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Anticipatory Postural Adjustment of the Core Muscles during Forward Arm Reaching in Children with Spastic Diplegia

Authors
Doaa A. Sanad[1], Amira M. ElTohamy[2], Ali M. Abdulmonem[3]
Department of Physical Therapy for Growth and Developmental Disorders in Children and its Surgery, Faculty of Physical Therapy, Cairo University
Corresponding Author
Doaa A. Sanad
Department of Physical Therapy for Growth and Developmental Disorders in Children and its Surgery, Faculty of Physical Therapy, Cairo University
Mob: 01222819074
Email: *Dr.doaa.sanad@gmail.com, doaa.mahmoud@pt.cu.edu.eg*

ABSTRACT

Background: *Children with cerebral palsy (CP) have disorders of the development of movement and posture, and they may have difficulties achieving trunk control. Trunk control is essential for free and selective movements of the head and extremities. Anticipatory postural adjustments (APAs) play an important role in the performance of many activities requiring the maintenance of standing posture.*

Objective: *To determine whether individuals with spastic diplegia exhibit anticipatory activation of postural muscles associated with voluntary arm movement while standing. In order to examine activity limitations to make plans for interventions we need good investigation methods.*

Methods: *In this study, Fifteen children with spastic diplegia (study group aged 7- 10 years) and fifteen age- and gender-matched children who were typically developing (TD)(control group, 7-10 years) performed unilateral arm reaching at their own timing while standing, during which electromyographic (EMG) activities of focal(anterior deltoid) and postural core muscles(both erector spinae (ES) and rectus abdominus(RA)) were recorded.*

Results: *In both group the left ES and left RA were activated in advance of the anterior deltoid muscle (AD) than those in the right other postural core muscles but EMG amplitudes of the left ES and left RA in the anticipatory range from 0 ms to +50 ms, with respect to burst onset of AD, were significantly smaller*

in the SDCP group than in the Control group.

Conclusion: *These findings suggest that individuals with spastic diplegia have the ability to anticipate the effects of disturbance of posture and equilibrium caused by arm movement and to activate postural core muscles in advance of focal muscles. However the anticipatory increase in postural muscle activity is insufficient in individuals with spastic diplegia, The outcomes of the study highlight the role of APAs in the control of posture of children with CP.*

Key Words: *cerebral palsy, anticipatory postural adjustment, EMG , standing*

INTRODUCTION

Spastic diplegia is a form of cerebral palsy which bilaterally affects the lower limbs more than the upper limbs.[1] Although many individual with SDCP have the ability to stand and walk independently with or without assistive devices, these individuals have problems with postural control while standing .[2] Because postural control is a prerequisite for daily living activity ,it is important to examine stance postural control in individuals with SDCP. This will enhance understanding of their postural deficits and thereby facilitate therapeutic development.

Anticipatory postural adjustments (APAs) are feed-forward mechanisms elicited by expected postural disturbances that produce preemptive muscle responses that help maintain stability. For example, when reaching for an object such as a book on a shelf, muscles in the trunk and legs activate in advance of muscle activity and movement in the shoulder and arm. These contractions in trunk and leg muscles constitute APAs because they precede the principal (focal) movement of the arm.[3]

Core Stability is the ability to control the position and motion of the trunk over the pelvis to allow optimum production of force and motion of the terminal segment. Inner core muscles are respiratory diaphragm (RD), transversus abdominus (TA), pelvic floor (PF), deep fibers of multifidus (DM). These muscles have been shown to activate prior to movement, creating anticipatory lumbar and pelvic stability, Outer core muscles are internal oblique (IO), external oblique (EO), rectus abdominus (RA), erector spinae (ES), gluteal muscles (GM), adductors (ADD) and latissimus dorsi (LATS). Coordinated effort of inner and outer core components seems to be required to provide "central stability for distal mobility".[4]

The trunk is described as a “key area”, and an area of “core stability” [5], Trunk control is defined as a part of postural control. [5] Trunk control involves stabilization and selective movements of the trunk. This stabilization is essential for free and selective movements of the head and the extremities.[6] Trunk control, as a part of postural control, is a prerequisite for adequate mobility. It is thus of great importance to understand the postural problems in children with CP.

