ORIGINAL ARTICLE

Conductive Education for Children With Cerebral Palsy: Effects on Hand Motor Functions Relevant to Activities of Daily Living

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ABSTRACT. Blank R, von Kries R, Hesse S, von Voss H. Conductive education for children with cerebral palsy: effects on hand motor functions relevant to activities of daily living. Arch Phys Med Rehabil 2008;89:251-9.

Objective: To study the effects of conductive education, a combined educational and therapeutic task-oriented approach for children with cerebral palsy (CP), on their hand motor functions and activities of daily living (ADLs).

Design: Individual cohort study (B-A-B design).

Setting: Ambulatory, referral center.

Participants: Sixty-four children with CP, severity Gross Motor Function Classification System levels II through IV, ages 3 to 6 years.

Interventions: Phases B: a 4.5-month period of special education, including 2 hours of individual physiotherapy or occupational therapy per week (special education). Phase A: during a 9-month period, conductive education was administered in 3 blocks of 4 weeks (7 hours daily from Monday through Friday); between the blocks, special education was applied as in the B phases.

Main Outcome Measures: Transformed sum scores (0.00–1.00) for coordinative (eg, force-movement synergy during object manipulation, aiming) and for elementary hand functions (eg, maximum grip force, tapping), based on kinetic and kinematic measures; standardized parent questionnaire to measure ADL competence scores from 0.00 (dependence) to 1.00 (independence). Outcome parameters were changes in these parameters during phase A (intervention) compared with average changes during the B phases (pre- and postintervention). Student *t* tests were used for dependent samples.

Results: Conductive education improved coordinative hand functions by 20% to 25% from baseline, compared with no improvement during special education; the preferred hand improved from .38 to .48 (mean, .10; 95% confidence interval [CI], .086−.114) and the nonpreferred hand improved from .39 to .47 (mean, .08; 95% CI, .034–.116). There were no changes in elementary hand motor functions. ADL competence improved by .11 (95% CI, .070–.149), from .50 to .61 (≈20%), compared with no significant improvement under special education.

Conclusions: Conductive education improved coordinative hand functions and ADLs in children with CP. There was no effect on elementary hand functions.

Key Words: Activities of daily living; Cerebral palsy; Education; Hand; Locomotor activity; Rehabilitation; Task performance.

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CONDUCTIVE EDUCATION, a combined therapeutic and pedagogic program for children with cerebral palsy (CP) developed by the Hungarian child neurologist Andras Petö, has been given increased attention in Western countries in recent years. The main elements of conductive education are: (1) task-oriented learning within highly structured programs; (2) facilitating and commenting on motor actions by *rhythmic intending,* for example, rhythmic speaking or singing; (3) integration of manual abilities into the context of activities of daily life (ADLs); and (4) child-oriented group settings to facilitate psychosocial learning to increase the level of participation.[1,2]

Conductors trained in special education and therapy administer the conductive education program. Because conductive education applies some of the key elements that are effective in the neurorehabilitation of adults—for example, repetitive task-oriented training[3-5] and rhythmic auditory facilitation[6,7]—a similar effectiveness on motor functions of CP children through conductive education appears possible. A meta-analysis of outcome studies of conductive education,[8] however, found that its efficacy on motor abilities and developmental changes was supported only by some uncontrolled, mostly anecdotal studies,[9-11] whereas controlled studies did not find any superior effects on general motor functions.[12,13] Recent studies again found conflicting results; Odman and Oberg[14] did not find better effects on activities, as measured by the Pediatric Evaluation of Disability Inventory, for conductive education versus another intensive training program, whereas Liberty[15] found advantages for conductive education in a group of young children.

Hand functions play a key role in self-care, and independence in self-care is a major goal of conductive education.

In contrast to previous studies that used qualitative scales or clinical tests, in this study we used objective kinematic and kinetic measures of different manual tasks as the main outcome measure. Such measures have been used to examine hand motor functions both in unimpaired children and in children with CP, and have been shown to be related to clinical measures.[16]

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Our hypothesis was that three, 4-week blocks of conductive education (phase A) embedded in a 9-month period of conventional treatment and special education improves coordinative hand functions relevant to ADL competence to a greater extent than does conventional treatment and special education alone, as performed during the preceding and subsequent 4.5-month periods (B phases). At the beginning of this study, this type of block intervention was commonly applied in so-called "summer camps" in Germany, or in block treatments in Hungary; families traveled every year for 2 to 3 block treatments of 3 to 5 weeks. Therefore, we attempted to assess the effectiveness of conductive education in such a temporal setting.

