FIVE-YEAR FOLLOW-UP OF FUNCTIONAL SITTING POSITION IN CHILDREN WITH CEREBRAL PALSY

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The choice of wheelchairs and other chairs is of major importance in the habilitation of non-ambulant children with cerebral palsy (CP). When reviewing existing adaptive seating systems, Mulcahy *et al.* (1988) found that the seats could often not be adjusted to accommodate or encourage changes in physical ability and growth. Those authors also held regular seating clinics, and found that children were continuing to develop fixed deformities due to the seating and other positioning devices used.

As part of a research project to investigate how children with CP can overcome these problems, a functional sitting position (FSP) was defined (Myhr and von Wendt 1990, 1991). In an FSP, postural control is sought to allow optimum use of arms and hands, *e.g.* when playing, eating or performing various daily activities when sitting at a table. In this context, postural control is defined as control of the body's position (posture) in space for the dual purposes of maintaining equilibrium and orientation in sitting; equilibrium is defined as control of the upper body (head, trunk and upper-extremity segments) over its base of support; and orientation means maintaining an alignment of body segments with respect to one another that is appropriate to the movement or task (Horak 1992, Shumway-Cook and Woollacott 1993).

The base of support in sitting is formed by the ischial tuberosities (ITs) (Åkerblom 1948, Pheasant 1986, McClenaghan 1989) and the thighs. Movements occur in the sagittal plane around the fulcrum at the ITs supported on the seat (Åkerblom 1948, Pheasant 1986, McClenaghan 1989) and also around the coronal axis through the hip joints (Åkerblom 1948). For the FSP, the pelvis had to be forward-tilted and the child's upper body had to be anterior to the fulcrum at the ITs, thus allowing an upright posture. A hip-belt was used to distribute the weight symmetrically and fix the pelvic position, and an abduction orthosis, to enchance these effects (Myhr and von Wendt 1990, 1991). The chairs had low back-rests, and foot-rests were placed directly under the knee-joint axes (Myhr and von Wendt 1991), allowing knee flexion and backward movement of the feet. Each child sat at a cut-out, level table*.

Until the early 1990s there was a lack of function-based assessment methods and it was difficult to measure sitting posture in children with CP (Bertoti 1988, Mulcahy *et al.* 1988, McEwen and Karlan 1989, Kluzik *et al.* 1990, Reddihough *et al.* 1990, Rosenbaum *et al.* 1990). This situation led to the development of a new observation technique, the Sitting

*A table with a semicircle cut out of the front edge.

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TABLE I
Characteristics of children with spastic diplegia at time of five-year follow-up (N=10)

Child	*Severity*	*Age (yrs:mths)*	*Method of mobility*	*Additional disabilities**
A	Moderate	10:9	Wheelchair	Visual impairment, dislocated hip, communication impairment, MR
B	Severe	8:8	Wheelchair	Communication impairment
C	Severe	8:8	Wheelchair	Visual impairment, communication impairment, MR
D	Mild	8:1	Wheelchair	Pes equinovarus
E	Mild	8:9	Walking	
F	Severe	8:9	Wheelchair	Visual impairment
G	Moderate	7:3	Wheelchair	Visual impairment, epilepsy, MR
H	Mild	7:8	Walking	Communication impairment, MR
I	Moderate	7:5	Gait orthoses	
J	Moderate	9:6	Wheelchair	Visual impairment

*MR = mental retardation.

Assessment Scale (SAS) (Myhr and von Wendt 1991). The SAS was designed to evaluate head-, trunk- and foot-control and arm- and hand-function before and after seating interventions in clinical physiotherapy practice and in research settings. The scale has been tested twice for reliability and has demonstrated high intra- and inter-rater reliability (Myhr and von Wendt 1991, Myhr *et al.* 1993).

The main aim of the present study was to re-assess children who were introduced to and tested in the FSP five years previously, since very few studies (Pope *et al.* 1994) have addressed the long-term effects of various sitting positions in children with CP.

A second aim was to re-examine the reliability of the SAS, since the standardization of the tasks to be performed had been developed further.