Amplitude modulation of EMG activity is considered to be one of the most subtle forms of fine tuning of postural control.[2] Perturbation experiments during standing revealed that from

the age of independent stance children are able to modulate EMG amplitude with respect to the size of the perturbation.

The aim of this study was to investigate anticipatory EMG activity of core stability muscle in children with SDCP associated with the performance of unilateral arm reaching performed in standing and to compare their performance to children with typical motor development. We hypothesized that children with SDCP will be able to produce direction specific APAs and there would be differences in baseline muscle activity and APAs between the children with typical development and the children with CP.

MATERIAL AND METHODS

In this study,Fifteen children with spastic diplegia, 10 male and 5 female (study group aged 7- 10 years) and fifteen age- and gender-matched children who were typically developing (TD)(control group, 7-10 years) participated in this study. The typically developing children will be recruited from physiotherapy undergraduate students' relatives, family, friends and co-workers who were without any physical or neurological problems. The spastic diplegic children will be recruited from out- patient clinic, Faculty of Physical Therapy, Cairo University.

To minimize motor variability, The Inclusive Criteria for the SDCP group was as follows: level II or III on the Gross Motor Function Classification System .[7] Spasticity ranged from 1 to 2 grades according to modified Ashwarth scale **(Bohannon and Smith, 1987).;** no surgical procedures within 2 years before participation; no history of any genetic or neurological disorder other than spastic diplegic CP; Able to understand procedures and follow directions and no flexion contracture of the hip or knee joint or plantar flexion contracture of the ankle joint. All participants with spastic diplegia could stand with their entire soles in contact with the floor without support for 3min or more. They could also independently walk indoors. All participants in the SDCP group and Control group had normal or corrected-to-normal vision. Exclusive Criteria included was Patient with history of epilepsy or receiving any anti spastic drugs. . No participants in the Control group had any history of neurological or orthopedic impairment.

The protocol of this study approved by the ethical committees of the faculty of physical therapy (Cairo University. Egypt). Following an explanation of the experimental protocols, written informed consent was obtained from all participants and their parents.

To measure APA of core muscle, Electromyograms (EMGs, The Noraxon MyoSystem 1400A U.S.A) was recorded using bipolar surface electrodes (Electrodes used with the MyoSystem 1400A satisfy the requirements for standard ANSI/AAMI EC12-1991 Disposable ECG electrodes) placed over the following muscles on both sides of the body: anterior deltoid (AD) muscle as a focal muscle of arm flexion; rectus abdominus (RA) and erector spinae (ES)) muscles as postural core muscles .[8] The electrodes will align along the long axis of the muscle with an inter-electrode distance of about 2 cm.

All children will stand at a stance width of 5–10 cm between the heels with their arms beside their trunk. Next, arm movement trials will be performed after 3 practice trials, Participants will be instructed to look directly forward and to perform each task ‘‘as fast as possible’’ in a self-paced mode after a computerized go-tone. They will be instructed to execute ‘sharp, clear movements. Participants start to move dominant arm forward for reaching of a small attractive ball at their own timing within 3seconds after an experimenter stop the buzzing sound; participants then stop their arm at a horizontal position for about 3 seconds before returning to the starting position and will also instruct to maintain a fully extended elbow joint during arm flexion. The presentation order of the tasks was randomized across participants.

EMG Root Mean Square (RMS) amplitude and EMG mean peak will measured to quantify the magnitude of muscle activity associated with APAs. To exclude electrocardiogram and movement artifacts, EMGs were high-pass filtered (20 Hz) using the third-order zero-phase then full-wave rectified. The time course of the EMG burst of focal and postural muscles in each trial was then analyzed. Because background activity of AD before burst onset was extremely small, burst onset of AD on the dominant side was identified by visual inspection. For postural core muscles, EMG Root Mean Square (RMS) amplitude and the mean EMG peak amplitude over the period from 0 ms to 50 ms with respect to burst onset of AD was defined as the anticipatory range. The time difference between the burst onset of postural muscles and AD onset was calculated as the start time of postural muscles and presented as a negative value when burst onset was earlier in postural muscles than in AD. Further analysis of EMGs was performed to examine anticipatory changes in EMG amplitude of postural muscles.