METHODS

Participants

Children with CP, aged 3 to 6 years, were recruited for the study over a 4-year period (1996–1999). The health insurance companies that funded this study insured them. They were tested at the Child Center Munich to determine if they met the study entry criteria. Inclusion criteria were: (1) a well-defined type of CP (spastic, dyskinetic, or ataxic form) as determined by a clinical examination by an experienced child neurologist; Gross Motor Function Classification System (GMFCS) levels II, III, and IV; (2) an intelligence level of at least 60 on the Kaufman Assessment Battery for Children (K-ABC)[17] (range, 60–96); (3) no severe behavioral disorder that could interfere with the group setting in conductive education; (4) no other concomitant neurologic disorders and no neurodegenerative disease; and (5) willingness of caregivers to give their informed consent for a child to participate.

We screened a total 143 children, but only 67 met the inclusion criteria. The local ethics committee approved the study.

Study Design

We used an individual cohort study design (multiple case-control design) following a B-A-B design (fig 1). The B phases consisted of 4.5-month periods with conventional special education (day care) for about 7 hours a day, including 2 individual therapy sessions of 30 minutes each per week (total, 60min) consisting of physiotherapy (PT) based on the Vojta concept or the Bobath method and additional occupational therapy (OT) (once a week for 60min). The program was tailored for each child individually. Within phase A (9mo), the children participated in three, 4-week inpatient blocks of conductive education. During the 3-month intervals, the children continued their individual programs in their special schools at home. All assessments before and after the 4-week conductive education blocks were taken at the Child Center Munich. The design was adapted to the application of summer camps and block treatments widely used in Europe for conductive education.

Measurement points for time 0 (t0), time 1 (t1), time 2 (t2), and time 3 (t3) are shown in figure 1.

Intervention

In the conductive education blocks during phase A, 4 experienced "conductors" from the National Petö Institute in Budapest planned and delivered the conductive education block treatments in groups of 6 to 10 children. The conductors, who are a combination of teacher and therapist, were trained at the university in Budapest for 4 years; the complex interdisciplinary training covers a wide spectrum of educational, pedagogic, and therapeutic content and is combined with basic psychologic and medical knowledge.

Additionally, a director of the Petö Institute supervised the therapy for 1 week during each conductive education block to ensure consistency among the different conductors in their application of the program.

The conductors planned the educational and therapeutic goals and contents of the conductive education for each child. Minute-to-minute protocols of the interventions were evaluated by a psychologist not involved in the intervention in order to assign the components to the predefined categories: ADLs, hand motor and gross motor training, cognitive training, or individual program.

The conventional treatment and education programs in special nurseries or kindergartens (reference or baseline therapy) were kept stable outside the conductive education block interventions. These programs and conductive education lasted about 7 hours a day, 5 days a week. Conventional programs usually included individual PT (Vojta or Bobath method) 1 hour a week and individual OT 1 hour a week, whereas conductive education programs integrated therapy and education and were carried out within group settings. Conventional programs were locally administered in institutions near the children's homes and we could not individually assess them. This, however, was not necessary because the programs and