Method

Patients

From 1987 to 1988, 55 children with CP, from two paediatric rehabilitation centres in Sweden, were assessed with the SAS: (1) in the original sitting position (OSP), (2) in the FSP, and (3) in various other sitting positions. The five youngest children from each group (two girls and eight boys) were selected for the present follow-up study, because they were initially least affected by contractures, pelvic obliquities, dislocated hips and scoliosis. However, the youngest child (aged 2.1 years) was selected for this study even though he initially had pes equinovarus. One of the children died and had to be replaced by the next youngest child, who had a subluxed hip (child A in Table I).

All the children had spastic diplegia, which, according to the classification by Hagberg and Hagberg (1993), can include children with very slight to very severe disability. Among the 10 children participating in this follow-up there was a roughly equal distribution of children classified as having mild, moderate and severe forms of CP (Table I), as defined by Trefler *et al.* (1978). However, all the children had unsolved seating problems initially. Mean age at initial assessment was 3.6 (range 2.1 to 5.8) years, with a mean age at follow-up of 8.7 (range 7.3 to 10.9) years.

Informed consent was obtained from the parents.

Procedure

In the 1987/88 assessment, the 10 children participating in the study were all videotaped and photographed from the side for five minutes while sitting at a table performing standardized tasks, and were assessed with the SAS. At the recent follow-up they were again video-taped (using a JVC Super-VHS video-camera) and photographed (with a Canon F1 camera) in the same standardized way, and re-assessed with the SAS. A paediatric physiotherapist known to each subject sat

TABLE II

Details of chairs in initial and follow-up sitting positions*

Child	Initial original sitting position					Initial functional sitting position					Five-year follow-up				
	Chair	*Seat inclin.*[1]	*Back inclin.*[2]	*Abduction orthosis*	*Foot support*	*Chair*	*Seat inclin.*[1]	*Back inclin.*[2]	*Abduction orthosis*	*Foot support*	*Chair*	*Seat inclin.*[1]	*Back inclin.*[2]	*Abduction orthosis*	*Foot support*
A	Maxit	5°b	0°	–	–	Maxit	5°f	0°	+	h	Panda	10°f	5°b	–	h[3,4]
B	Maxit	15°b	0°	–	–	Maxit	5°f	0°	+	h	Maxit	5°f	0°	+	h
C	Rida	10°b	0°	–	h	Rida	5°f	0°	+	h	Real	0°	0°	+	+
D	Maxit	5°b	0°	–	h	Maxit	5°f	0°	+	h	Real-3011	5°f	0°	Lower-leg support	+
E	Rida	0°	0°	–	h[3]	Tripp-Trapp	5°f	0°	+	+	Real-3011	5°f	0°	–	Floor
F	Tripp-Trapp[5]	0°	0°	–	+	Tripp-Trapp	10°f	0°	+	+	Real-3011	0°	0°	–	+
G	Maxit	5°b	5°f	–	h	Rida	5°f	0°	+	h	Real-3011	10°f	0°	+	+
H	Maxit	5°b	0°	–	h	Maxit	5°f	0°	+	h	Real-3011	0°f	0°	+	+
I	Mercado	0°	5°f	–	h[3]	Mercado	5°f	0°	+	+	Real-3011	8°f	0°	+	+
J	Wheel-chair	10°b	10°b	–	h[3]	Mercado	5°f	0°	+	+	Real-3011	5°f	0°	+	+

*Inclin. = inclination; b = backward; f = forward; h = foot-support including heel-cups; +/– = present/absent

[1]From horizontal plane.

[2]From vertical plane.

[3]Foot-supports were placed anterior to knee-joints.

[4]Specially adapted foot-support.

[5]With loop hindering forward movements.

