.05	-0.58	0.56	NS
-Post treatment	23.80± 6.28	28.30 ± 5.60	-4.5	-2.39	0.02	S
-MD	-2.45	-5.9				
-% of change	11.48	26.34				
-t-value	-9.2	-18.71				
Knee angle (degrees)						
-Pre treatment	11.35 ± 2.71	11.65 ± 2.12	-0.3	-0.39	0.69	NS
-Post treatment	9.95 ± 2.22	9.55 ± 1.43	0.4	0.67	0.5	NS
-MD	1.4	2.1				
-% of change	12.33	18.03				
-t-value	4.1	7.56				

SD, Standard deviation; MD, Mean difference; S, significant, NS, non-significant

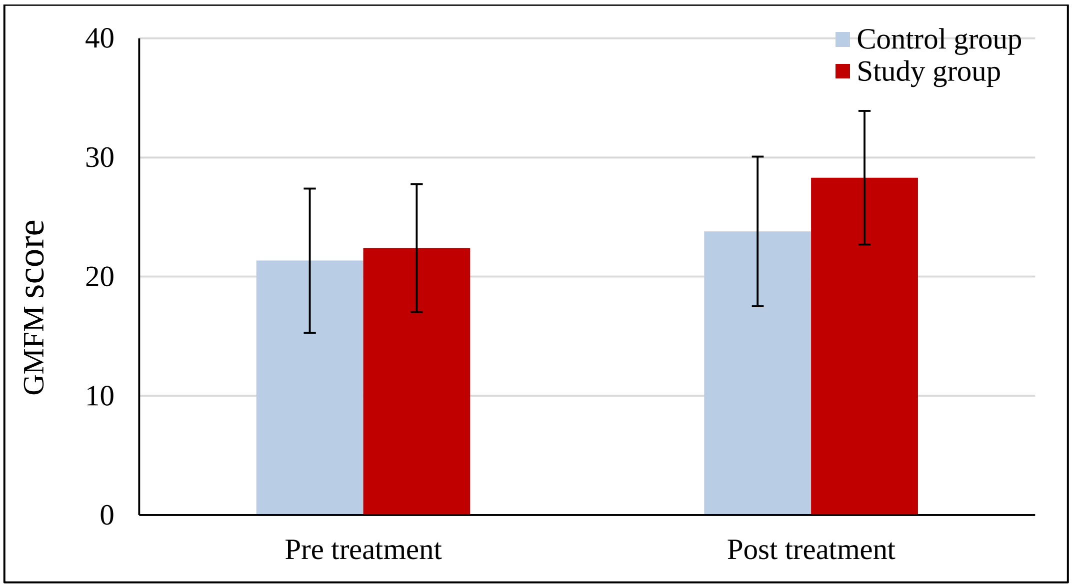

Figure (1): Mean GMFM pre and post treatment of both groups.

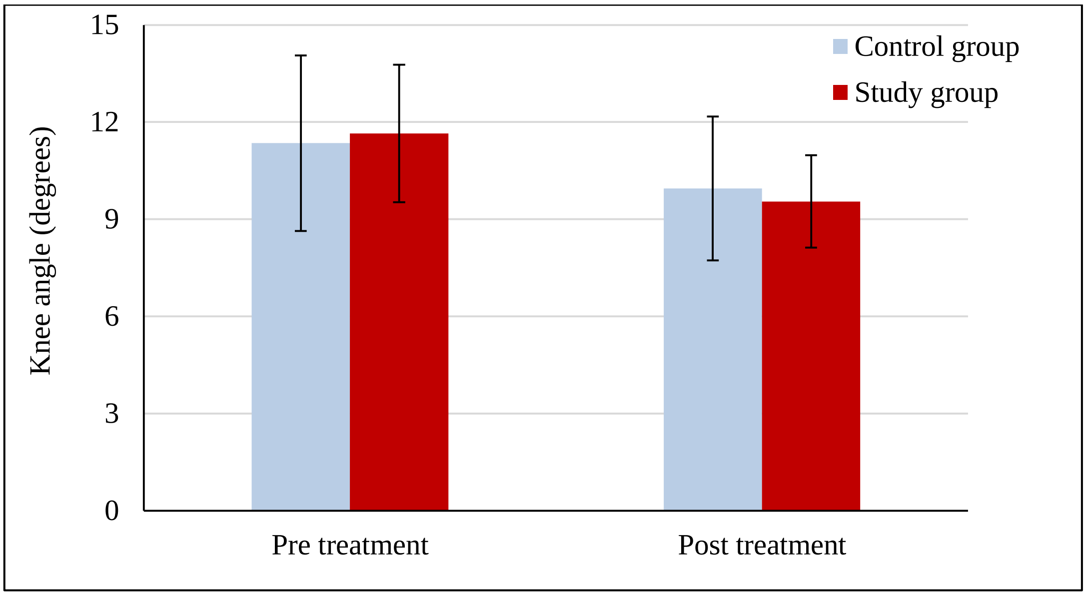

Figure (2): Mean knee angle before and after treatment of both groups.

