Postural Dysfunction in Children with Cerebral Palsy: Some Implications for Therapeutic Guidance

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ABSTRACT

Postural problems play a central role in the motor dysfunction of children with cerebral palsy (CP). Therefore, they spend more time in sitting than in standing to perform vital tasks of daily life. The focus of this article is to describe the pathophysiology of postural control in sitting and outline some implications for management and treatment. In general, children with CP exhibit muscular activity counteracting forces that disturb equilibrium. Only 'non-sitting' children with severe CP lack such 'direction-specific' adjustments, possibly ruling out achievement of independent sitting. Most frequently, the children display dysfunctions in the adaptation of the adjustment. Typical characteristics of this adaptation in children with CP are a top-down recruitment of postural muscles, an excessive degree of antagonistic co-activation, and an incomplete adaptation of the EMG-amplitude to task specific constraints. Despite our knowledge on the pathophysiology underlying the postural problems in children with CP, little 'high-level' evidence (according to Sackett) exists on how different interventions can affect these problems. Therapeutic attention to promote motor performance in sitting focuses on adaptive seating, tilting of the support surface, and ample, variable training in motivating settings. The challenge facing us now is to provide evidence about the efficacy of specific treatment approaches facilitating that children reach an optimal level of functioning in daily life.

KEY WORDS

CEREBRAL PALSY

Cerebral palsy (CP) is the most common physical disability in childhood, with a prevalence of 2 to 2.5 per 1000 children in the Western countries. The disorders covered by the term CP are very heterogeneous, both in clinical symptoms and in lesions causing these symptoms. Many attempts have been made through the years to define CP. The most recent consensus definition states that CP is "*an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development*" (Mutch et al., 1992; 549). This definition addresses primarily the motor symptoms, whereas other aspects of common co-morbidity that significantly influence the children's day-to-day performance are omitted. Therefore, a new definition was suggested in July 2004:

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Cerebral palsy describes a group of developmental disorders of movement and posture, causing activity restrictions or disability that are attributed to disturbances occurring in the fetal or infant brain. The motor impairment may be accompanied by a seizure disorder and by impairment of sensation, cognition, communication, and/or behavior. This definition is currently under debate (www.casting foundation.net).

CLASSIFICATION OF CP

Severity of dysfunction in children with CP can best be classified according to the Gross Motor Function Classification System (GMFCS; Palisano et al., 1997). The classification system is based on the child's self-initiated movement with an emphasis on controlling sitting and walking abilities, with or without the use of assistive technology, such as walkers, crutches, and wheel chairs. The GMFCS contains five levels; a child classified at Level I shows minor gross motor dysfunction whereas a child at Level V exhibits limited voluntary control of movement. As motor function is related to age, the classification has four age bands (< 2 years, 2–3 years, 4–5 years, 6–12 years). Children with CP can also be classified according to diagnosis (i.e. hemiplegia, diplegia, tetraplegia—the latter two more recently being classified as bilateral spastic CP to describe the distribution of the impairment).

This categorization, however, only provides a vague idea about the child's functional performance. Most children with diplegia are distributed across Levels I to IV, those with hemiplegia at Levels I to III, and children with tetraplegia and dystonic CP at Levels IV and V (Østensjø et al., 2003). The GMFCS classification thus offers a possibility to create a functionally more homo-geneous representation of the heterogeneous group of children with CP. Rosenbaum and colleagues (2002) longitudinally followed gross motor function of children

with CP at various functional levels. The authors created 'gross-motor curves' that provide an approximate idea of prognosis. The curves form an important basis for clinical decision-making and for rating change in gross motor function related to specific interventions (Ekström Ahl et al., unpublished). The aim of the present paper is to discuss the postural dysfunctions of children with CP and the implications of these dysfunctions for therapeutic guidance.

POSTURAL DYSFUNCTION IN CHILDREN WITH CP

Postural problems play a central role in the motor dysfunction of children with CP. The performance of everyday activities is noticeably influenced by such postural deficits; the extent however, varies with the degree of the disability. Apart from severity of disability, biomechanical constraints, such as the size of the support-base, also influence the child's possibility to control posture. The small base of support in standing induces a more pronounced deficiency when compared with the postural deficit seen in the sitting position, which offers larger stability limits. To perform the vital tasks of daily life adequately, many children therefore spend much time sitting. In this text, we will therefore largely focus on postural control in the sitting position because it offers good possibilities to investigate the pathophysiology of postural control in a large group of children with CP. Knowledge on the specific nature of the postural problems is vital because it can enrich our thinking when choosing therapy and can be useful when adjusting therapy to the difficulties of a specific patient.