For each postural muscle and for each participant, EMGs from 0 ms to +50ms with respect to AD onset were averaged for all trials in which the EMG burst of the postural muscle was observed within.

RESULTS

In the SDCP group, mean age, height and weight were 7.35 years (standard deviation [SD] = 1.76), 117.89cm (SD = 7.5), 21.89 kg (SD = 4.67), respectively. In the Control group, these measurements were 8.99 years (SD = 1.71), 129.78cm (SD = 10.64), 27.89 kg (SD = 9.53),respectively. No significant difference between the 2 groups was shown regarding age and weight ($P>0.05$) while there was significant difference in height ($P<0.05$). Data were obtained from both groups (control group and SDCP group) , statistically analyzed and compared with measurable variables [peak amplitude and Route Mean Square (RMS) amplitude] using unpaired T-test to detect level of significance

% of trials	SDCP group	Control group	Significance level
Mean peak amplitude of core muscle(uV)			
Rt Rectus Abdominus	6.96 (2.90)	6.44 (4.06)	NS (P>0.05)
Lt Rectus Abdominus	8.18 (7.89)	14.18 (8.91)	NS (P>0.05)
Rt Erector Spinae	1.30 (0.58)	1.03 (0.29)	NS (P>0.05)
Lt Erector Spinae	9.29 (7.06)	14.19 (2.91)	NS (P>0.05)
Route Mean Square (RMS) Amplitude(uV)			
Rt Rectus Abdominus	14.81 (4.51)	10.19 (2.72)	S (p<0.05)
Lt Rectus Abdominus	5.83 (2.33)	10.36 (3.53)	S (P<0.05)
Rt Erector Spinae	3.41 (0.82)	4.05 (1.11)	NS (P>0.05)
Lt Erector Spinae	7.79 (2.46)	17.08 (4.42)	S (P<0.05)

Table (1) shows The percentage of trials of mean peak amplitude and route mean square(RMS) in each participant group in which the EMG burst was observed in the anticipatory range. Mean (standard deviation).

As shown from (Table 1) there was No significant difference between the 2 groups in the percentage of Mean peak amplitude of any of postural core muscle. The percentage of trials of route mean square (RMS) in which the EMG burst was observed in the anticipatory range was higher in the dorsal and ventral core muscles on the opposite side.

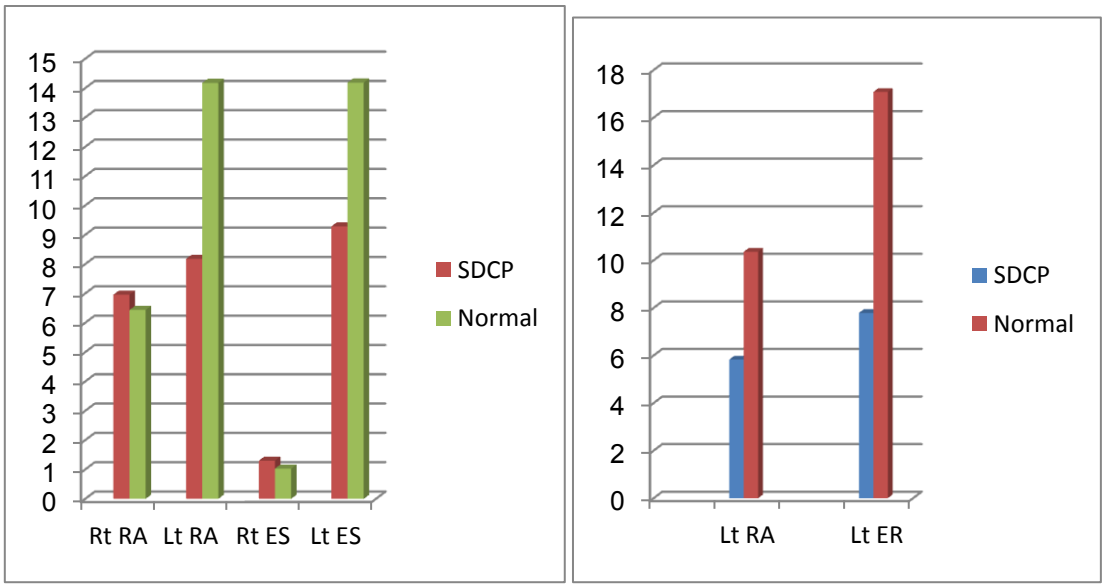

Fig. 1 (A) anticipatory changes in EMG peak amplitude of the postural core muscles in participants with spastic diplegia (SDCPgroup) and those without disability (normal), which indicated no significant difference (p> 0.05). (B) anticipatory changes in EMG route mean square amplitude of the left rectus abdominus and left erector spinae muscles in both groups.

