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Effects of Forward Tilting of Seat Surface on Arm-hand Mobility of Young Children with Bilateral Spastic Cerebral Palsy: a Preliminary Study

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Abstract

This preliminary study is on the effect of forward-tilting of the seat-surface on arm-hand function of young children with cerebral palsy (CP). Five children were recruited (two females, three males; median age 2 years 7 months). Inclusion criteria: preschool age, bilateral spastic CP with truncal hypotonia, Gross Motor Function Classification System levels II-IV. Participants served as their own controls. Adaptive seating with three wedge-inserts inducing 10, 20 or 30 degrees forward-tilt of the seat-surface was used. The tilt which induced best postural stability and alignment was applied. Arm mobility was assessed three times with one week intervals. Arm-hand function was assessed using the upper limb physicians rating scale (ULPRS) in the horizontal condition (H), and forward tilt condition (FW), 10 minutes per condition in random order. Two children were tested with 10-degree FW tilted seating, three children with 20 degrees. Mean ULPRS scores were higher in FW [dominant arm: 19.73 (1.94), non-dominant arm: 16.53 (2.21)] than in H condition [dominant arm: 17.93 (1.92), non-dominant arm: 13.73 (2.52)]. ANOVA demonstrated an effect of condition (dominant arm: p=0.001, non-dominant arm: p=0.009), but not of the testing session (dominant arm: p=0.970, non-dominant arm: p=0.724). Therefore, forward-tilting of the seat-surface may enhance arm-hand function in preschool children with Bi-CP.

Keywords : Cerebral palsy, Adaptive seating, Forward-tilting seat, Arm-hand mobility

Clinical Messages:

The preliminary study suggests that 10 to 20 degrees forward tilting of the seat surface with additional foot support may enhance arm-hand function in preschool children with bilateral spastic cerebral palsy

Introduction

Cerebral palsy (CP) is characterized by an impaired development of motor control causing activity limitation (Beckung & Hagberg, 2002; Hadders-Algra & Carlberg, 2008). Postural dysfunctions play a pivotal role in motor impairments (Hadders-Algra & Carlberg, 2008; Shumway-Cook & Woollacott, 2007). Seating devices are used to assist postural control and to enhance functional activities of children with CP. However, the specifics of optimal seating, such as tilting of the seat-surface, are debateable. Several studies reported that forward tilting of the seat-surface improved reaching and grasping efficiency and postural control (Miedaner, 1990; Myhr & von Wendt, 1991; Myhr, Wendt, von Norrlin, & Radell, 2008; Sochaniwskyj, Koheil, Bablich, Milner, & Lotto, 1991). Yet, only McClenaghan and colleagues (1992) indicated that especially 5-degree backward tilting was associated with better hand function, whereas forward tilting had only a minimally positive effect. In addition, Nwaobi and colleagues (Nwaobi, 1987; Nwaobi, Brubaker, Cusick, & Sussman, 2008) reported that a horizontal seat surface was associated with best performance of the arm and forward tilting with worst performance. Unfortunately, those studies did not include sufficient information on the type of CP, i.e. many of them did not clarify whether the studied children were unilateral or bilateral spastic CP. Likewise, some studies included only children with bilateral spastic CP (Sochaniwskyj, Koheil, Bablich, Milner, & Lotto, 1991; Nwaobi, 1987; Nwaobi, Brubaker, Cusick, & Sussman, 2008).

The conflicting findings may be caused by differences between the studies in seating position, the nature of the arm task, the age of the subjects and the type of CP. Previously, only the study of Hadders-Algra, Heide, Fock, Stremmelaar, Eykern & Otten. (2007) specified the type of CP and its different effects on measurement outcomes. Hadders-Algra, Heide, Fock, Stremmelaar, Eykern & Otten (2007) found that for seated reaching condition, in children with unilateral spastic CP, 15-degree forward tilting of the seat improved efficiency of sitting posture and reaching. For children with bilateral spastic CP (Bi-CP), a horizontal seat-surface was the best sitting condition, whereas, both 15-degree forward tilting and backward tilting of the seat-surface increased worse sitting postural control and had no effect on arm-hand function. However, the study by Hadders-Algra, Heide, Fock, Stremmelaar, Eykern & Otten (2007) did not apply foot-support during seated reaching. This is in contrast to sitting in daily-life situations (Angsupaisal, Maathuis, & Hadders-Algra, 2015). The latter finding also contrasts with our daily physical therapy practice, where we have the impression that young children with Bi-CP benefit from forward tilting of the seat-surface in daily-life situations.