Postural control in children with CP has been studied using two experimental paradigms: (1) a sudden destabilization by means of a movable support-surface (Nashner et al., 1983; Woollacott et al., 1998; Brogren et al., 2001), and (2) disturbing

forces produced by voluntary movements (Hadders-Algra et al., 1999a; van der Heide et al., 2004). Destabilization by external forces demands a quick reaction to counteract the forces, whereas destabilization caused by voluntary movements often can be estimated in advance and thus anticipated, due to experience. At a first glance, the two modes of control (compensatory or feed-back control and anticipatory or feed-forward control) can appear to be separate entities but in daily life, they are often combined. When disturbing forces from a voluntary movement are not fully anticipated, compensatory strategies are called into action.

Basic level of postural control: direction-specificity

A primary goal of postural control is efficiently counteracting the disturbing force by means of direction-specific postural adjustments (see Hadders-Algra & van der Heide, 2005; Hadders-Algra, 2005). In general, children with CP can produce such direction-specific postural muscular activity.

Only children with severe CP (GMFCS level V), who cannot sit independently, display a total lack of such 'direction-specific' postural adjustments (Hadders-Algra et al., 1999a; 1999b). This severe deficit cannot be attributed to the inability to sit without help, as 'non-sitting', typically developing infants already show direction-specific adjustments at a very early age (Hadders-Algra et al., 1996; Hedberg et al., 2004). Two explanations for the lack of direction-specificity in children with severe bilateral spastic CP at GMFCS level V can be offered: (1) the postural synergies cannot be programmed; (2) the sensory pathways cannot elicit activity in the synergies. We can assume that children who lack this basic postural building block will never learn to sit independently—even with ample practice. A partial loss of direction-specific adjustments at the level of the hip was found in children at GMFCS level IV and in young children at level III, especially during external perturbations (Brogren et al., 1996) (Fig. 1), as well as occasionallyduring successful reaching
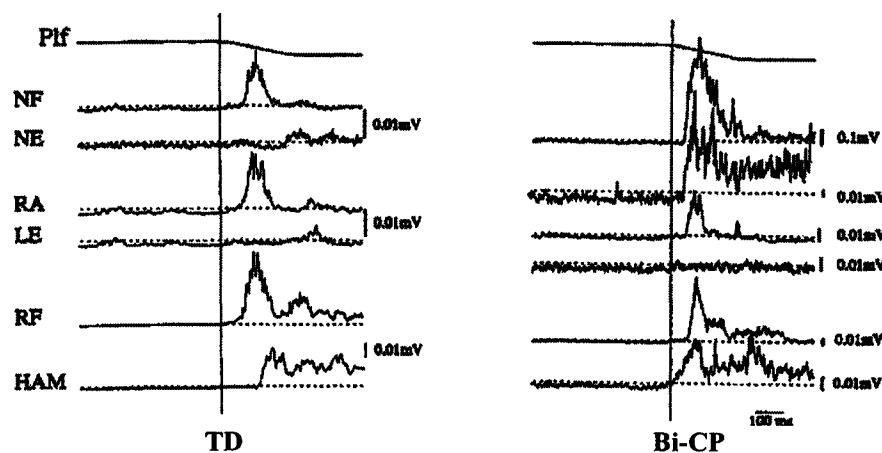

Fig. 1: Mean averaged EMG recordings of postural responses to forward platform perturbation while sitting in a typically developing child (TD) and a child with bilateral spastic CP (Bi-CP), GMFCS- level IV. TD child - shows appropriate direction specific activity in the ventral neck-, trunk-, and leg muscle; Bi-CP child: a partial lack of direction-specific adjustment: activity in HAM precedes activity in RF. Plf=platform signal; NF=neck flexor; NE=neck extensor; RA=rectus abdominis; LE; lumbar extensor; RF=rectus femoris; HAM=Hamstrings. Dotted lines indicate baseline muscular activity + 2 SD; vertical line denotes perturbation onset. (Adapted from Brogren et al., 1996)

(van der Heide et al., 2004). A partial loss of direction-specificity is often accompanied by difficulties in sitting independently, difficulties that seem possible to overcome with training (Butler et al., 1998).

Second level of postural control—adaptation of the adjustment

The most frequently occurring dysfunctions in children with CP are in the adaptation of postural muscular activity. This adaptation involves a fine-tuning of the basic direction-specific adjustment to environmental conditions, based on experience and concurrent sensory input from somatosensory, visual, and vestibular systems. Typical characteristics of this

adaptation in children with CP are

1. top-down recruitment of postural muscles (Nashner et al., 1983; Brogren et al., 1996),
2. excessive degree of antagonistic co-activation during external perturbations (but not during reaching) (Woollacott et al., 1998; Brogren et al., 2001; Van der Heide et al., 2004), and
3. lack or an incomplete modulation of the EMG-amplitude to task specific constraints (Brogren et al., 2001).