Fig, 1(A) shows no significant main effect of participant group was found for the anticipatory changes in peak EMG amplitude of right rectus abdominus(RA), left rectus abdominus, right erector spinae(ES) and left erector spinae (t values were 0.314, 1.25, 1.93 and 1.51 respectively) , ($p > 0.05$).

In Fig 1(B) . A significant main effect of participant group was found for the anticipatory changes in EMG route mean square amplitude of the left rectus abdominus and left erector spinae muscles in both groups (t value were 3.21, 5.51 respectively) ($p<0.05$, in which these anticipatory changes in EMG(RMS) amplitudes of left(RA) and left(ES) were both significantly smaller in the SDCP group than in the Control group.

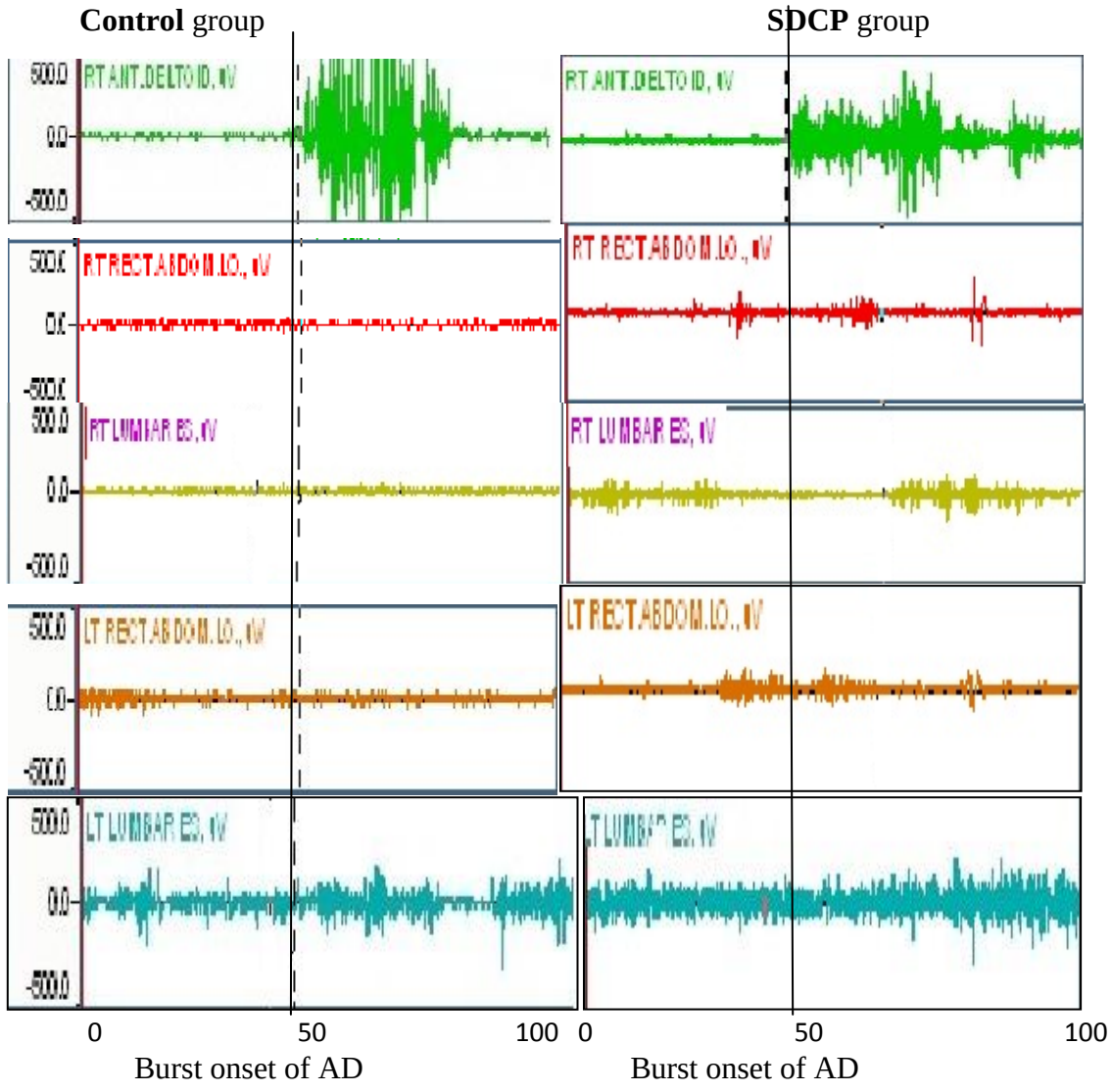

Fig.2. Representative EMG data for activity in a focal muscle (right anterior deltoid [AD]) and postural core muscles (right rectus abdominus(RA), right erector spinae [ES] , left rectus abdominus(RA) and left erector

spinae [ES] during unilateral arm reaching in a participant with spastic diplegia (SDCP) and a participant without disability (Control).

DISCUSSION

This study was conducted to determine whether individuals with spastic diplegia exhibit anticipatory activation of postural core muscles associated with voluntary arm movement while standing. Consequently, the activation of postural core muscle before burst onset activation of AD was observed in both the SDCP group and Control group (Fig 2). This result suggests that individuals with spastic diplegia have the ability to anticipate the effects of disturbance of posture and equilibrium caused by arm movement and to activate postural core muscles in advance of focal muscles. In addition, this result also suggests that direction specific postural core muscle activities during voluntary movement are basically intact in individuals with spastic diplegia, since activities of postural core muscles on the left side of the body are required to resist postural disturbance in the forward direction on the right side caused by unilateral arm reaching(Fig 1B).

The percentages of left ES and left RA were much higher than those in the right other postural core muscles in both group (table 1). The anticipatory changes in EMG amplitudes of left rectus abdominus(RA) and left erector spinae [ES] were significantly smaller in the SDCP group than in the Control group. Therefore, it is likely that an anticipatory increase in postural muscle activity is insufficient in individuals with spastic diplegia. **Roncesvalles et al.