Objectives

We aimed to study the effect of forward tilting of the seat-surface on arm-hand performance of young children with Bi-CP. To this end, we developed an adaptive chair with an adjustable seat angle by using a simple wedge-insert that allowed three different degrees of forward tilting of the seat-surface. In this exploratory preliminary study, we address the following question: does application of forward seat-surface tilting (FW-condition) in pre-school children with Bi-CP result in better performance of arm-hand mobility, expressed by means of the upper limb physician rating scale (ULPRS) compared to the horizontal sitting condition (H-condition)

Methods

Study Design

We conducted a single group, time-series, experimental, repeated-measures design (condition x testing session). This preliminary study has been approved by the Naresuan University Research Ethics Committee, Pitsanuloke, Thailand.

Abbreviation:

Bi-CP	Bilateral spastic cerebral palsy
FW	forward tilting seat-surface condition
H	horizontal seat-surface condition
ULPRS	the upper limb physician rating scale

Participants

All children, referred to the Division of Physical Medicine and Rehabilitation at the Buddhachinaraj Hospital, Pitsanuloke, Thailand with a primary diagnosis of CP from May to August 2009, were eligible. A convenience sample of five children with CP aged 1 to 4 years (two females, three males; median age 2 year 7 month) was recruited. All subjects met the following inclusion criteria: (a) Gross Motor Function Classification System levels II to IV (Palisano, Rosenbaum, Walter, Russell, Wood & Galuppi, 2008) (assessed by MA); (b) diagnosed with bilateral spastic CP with hypotonia of the trunk (SCPE, 2009); the diagnoses were confirmed by assessment of MA and one physical therapy (PT) student; and (c) required adaptive equipment during supported sitting in a chair. Exclusion criteria were the presence of fixed hip deformities, scoliosis, severe visual impairment and severe communication problems. All parents signed a form of consent.

Procedure

An adaptive chair with an adjustable seat angle was developed. With a wedge insert, the seat angle could be set at three different angles, i.e., at 10-, 20- or 30-degree forward tilt. First, MA and two other PT students (SP and WP) determined the child's best degree of forward tilting on the basis of the following criteria: The presence of the wedge should result in (a) stable sitting with the head and trunk as upright as possible; (b) projection of the centre of mass in front of the line through the ischial tuberosities; (c) weight bearing on the pelvis and feet. The child was placed in front of a grid line mirror for posture checking. Arm mobility was assessed three times with an interval of a week. Sessions were scheduled in the morning with each individual's session taking place at the same time of the day. Subjects served as their own controls. During the three-week period, participants attended daily rehabilitation sessions from Monday to Friday.

During each session, arm-hand performance was tested with the Upper Limb Physicians Rating Scale (ULPRS) (Graham, Aoki, Autti-Ramo, Boyd, Delgado & Deborah, et al., 2000). in two seating conditions, 10 minutes per condition: (1) condition H, in which seat-surface was oriented horizontally (Figure 1a) and (2) condition FW, in which the child's best degree of forward tilting was used (Figure 1b). Conditions H and FW were applied in random order with an interval of 20 minutes. Both seating conditions also included (a) a backrest at the lower back; (b) a pelvis strap to avoid sliding; (c) an abductor pad attached to the seat; (d) knee locks attached to the front of the seat base; and (e) a foot plate (without additional foot support/orthosis). Participant S3 was tested while sitting independently without a pelvis-strap as he enjoyed this 'free' situation. The sessions were recorded by two cameras with a frontal and lateral view (side of the tested arm). The hand which the child preferred to use to draw or manipulate an object was regarded as the dominant hand. The ULPRS is a clinical assessment, developed for the evaluation of change in arm movement patterns in children with CP during spontaneous behaviour (Graham, Aoki, Autti-Ramo, Boyd, Delgado & Deborah, et al., 2000). In the current study the child was offered a standardized set of three playing conditions. The conditions aimed at eliciting specific motor behaviour assessed by the ULPRS (see supporting information, Table 3). The conditions consisted of (a) a children's book; (b) cubes and a cup; and (c) a ball. The child played with the objects, encouraged by the assessor who was a Bachelor undergraduate student and trained to use ULPRS. The play situation resulted in spontaneously generated behaviour that could be assessed with the ULPRS. For instance, in the 'book condition' the child often started to open the book. This allowed for assessment of the ULPRS item of "active supination with elbow flexion". In the condition with the cubes and cup, the child often started to put the cubes into the cup, allowing for assessment of "active wrist dorsiflexion". The ball condition was introduced by putting the ball in three different positions, thus eliciting reaches to the midline and to both sides.

On the basis of the video recording, the whole set of the 9-item ULPRS assessment was run for each arm separately, with the right and left arm in random order. The maximum ULPRS score which each arm could obtain is 24 points. The 30 videos (5 children assessed in 2 conditions during 3 sessions) were assessed in random order by a masked and well-trained observer (SP). Two assessors (WP and WS) assisted in testing and video-recording.