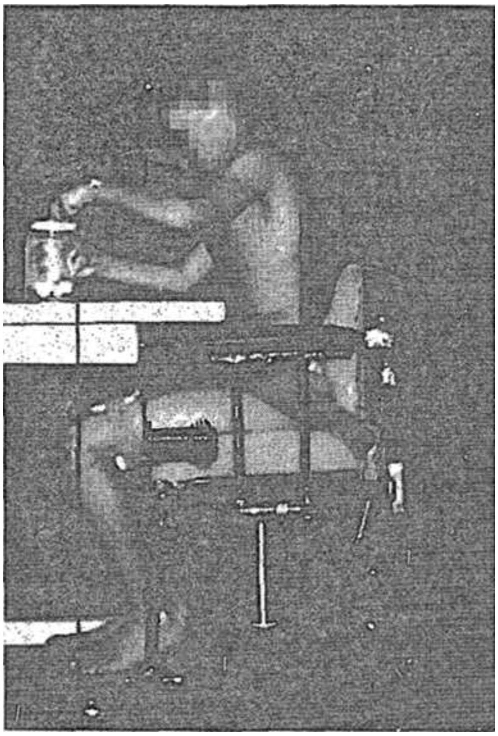

Fig. 1. Child (H) with cerebral palsy sitting in functional sitting position (FSP) at the five-year follow-up. Fulcrum at ischial tuberosities and knee joint axis are indicated by lines drawn vertically through landmarks.

opposite each child and offered assistance. The children sat in their usual school chairs (Table II). No adjustments to the chairs or the children's sitting positions were made. The children selected for this follow-up were all followed and treated at the same centres as five years previously, with physiotherapy, occupational therapy and speech therapy carried out according to the same principles.

Before filming and photographing, white adhesive paper markers were placed on the children as anatomical landmarks (Myhr and von Wendt 1990, 1991). Because the marking-point at the greater trochanter was concealed by the hip-belt, this landmark had to be transferred to the corresponding point on the belt.

In the original experimental situation (Myhr and von Wendt 1991), the tasks were standardized so that the child had to do the following: hold up the head; turn the head to one side and then the other; reach out to grasp, hold and release a familiar toy or object; and support himself or herself against the table and perform the same simple operations. In the present study the guidelines were identical, although some minor tasks were added. Materials used were placed on the table sequentially at marking points for an arm's length and $1^1/_2$ arm's lengths anterior to the trunk midline when the child sat upright (modified after Fife *et al.* 1991). The children had to perform the following actions: lean forward to touch a rattle $1^1/_2$ arm's lengths away, and then right himself or herself; reach forward, grasp two or three toys an arm's length away (one at a time) and release the toys into a box on the table; unscrew and replace the lid of a jar; place six dice in a jar, one at a time; and lift the jar using both hands.

Photographs were taken (1) when the child reached forward, (2) when the child performed the task, and (3) when the child righted himself or herself. (A detailed manual with scoring instructions is available from the first author.)

DATA ANALYSIS

Two different methods of evaluation were used. First, photographs were used to determine FSP. Postural alignment was estimated from the position of the child's upper body relative to the marking-point on the hip-belt over the greater trochanter (used as an approximate marking-point for the fulcrum) (Myhr and von Wendt 1990, 1991), and the positions of the feet were estimated relative to the knee-joint axis. A line was drawn vertically through the landmarks for the greater trochanter and at the lateral epicondyle of the femur (Figs. 1 and 2). Second, head-, trunk- and foot-control, arm- and hand-function and SAS results obtained in 1987/88 were compared with those obtained in 1993. Differences between the two periods were statistically tested by Wilcoxon matched-pairs signed-ranks test.

Intra- and inter-rater reliability was assessed for the SAS. Two physiotherapists with three and six years' experience of working with children were instructed (by U.M.) and provided with video-films of all 10 children and the SAS scoring manual. These physiotherapists were unacquainted with all but one child in each of the groups studied. They assessed both the FSP from the initial study and the

TABLE III

Results in initial and follow-up sitting positions assessed by Sitting Assessment Scale (SAS)[1]