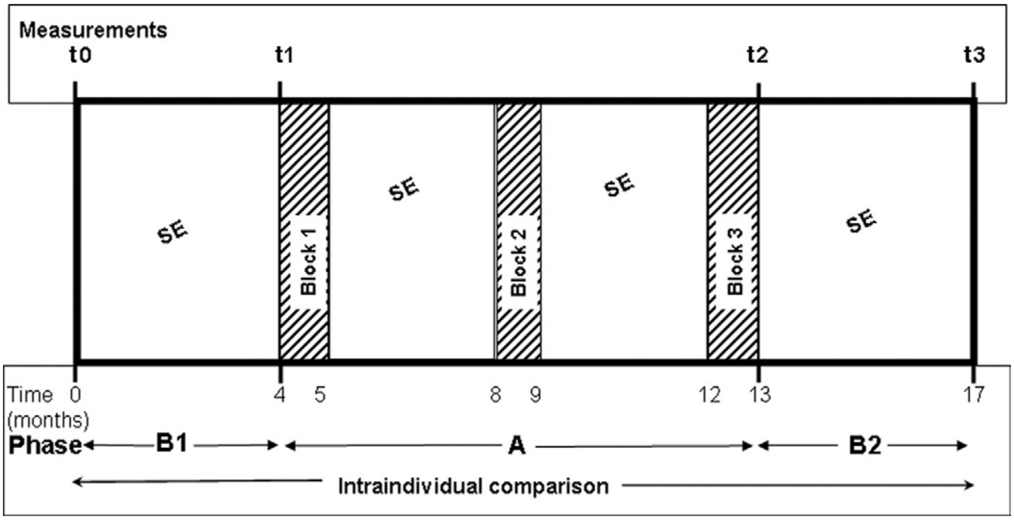

Fig 1. Study design. Phase B: baseline with conventional special education (SE) including individual physical therapy [PT] (1h/wk) and occupational therapy [OT] (1h/wk). Phase A: conductive education; three, 4-week blocks and two, 3-month PT, 1h/wk; OT, 1h/wk and conductive education home tasks. Participants: 3- to 6-year-old children with CP (N=64).

therapeutic input were not changed over the entire observation period and each child served as his/her own control.

Assessments

There were 2 parts of the assessment: first, we applied a battery of objective quantitative measurements of finger-hand functions; second, we applied the Measurement of Activities of Daily Living (M-ADL) questionnaire in a subgroup of 33 children. The M-ADL questionnaire was introduced later because when we began the study there was no standardized German instrument for measuring ADLs and because after the first blocks, parents reported considerable changes in their children's daily living; we therefore attempted to validate these reports with a standardized test which by then had become available.

An independent researcher, blind to the actual treatment period, assessed the patients' measurements of finger-hand functions in an upper-limb motor function laboratory separate from the treatment unit.

For the quantitative measurements of finger-hand functions, the children sat in a stable and comfortable position in a special chair designed for individual adaptation and fixation.[a]

We used the following instruments for the assessments (fig 2)[18-21]: (A) a grip force analysis system with a 200g object containing a uniaxial force transducer and 3 accelerometers[b]; a precision scale[b]; a small cylindrical 20g grip object[b]; (B) a drawing analysis system containing a pressure-sensitive pen and a digitizer tablet[c]; and (C) a 3-dimensional ultrasound-based movement analysis system.[d]

The 3-dimensional movement analysis system was an active marker system, which means that small markers on the hand transmit ultrasound waves to a receiver. There, the markers can easily be identified and the temporospatial variables calculated. Markers were put on the nail of the index finger, over the joint between the index finger and the hand, and over the joint of the wrist (in the middle of the wrist).

Patients performed standardized tasks with their preferred and their nonpreferred hands separately. Only the preferred hand was used in the drawing tasks. Each test was practiced before measurements were taken to ensure that a child understood the task. Further, each task was completed at least 3 times within a defined time interval and a mean was then calculated. From each task, we selected 1 target variable for further analysis. These variables were chosen according to a previous analysis of a reference sample of 192 children, a clinical sample of 103 children with CP,[22] and from other studies.[18,23-26] The tasks and the target variables were as follows:

1. Task: squeeze the 200-g grip object as tightly as possible. The target variable was maximum grip force. Task dimensions were measured in newtons.
2. Task: while holding the grip object increase and decrease grip force as often and as fast as possible (repetitive fastest voluntary isometric force changes). The target variable was the periods of force increase and decrease per seconds. Task dimensions were measured in periods per second.
3. Task: tap with the index finger on the table as fast as possible. The target variable was tapping frequency. Dimensions were measured in number of movements per second.
4. Task: tap with the hand on the table as fast as possible. The target variable was tapping frequency. Dimensions were measured in number of movements per second.
5. Task: lift the grip object from the precision scale. The target variable was duration between touching and lifting the object. Dimensions were measured in milliseconds.
6. Task: move the grip object up and down in defined velocities. The target variable was synchronization of grip force adaptation to the load forces during movement. The dimension was the cross power spectrum density as described by Blank et al.[18]