Figure 1: A participant in the two sitting conditions

Fig. 1(a)

Fig.1(b)

(a) condition H and (b) condition FW at 20 degrees. The black line denotes the line of gravity. It is slightly anterior to the ischial tuberosities in both conditions. In the condition FW (panel b) the child has a straighter neck, a more upright back, and more weight bearing on the feet. Figures published with parental permission.

Statistical analysis

Firstly, all ULPRS scores of all participants were pooled in order to assess homogeneity of variance in the two conditions. The assumption of Mauchly's test of sphericity indicated that parametric tests could be used for data analysis ($p>0.05$). To evaluate the effect of position on the ULPRS scores of each arm, two-way repeated measures ANOVA was applied using condition (H and FW) as a within-participants factor, and session (1st, 2nd, 3rd week) as a between-participants factor. To identify the source of significant differences among means, post-hoc analysis was performed using the Bonferroni test. Differences reaching $p<0.01$ (two-tailed) were considered statistically significant.

Reliability

Prior to the study, training of scoring was done and reliability of scoring was assessed by evaluating the agreement of three raters, including SP, on scores of four videos of two children with CP not included in the present study. Interrater agreement for the total ULPRS scores between the three assessors was satisfactory (ICC = 0.764). The ICCs greater than 0.7 were considered reliable for sample-based research (Morris, Kurinczuk, Fitzpatric & Rosenbaum, 2006). SP was randomly selected to be a masked assessor. The other two trainees (WP and WS) assisted in testing and video-recording.

Results

The participants' characteristics are described in Table 1. The evaluation of the child's best degree of forward tilting resulted in the application of the 10-degree insert in two children and the 20-degree insert in three. The 30-degree wedge insert was not applied as it was associated with postural instability. All participants completed all testing sessions.

ULPRS scores [median (range)] were higher in the FW [dominant arm: 20 (16-22), non-dominant arm: 16 (11-21)] than in the H condition [dominant arm: 17 (13-21), non-dominant arm: 13 (9-20)]. The ANOVA revealed a significant main effect of condition (dominant arm: $F(1,4)=63.39$, $p=0.001$, non-dominant arm: $F(1,4)=23.06$, $p=0.009$), but not of testing session (dominant arm: $F(1.21,4.83)=0.03$, $p=0.970$, non-dominant arm: $F(1.91,7.66)=0.37$, $p=0.724$).The Bonferroni post-hoc analysis confirmed the significant effect of the FW condition. The results of the condition (H and FW) are presented in Table 2.

Table 1: Clinical characteristics of participants

Variables	S1	S2	S3	S4	S5
Sex (F, M)	F	M	M	F	M
GMFCS	2	3	3	4	4
Age (y. mo)	1.1	1.9	2.7	3.5	4
GA (wk)	28	28	40	28	40
Wedge insert (degrees)	+20	+10	+20	+20	+10
Severity of UE spasticity	R>L	L>R	R>L	L>R	R>L
Handedness	L	R	L	R	L
Weight (kg)	15	11	15	11	14
Height (cm)	84	83	87	85	103

S= Subjects, all had bilateral spastic CP with signs of truncal hypotonia, Functional skill: S2-S5 can do floor sit independently, S1does floor sit with support of hips, F=female, M=male, GMFCS= Gross motor function classification system, age represented in y= year, mo= month, +10 and +20 = 10 and 20 degrees of forward tilting of seat-surface, UE= upper extremity, R= The Right handedness, L= The Left handedness, GA= gestational age at birth (median = 28 wk GA), median weight = 14 kg, median height = 85 cm. The dominant hand was defined as the hand with which the child preferred to use, draw or manipulate objects.

Table 2: The results of the condition (H and FW)

Arm-hand function	Seating	ULPRS scores [median (range)]	ANOVAa
Dominant arm	FW position H position	20 (16-22) 17 (13-21)	$F_{1,4}$ = 63.39, p = 0.001
Non-dominant arm	FW position H position	16 (11-21) 13 (9-20)	$F_{1,4}$ = 23.06, p = 0.009

a ANOVA Statistics = statistical significance after Bonferroni correction. H=horizontal seating condition, FW=forward tilting condition, ULPRS scores = median scores of the Upper Limb Physician Rating Scale [median (range)] of five participants.