The predominant early recruitment of neck muscles in children with CP forms a good basis for training of head control (Fig. 2). Improved control of the head is a vital goal of intervention for children with moderate to severe disabilities, since it is a prerequisite for communication, feeding and eating, and successful reaching.
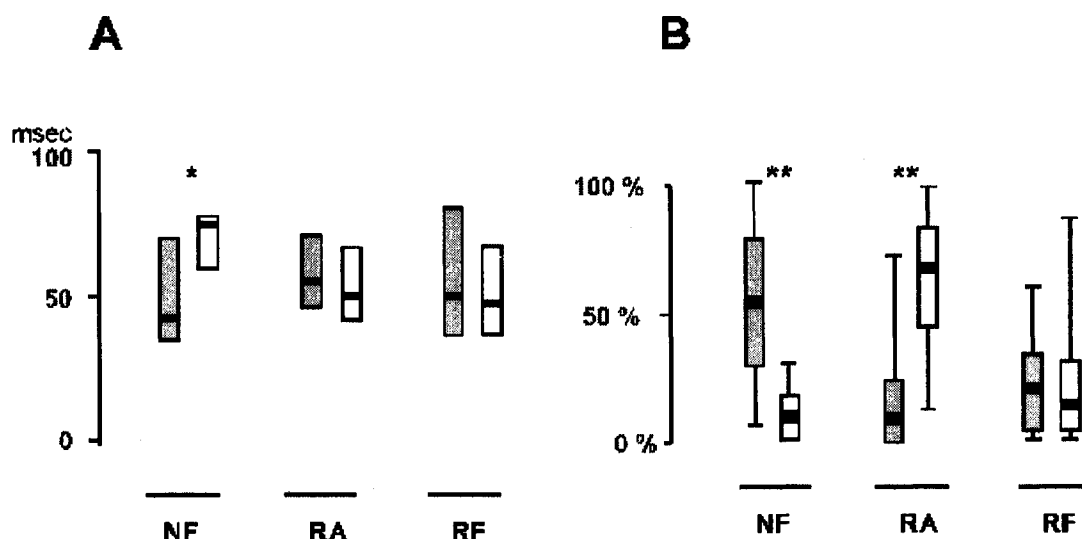

Fig. 2: Differences in postural activity during backward body sway in sitting position induced by forward perturbations from a moving support surface between typically developing children and children with CP. Panel A: latencies (msec) to EMG responses in NF=neck flexors, RA=rectus abdominis, and RF=rectus femoris. Panel B: rate of response (%) during which a specific muscle started the adjustment. Filled boxes represent children with CP and open boxes represent typically developing children. Boxes indicate 25th and 75th centiles, vertical bars the total range, and black horizontal bars denote the median value. Asterisks indicate statistically significant differences * p<0.05, ** p<0.01 (Wilcoxon). (Adapted from Brogren et al., 1996 and Brogren et al., 1998).

A high degree of antagonistic co-activation has been demonstrated in children with CP, especially during backward body sway induced by a movable support-surface (Brogren et al., 1998; Brogren et al., 2001). During forward body sway induced by a backward moving support-surface, the degree of co-activation decreases. This lower degree of antagonistic activation could be related to the larger stability limits in forward direction but might also reflect differences in the supraspinal control of flexor muscles and extensor muscles (Dietz et al., 1989, Hadders-Algra et al., 1998). During self-paced voluntary reaching, the antagonistic muscles are rarely active (van der Heide & Hadders-Algra, 2005). Thus, the degree of co-activation in children with CP seems task-specific and cannot be explained solely by altered spinal circuitry like reduced reciprocal inhibition (Leonard et al., 1990).

A high degree of antagonistic co-activation provides stability but reduces flexibility. The strategy is commonly used in the cognitive phase of learning when forces linked to a specific task have not yet been fully integrated into the motor behavior. A high degree of co-activation could therefore be viewed as a strategy to cope with deficient postural control rather than a problem per se. Providing support and thereby decreasing the degrees of freedom might be one therapeutic solution that can facilitate learning in children with CP as they gain control over various motor tasks that challenge the control of posture. The support can then gradually be decreased to a level that the child can cope with.

The deficient modulation of EMG-amplitude seen in a majority of children with CP could represent difficulties in implicit learning, leaving them with co-activation as one solution to this problem (Gentile, 1998).