DISCUSSION

The current work was conducted for investigating the impact of core stabilization exercises on standing function and the degree of knee recurvatum in spastic diplegic children.

In the current work, genu recurvatum was evaluated because it has been described to affect the structure of the knee joint; it includes tibial bowing in the sagittal and frontal plane, altered compressive forces at the tibiofemoral and patellofemoral joints, ligament laxity, posterior capsule stretching and muscle imbalance (quadriceps weakness/hamstring over-recruitment) [(23)].

Additionally, standing function was also selected to be evaluated in this study since it is a prerequisite for daily tasks including walking, changing direction, and climbing stairs [(24)].

Stability of core muscle is important for avoiding knees, hips and lumbar spine injuries [(25)]. Core stability enhances the upper and lower limbs strength because the more stable the core, the more power the limbs can produce [(26)].

Concerning the findings of the present work, there was a significant improvement regarding the knee angle and GMFM before and after treatment results in both groups.

The improvement in knee angle and GMFM in the control group was reinforced by **Khan *et al.*** [(27)], who stated that neurodevelopmental therapy decreases spasticity and promotes movement patterns nearly normal while focusing on motor skills. Neurodevelopmental therapy demonstrated a considerable increase in postural control and gross motor function.

The decrease of genu recurvatum angle in the control group may be due to the impact of active knee flexion exercises that enhance erect body posture and knee stability. This comes in accordance with

Lee *et al.* [28]**,** who found that weakness of knee flexor muscles aggravates genu recurvatum. Also stretching exercises, to increase soft tissue flexibility and maintain the length of the tight muscles specially the planter flexors and hip flexors, may enhance balance and body alignment. This was explained by **Bauer *et al.*** [29]**,** who revealed that the plantar flexor knee extensor couple was the primary reason of people, with passive knee hyperextension, to walk in hyperextension pattern.

The improvement of standing domain of GMFM and knee hyper-extension angles in the experimental group might be due to the effect of closed kinetic chain exercises that were taken into consideration in various tasks. This was explained by the work of **Dannelly *et al.*** [30]**,** who found that closed-kinetic chain motion improved the stability of joint, promotes contraction of agonist and antagonist muscles, and support of limbs leading to trunk stabilization and balance improvement.

Our study focused on active participation of children during treatment sessions to enhance standing function. This agreed with the results of **Song *et al.*** [31]**,** who revealed that functional areas of the physical activity were more strongly connected with the active treatment method than with the inactive one. This can be considered to be more applicable to children with impairments that struggle to engage in social activities due to the time it takes them to practice self-management in everyday activity.

The correlation of trunk muscular activity with lower extremity function and movement may explain the improvement in genu recurvatum after core stability training. These findings were agreed with the study of **Al-Nemr and Kora** [32]**,** who found that core stabilization program, can enhance muscle strength and functional activities of lower limbs.

The decrease of genu recurvatum post treatment in the experimental group may be related to the application of various tasks of core stability training on unstable surface such as BOSU ball and Swiss ball to stimulate proprioception and enhance more muscles activation.

Exercises that are performed on unstable surfaces, like the physioball, can increase activity and are effective in alleviating musculoskeletal injuries by enhancing dynamic balance, strengthening the core muscles of the trunk, and maintaining stability in upright posture [33]**.**

This comes in agreement with **Yaprak** [34]**,** who suggested that unstable surfaces, such as BOSU balls, might improve balance, strength, and coordination. Also, EMG activity of the core muscles increased during core training on unstable surfaces. Moreover, using a BOSU ball to do bridge exercises on unstable surface is more beneficial than those on steady ones since it can activate more muscles, stimulate proprioception, and improve the thickness of the abdominal muscles [35]**.**

CONCLUSION

For children with spastic diplegic CP, core stability exercises may be a useful strategy to enhance standing function. Physical therapy intervention was found to be beneficial for knee hyperextension angle.

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