**[9] reported that the primary constraint on balance recovery to support surface translation, i.e., automatic postural response, in children with spastic diplegia is an insufficient increase in the activities of agonist postural muscles. In addition, it has been suggested that limitation of voluntary changes in the standing posture exhibited by children with spastic diplegia is related to their inability to increase postural muscle activity.[10] These findings suggest that individuals with spastic diplegia have difficulty increasing postural muscle activity during various postural tasks.

During forward right arm reaching, in both groups, the dorsal muscle group of the trunk LT (ES) was more active than ventral muscle group LT(RA) prior to the perturbation restricting forward movement of the body and preserving balance on right side(Fig1 B). The results demonstrate that despite CNS injury, children with CP who ambulate without assistive devices, were able to organize directionally specific anticipatory postural adjustments in muscles of the trunk prior to forward movements performed in standing.[11]

Finally, the standard deviations for the LT(ES) and LT(RA) percentage of anticipatory muscle activity were significantly greater in the SDCP group than the standard deviations calculated for TD groups (see Table 1) We believe there will be greater variability in the muscle activity of children with diplegia because of the musculoskeletal, neurological and balance issues associated with this diagnosis. [12,13] Indeed, APA

studies have found larger standard deviations associated with the integral of EMG activity of individuals with neurological disorders and the elderly when compared to the standard deviations calculated for healthy adult controls. [14,15]

CONCLUSION

The results of this study indicate that children with SDCP between the ages of 7 and 10 years, are able to generate directionally specific anticipatory postural adjustments by the preceding activation of core postural muscles with respect to focal muscles during unilateral arm reaching while standing . it is likely that the anticipatory increase in postural muscle activity is insufficient in individuals with spastic diplegia. Further testing of other individuals with spastic diplegia, including those who are 12 years of age and older will needed to show characteristics that are similar to those obtained in this study or not and to measure the development of APA in SDCP in respect to normal development.

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