In conclusion: children with CP exhibit in general muscular activity counteracting forces that disturb equilibrium. Only 'non-sitting' children with severe CP lack such 'direction-specific' adjustments,

possibly ruling out the achievement of independent sitting. Virtually all children with CP display dysfunctions in the adaptation of the adjustment. Typical characteristics of this adaptation in sitting children with CP are a top-down recruitment of postural muscles, an excessive degree of antagonistic co-activation, and an incomplete adaptation of the EMG-amplitude to task specific constraints.

SITTING POSITION AND ARM-HAND FUNCTION

Stimulation of motor development, including postural development results in better functional performance of activities of daily life. It is, however, far from clear what the best ways are to stimulate motor development in children with CP. Two questions often asked in clinical practice are

1. Is there a best sitting position for children with CP?
2. Does a specific sitting position result in good arm-hand function?

Special seating plays a significant role in the management of children with CP. Various studies have attempted to elucidate which sitting position can be considered optimal. There are advocates of an erect posture (Nwaobi , 1986., 1987; Green & Nelham., 1991), of a straddle position sometimes combined with a forward leaning of the trunk (Myhr & von Wendt., 1991; Pope et al., 1994; Reid, 1996), and a few promoters of a reclined posture (McClenaghan et al., 1992; Hadders-Algra et al., 1999; Brogren et al., 2001). The confusing results can be attributed to many factors, the substantial heterogeneity of the study groups being one. A primary goal in habilitation is to find a sitting position that gives the child an opportunity to control the arm and the hand in an optimal way in such activities as eating, communication, and dressing. Few studies, however, have evaluated whether adaptive seating leads to better arm-hand

function. No advantage on the smoothness and precision of the arm-hand movement was reported in changing the seat angle (Seeger et al., 1984; McPherson et al., 1991), whereas anterior tilting of the support surface decreased the speed of arm movement (Nwaobi, 1987).

Van der Heide et al. (unpublished) recently investigated the effect of seat surface inclination on postural stability and quality of reaching in freely sitting children with CP. The authors found that in children with spastic hemiplegia and in children with bilateral spastic CP, tilting of the seat surface differentially affected postural adjustments and the quality of reaching. In children with spastic hemiplegia, forward tilting of the seat surface improved postural efficiency and quality of reaching, whereas back-ward tilting was associated with increased postural muscle activity and less stability of the head. In children with bilateral spastic CP, both forward and back-ward tilting of the seat surface was associated with postural instability. The results of these studies suggest that in children with spastic hemiplegia, the forward-tilted position is the optimal sitting condition, whereas in children with bilateral spastic CP, the horizontal sitting position seems to be optimal.

Children with CP move their trunks during reaching just as much as typically developing children do (Van der Heide et al., unpublished). In typically developing children, movements of the trunk are not related to the quality of reaching. In children with CP however, a positive link exists between trunk movements and reaching quality. Thus, it seems that the arm, hand, and trunk are programmed together in a fixed temporal order during the reaching movement to assist transporting the hand to the target in a precise way. This program strategy can be useful in movement coordination but requires stable control of the trunk through a longer movement path. This control, in turn, may decrease the child's ability to function optimally in daily life. From a clinical perspective, we presume that if a child with CP

can activate the arm and trunk muscles independently, better control can be gained in various activities, but this means that the child has to learn to deal with many degrees of freedom. How could this be done? One suggestion could be to restrain the trunk loosely to make it possible for the child to start the reaching movement with both the arm and the trunk, but in order to reach a desired object, the arm has to travel the path to the end-point isolated from the trunk. This would provide a more relevant somatosensory input from the arm that can be used to modulate the reaching pattern. Reaches beyond arm length could also provide a possibility to experience a freely moving arm detached from the trunk.

Another way to influence the control of posture could be to augment the intensity of the somatosensory input by putting a bracelet with a weight on the moving arm (Hadders-Algra et al., 1999). From functional goal-directed training (Ketelaar et al., 2001; Ekström-Ahl et al., unpublished), we now know that ample, variable training in motivating settings is an important prerequisite for learning. Trial and error can thus form the basis for selecting efficient movement patterns (Hadders-Algra, 2000).

CONCLUDING REMARKS

Postural problems in children with CP and the pathophysiology underlying these problems are presently fairly well described. On the other hand, we have little 'high-level' evidence on how different interventions can affect these problems. Therapeutic attention to promote motor performance in sitting focuses on adaptive seating, tilting of the support surface, and ample, variable training in motivating settings. The challenge facing us now is to provide evidence about the efficacy of specific treatment approaches facilitating that children reach an optimal level of functioning in daily life.

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