Child	*Head-control*			*Trunk-control*			*Foot-control*			*Arm-function*			*Hand-function*			*Total*		
	Initial		*5-yr follow-up*	*Initial*		*5-yr follow-up*	*Initial*		*5-yr follow-up*	*Initial*		*5-yr follow-up*	*Initial*		*5-yr follow-up*	*Initial*		*5-yr follow-up*
	OSP	*FSP*		*OSP*	*FSP*		*OSP*	*FSP*		*OSP*	*FSP*		*OSP*	*FSP*		*OSP*	*FSP*	
Did not use FSP[2]																		
A 3	4	2	3	4	2	1	3	1	2	3	2	3	3	2	12	17	9	
B 1	3	2	2	3	1	1	2	1	2	3	2	1	3	2	7	14	8	
Total	4	7	4	5	7	3	2	5	2	4	6	4	4	6	4	19	31	17
Used FSP[2]																		
C 2	3	3	1	3	3	1	3	4	2	3	2	2	3	2	8	15	14	
D 4	4	4	4	4	4	2	3	3	4	4	4	4	4	4	18	19	19	
E 4	4	4	1	4	4	2	3	4	4	4	4	4	4	4	15	19	20	
F 2	2	3	2	2	3	3	4	4	2	2	3	2	2	3	11	12	16	
G 2	3	4	2	2	3	4	4	4	3	3	3	3	3	3	14	15	17	
H 3	4	4	3	3	3	3	3	4	4	4	4	3	3	4	16	17	19	
I 4	4	4	3	4	4	2	4	4	3	4	4	3	3	4	15	19	20	
J 2	3	4	2	3	4	3	4	4	3	3	4	3	3	4	13	16	20	
Total	23	27	30	18	25	28	20	28	31	25	27	28	24	25	28	110	132	145*

[1]Scoring: 1 = no control/function; 2 = poor control/function; 3 = fair control/function; 4 = good control/function.
[2]During the five years between initial and follow-up assessments.
*Significant improvement in comparison to initial functional sitting position ($p<0.05$), Wilcoxon matched pairs signed-rank test.
OSP = original sitting position; FSP = functional sitting position.

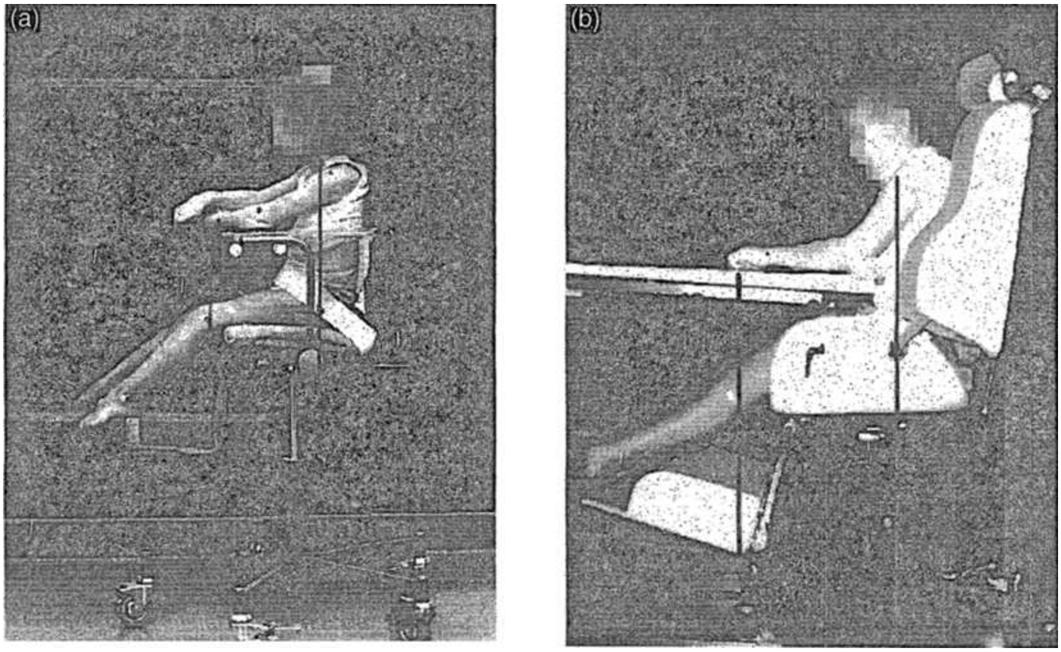

Fig. 2. Child (A), who had deteriorated after initial study, (a) sitting in initial original sitting position (OSP) five years ago, and (b) at five-year follow-up. Fulcrum at the ischial tuberosities and knee joint axis are marked with lines drawn vertically through landmarks.