Table 3: : Support Information, Upper Limb Physicians Rating Scale (ULPRS) (Adapted from Graham *et al., 2000) (In brackets: playing conditions eliciting spontaneous behaviour of ULPRS parameters, designed activities used in this preliminary study)*

ADL = Activity daily living

Parameter	Definition	Scores
1. Active elbow extension (normal 180°) *(reach out in midline)*	>10° reduction 0–10° reduction No reduction None	0 1 2 0
2. Active supination in extension (elbow extended, forearm supinates) Mid-position: palm 90° to horizontal *(reach out to the side)*	Under mid-position To mid-position, Past mid-position	1 2 3
3. Active supination in flexion (elbow flexed 90°, forearm supinates) *(open a book)*	None Under mid-position To mid-position, Past mid-position	0 1 2 3
4. Active wrist dorsiflexion (forearm supported, active dorsiflexion of wrist) Mid-position: palm level with forearm (*grasp & release a cube/a ball/ put a cube in a cup)*	None Under mid-position To mid-position, Past mid-position	0 1 2 3

Parameter	Definition	Scores
5. Wrist dorsiflexion (angle of movement) *(throw a ball)*	With ulnar deviation With radial deviation Neutral	0 0 1
6. Finger opening *(grasp & release a cube/a ball)*	Only with wrist flexion, With wrist in neutral position With wrist in dorsiflexion	0 1 2
7. Thumb in function *(grasp & release a cube/a ball)*	Within palm Pressed laterally against index finger Partly assists in grasp Thumb-finger grasp possible Active abduction	0 1 2 3 4
8. Associated increase in muscle tone *(clinical impression during tasks)*	In all manipulative functions Only with fine motor manipu-lation Only with walking or running None	0 1 2 3
9. Two-handed function *(transfer a cube/a ball/ put a cube in a cup/drink from cup/ throw a ball or during all tasks)*	None Poor, no use or hidden functions Use of all functions but limited in ADL Use of all functions, not limited in ADL	0 1 2 3
Total scores	= 24	

Discussions

This exploratory preliminary study indicated that the FW condition was associated with a significant improvement of arm-hand function, with no effect of testing sessions. A latter result indicated that a repeated measure on these seating conditions did not affect participants' learning of a task. Our results are in agreement with several studies (Miedaner, 1990; Myhr & von Wendt, 1991; Myhr, Wendt, von Norrlin & Radell, 2008; Sochaniwskyj, Koheli, Bablich, Milner & Lotto, 1991). Also, McClenaghan, Thombs & Milner. (1992) found a positive effect of FW tilting, be it just a minor one, which could be related to the minor degree of FW tilting, i.e., 5 degrees. However, Reid and colleagues did not find an effect of 10- and 15-degree FW tilting, presumably due to the limited power of the studies (Reid, 2008; Reid, Sochaniwskyj, & Milner, 1992). The systematic review by Stavness (2006) also suggested that 15 degrees is an optimal degree of tilting position. The studies which reported an adverse effect of FW tilting either studied children that had more severe forms of CP than the children we studied (Nwaobi, 1987; Nwaobi, Brubaker, Cusick & Sussman, 2008), or did not use foot support (Hadders-Algra, Heide, Fock, Stremmelaar, Eykern & Otten, 2007). Thus, our data suggests that 10 to 20 degrees FW tilting, in combination with foot support in children with mild to moderate bilateral spastic CP, may be beneficial for arm-hand function. The strength of this small preliminary study is that we limited ourselves to young children with Bi-CP, who were tested in their own best FW sitting condition. Additional strengths are the use of a reliable tool to assess arm-hand function (Graham et al., 2000; Park, Joo, Kim, Rha & Jung, 2015), the 3-repeated measures, the random application of sitting conditions, the use of a frontal and lateral video view, the fact that the video-assessor was masked to the testing condition (H or FW) and testing session (1^{st}, 2^{nd} or 3^{rd}).

Limitation

The major limitation of this exploratory preliminary study is the small sample size. Another limitation was that we realize that the ANOVA is a parametric test and thus not optimal for the present set of data, but it was the only way to get some idea of the effect of multiple testing. Therefore, our findings do not allow for generalization. Future studies in larger groups are needed to evaluate the exact nature of the effect of FW tilting of the seat surface in children with CP, on arm-hand function and postural performance. These studies should address the effect of additional foot support and include children with bilateral and unilateral spastic CP.

In conclusion, our preliminary study suggests that FW tilting of the seat-surface may enhance arm-hand function in preschool children with Bi-CP. Similar studies in larger groups are needed to confirm this suggestion.

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Conflict of Interest Statement

MA received another adaptive chair produced by Kit for life, Co. Ltd. Thailand, as part of the industrial co-project of the IPUS3 grant. The latter grant is part of the Thai governmental IRPUS Research Program, which promotes collaboration between scientists and industry. The author alone is responsible for the content and writing of the article.

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