actual sitting position from the present study, using the video-tapes, in accordance with instructions in previous studies (Myhr and von Wendt 1991, 1993). Two weeks after their first assessment, the physiotherapists saw the videos again and re-rated the children. The first author, who had five years earlier assessed all 10 children in the initial studies, also re-rated the same 10 children without simultaneously reviewing the initial recordings. Comparisons between the ratings of the two physiotherapists and also between those of the physiotherapists and the first author were made, and analysed using Spearman's rank order correlation coefficient and Kendall's coefficient of concordance. The time that the two physiotherapists needed to administer the SAS was measured, because this affects its clinical use (Jette 1984).

Results

After five years, eight of 10 children were sitting according to the guidelines for an FSP (Fig. 1).

These eight children showed significant improvements in head-, trunk- and foot-control and arm- and hand-function ($p<0.05$) (Table III). Five children sitting in an FSP had total scores of 19 or 20 (out of a maximum 20 points), indicating that they had fair to good head-, trunk- and foot-control and arm- and hand-function (Table III).

Analyses of the photographs and video-films showed that all eight children sitting in an FSP were sitting with their pelvis tilted forward, and with their upper bodies anterior to the fulcrum at the ITs when they performed the standardized tasks at the table (Fig. 1). They were all held to the seat by a hip-belt, except one who did not need the belt any longer (child E). Five children used an abduction orthosis, one child held the hips abducted using a lower-leg support, and the other two children held their hips abducted without any special equipment (Table II). The children who had previously sat with their lower extremities extended (because of spasticity) sat with their knees flexed at the follow-up. Moreover, all eight children sat with their feet on the foot-rest without any fixation (Fig. 1).

The two children (A and B, Table I) who did not sit in an FSP sat with a backward-tilted pelvis and with their centre of gravity behind the ITs (Fig. 2b, Table II). They had deteriorated on all items assessed, and their trunk-control had worsened (Table III). The most striking result was that of child A, who in the initial study had scored 'no foot-control' in the OSP (Fig. 2a) and 'fair foot-control' while sitting in the FSP, but in the present study had deteriorated to 'no foot-control' (Fig. 2b, Table III). Child A had her lower extremities strongly extended the whole time (Fig. 2b), whereas child B extended the lower extremities occasionally so that his feet were anterior to the knee-joint axis. Child B used the same chair as five years earlier (when he had been only three years old). The foot-supports did not support his feet, and he lost balance easily.

There was high intra- and inter-rater agreement between the two rating physiotherapists and also between the two physiotherapists and the first author (Table IV). The mean time for using the SAS was 16 minutes per child (two sitting positions lasting five minutes each).

TABLE IV
Inter-rater and intrarater reliability for Sitting Assessment Scale (SAS)

Raters	*Inter-rater* W	r_s	*Intrarater* r_s
PT_1 - PT_2 - PT_3	0.94**		
PT_1 - PT_2		0.89*	
PT_1 - PT_3		0.93*	
PT_2 - PT_3		0.91*	
PT_1			0.98*
PT_2			0.90*
PT_3			0.97*

r = Spearman rank order correlation coefficient; W = Kendall coefficient of concordance. PT_1, PT_2 = physical therapists' ratings; PT_3 = first author's ratings.
*$p<0.01$; **$p<0.001$.

Discussion

With the change from the OSP to the FSP in the initial studies (1987/88), the effect on posture and arm- and hand-function was instantaneous and striking, with a significantly improved score in the FSP according to the SAS ($p<0.001$) (Table III) (Myhr and von Wendt 1991). The central finding of the present study was that this favourable development appeared to continue in the children who maintained their FSP. However, there were factors which make it difficult to draw definite conclusions. There was no true control group, because we considered such a design ethically questionable. The other reason for not using a control group was the consideration that a strict one could not possibly be created so that all other therapy over the five years could remain identical. There was also the difficulty of finding matched controls. The two children who did not sit in an FSP and who deteriorated give support to our hypothesis of the favourable effect of the FSP, but they should be viewed as examples of the effect of inadequate sitting solutions and not as true controls.

The children sitting in the FSP did not deteriorate but continued to improve significantly. Whether deterioration or improvement should be expected in these children is difficult to judge as there are no detailed prospective follow-up studies of the natural course of motor impairments in CP (Nelson and Ellenberg 1982). Theoretically a favourable effect of the FSP over time could be expected, as we previously demonstrated that leg-muscle activity in knee extensor, adductor and plantarflexor muscles, measured by surface electromyography, decreased in the forward-leaning and flat-sitting positions with the use of an abduction orthosis (FSP) in comparison with muscle activity measured in reclining and flat positions without abduction orthosis (Myhr and von Wendt 1993).

An important factor in obtaining equilibrium is that the chair design does not hinder movement of the body segments relative to each other. The L-shaped heel-cups of the chairs (the type of foot-support shown in Fig. 2a) appeared to cause such hindrance. These facts were obvious from the SAS observations. The evident reduction of extensor spasticity when sitting in the FSP, and the optimal 'foot-control' as scored by the SAS in the present study, further emphasize the need to ensure that the design of the foot-supports themselves does not generate problems for the child in achieving upright posture and postural control when sitting 'working' at a table. Furthermore, fixation indeed hindered the individual child in the ability to practise and develop righting and equilibrium reactions. For example, 22 of 23 children while sitting initially in the OSP were fixed to the back-rests by straps and shells of various types without the possibility of postural adaptations or balance (Myhr and von Wendt 1991).

A possible explanation for the improvements obtained could be the meticulous adjustments of the chairs according to the principles for FSP carried out during the five-year period. For example, hindrances such as plates or straps in the back of the foot-rests, which had previously been removed in the experimental situation in the FSP, had also been removed in the chairs that the children used daily, and foot-plates had been adjusted parallel to the floor, so there was no longer any limitation to moving the feet in an anterior–posterior direction along with the child's upper-body movements (Fig. 1). While sitting in an FSP the children could balance their upper bodies anterior or above the fulcrum at the ITs within stability limits determined by the base of support (Shumway-Cook and Woollacott 1993) and the vertical back-rest, with further consequences for other segments of the body.

The absence of improvement and actual deterioration over time for the two children (A and B) who were not sitting in an FSP is probably the result of several factors, but it is clear that the children's clinical disorders did not differ from those of the remainder of the group with respect to level of impairment. Further analysis of the photographs revealed that minor but essential details of the chairs can have obvious effects. Thus for child A, who had deteriorated the most, the chair was newly equipped with specially adapted but unsuitable foot-supports, and the back-rest was reclined (Fig. 2b, Table II). With the knees extended, the hamstring muscles caused backward tilting of the pelvis. Furthermore, in such a position, with the back-rest reclined, postural control will be restrained and extensor spasticity in the legs evoked. This is in agreement with the findings of Falk Bergen and Colangelo (1985), who noted that elevating the leg-rests of sitting patients with increased tone, when the hamstring muscles are tight, causes a posterior pelvic tilt, and also contributes to asymmetric sitting. Child B, on the other hand, was totally unstable when sitting, dangling his legs without support from the foot-rest. The chairs of the two children whose condition had deteriorated had been adjusted without consideration for upper-body function, which could have contributed to the unfavourable outcome.

There is continuing discussion as to whether seat inclination does affect arm- and hand-function (McPherson *et al.* 1991, McClenaghan *et al.* 1992) and whether orientation of the body relative to the vertical plane affects upper-extremity function (Nwaobi 1987). Our results (Myhr and von Wendt 1990, 1991, 1993) indicate that it is not the seat inclination itself but the relative position of the pelvis, the upper body and the feet that is critical in obtaining the optimal postural control and arm- and hand-function. For correct positioning of these body segments, however, it is crucial that the back-rest inclination is vertical, supporting the pelvis, so that the upper body is held anterior to or above the fulcrum at the ITs and above the supporting seat surface. The outcome for child A in the present study (Fig. 2b, Table III) shows the difficulties in preserving the optimal arm- and hand-function when sitting with the pelvis tilted backward and the upper body posterior to the fulcrum. These suggestions seem to be in agreement with Nwaobi (1987), whose results implied that the level of upper-extremity performance was higher with the body in an upright position and with the seat flat than with posterior-reclined back-rest. Seat inclination may vary individually. However, tilting the seat slightly forward can be an efficient way of facilitating a forward tilt of the pelvis. In our experimental situations in the initial study (Myhr and von Wendt 1991), the seat in the FSP was inclined forward for that purpose.

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SUMMARY
Ten children with cerebral palsy (CP) were videotaped and photographed after the introduction to a functional sitting position (FSP—defined as a position in which children with CP could gain head-, trunk- and foot-control and the maximum degree of independent function when performing arm and hand movements during tasks) and again five years later. Head-, trunk- and foot-control, and arm- and hand-function were assessed from video-tapes by the Sitting Assessment Scale. The eight children who had been using the FSP throughout this period showed slight but significant improvement; the remaining two had deteriorated. Since all 10 children had undergone similar rehabilitation programmes, it is concluded that sitting in an FSP contributed to their improvement in the ability to use the hand and arm.

RÉSUMÉ
Un suivi de cinq ans d'une position assise fonctionnelle chez des enfants IMC
Un examen vidéo et photographique a été effectué chez dix enfants IMC après la mise en place d'une position assise fonctionnelle (FSP—définie comme une position où les enfants IMC pouvaient acquérir un bon contrôle de la tête, du tronc et des pieds, et une fonction indépendante en réalisant des mouvements des bras et des mains au cours d'une tâche) et de même cinq ans plus tard. Le contrôle de la tête, du tronc et des pieds, et la fonction des bras et des mains furent évalués à partir des bandes vidéo selon la Sitting Assessement Scale. Les huit enfants qui avaient utilisé la FSP tout au long de la période d'examen présentèrent un progrès léger mais significatif; l'état se déteriora pour les deux autres enfants. Puisque le programme de rééducation entrepris pour les dix enfants était identique, les auteurs concluent que la position assise en FSP contrbue à leurs progrès dans l'utilisation du bras et de la main.

ZUSAMMENFASSUNG
Verlaufskontrolle einer funktionellen Sitzposition bei Kindern mit Cerebralparese über fünf Jahre
Zehn Kinder mit Cerebralparese (CP) wurden auf Video aufgenommen und fotografiert, nachdem sie in eine funktionelle Sitz-position (FSP) eingeführt waren—diese ist definiert als eine Position, in der Kinder mit CP Kopf, Rumpf und Füße unter Kontrolle haben und ein Maximum an Freiraum haben, wenn sie bei der Ausführung von Aufgaben Arm- und Handbewegungen machen—und dann ein zweites Mal nach fünf Jahren. Kopf-, Rumpf- und Fußkontrolle, sowie Arm- und Handfunktion wurden anhand der Videobänder gemäß der Sitting Assessment Scale beurteilt. Bei den acht Kinder, die die FSP während der gesamten Zeit beibehalten hatten, zeigte sich einer leichte, aber signifikante Besserung; die beiden anderen hatten sich verschlechtert. Da alle Kinder ähnliche Rehabilitationsprogramme mit-gemacht hatten, wird der Schluß gezogen, daß das Sitzen in einer FSP dazu beitrug, den Bewegungsfreiraum von Händen und Armen zu verbessern.

RESUMEN
Seguimiento durante cinco años de la sedestación funcional en niños con parálisis infantil
Diez niños con parálisis cerebral (PC) fueron registrados en video y fotografiados tras la introducción de una sedestación funcional (SF), definida como una posición en la que los niños con PC pudieran ganar control de su cabeza, tronco y pies así como la maxima función independiente al realizar movimiemtos con los brazos y las manos. El estudio se repitió cinco años más tarde. El comtrol de cabeza, tronco y pies, así como la función de brazos y manos se evaluaron a partir del video con la Escala de Evaluación de Sedestación. Los ocho niños que habían usado la SF durante este periodo mostraron una ligera, pero significativa, mejoria; los otros dos empeoraron. Dado que los 10 niños habían seguido programas de rehabilitación similares se concluye la SF contribuyó a la mejoria del uso de brazo y mano.

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