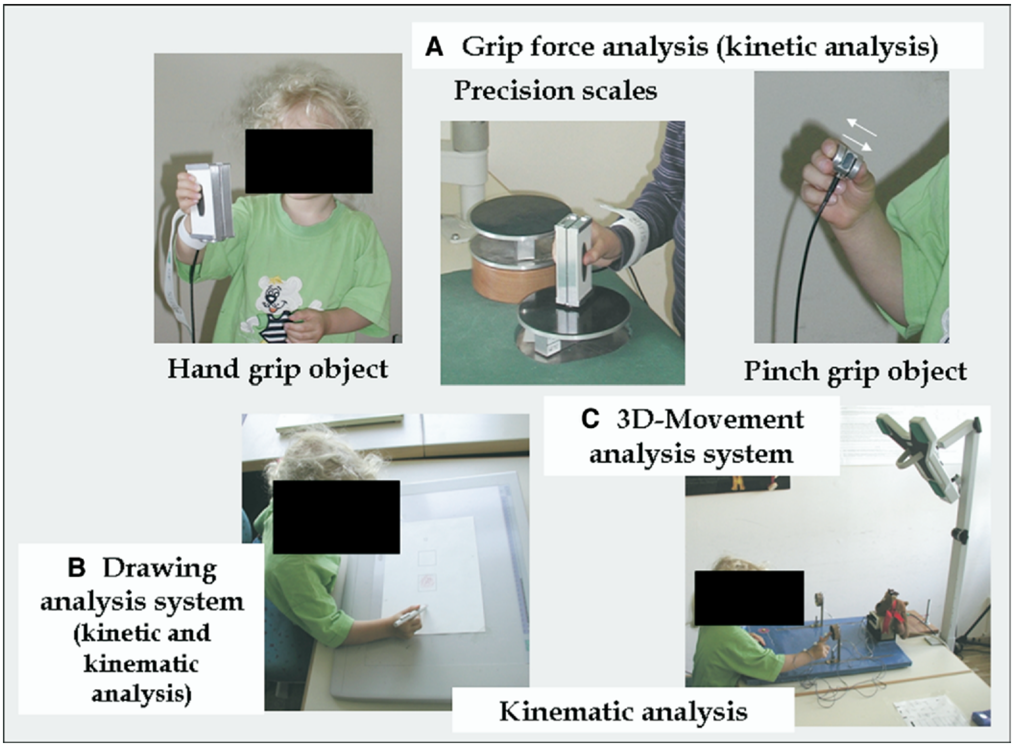

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Fig 2. (A) The kinetic analysis system consisting of a 200g object that contains a uniaxial force transducer, 3 accelerometers, a precision scale, and a small cylindrical 20g grip object (tasks: moving an object up and down, lifting an object, fastest isometric force changes). (B) A drawing analysis system containing a pressure-sensitive pen and a digitizer tablet (tasks: drawing lines and circles). (C) A 3-dimensional (SD) ultrasound-based movement analysis system (task: aiming).

7. Task: point with the index finger to a defined target (20cm in sagittal direction from the child). The target variable was the length of the aiming movement by the index finger. Dimensions were measured in millimeters.

8a. Task: draw repetitively small circles (diameter, ≈1cm) resembling rolling wheels as fast as possible. Drawing small circles required combined movements with fingers and wrist. The target variable was frequency. Dimensions were measured in movement periods per second.

8b. Task: draw repetitively big circles (diameter, ≈4cm) resembling rolling wheels as fast as possible. Drawing big circles required combined movements with elbow and arm while keeping fingers and wrist fixed. The target variable was frequency. Dimensions were measured in movement periods per second.

9a. Task: draw repetitively small lines (length, ≈1cm) up and down as fast as possible. Drawing small lines required fast wrist extension and flexion movements. The target variable was frequency. Dimensions were measured in movement periods per second.

9b. Task: draw repetitively big lines (length, ≈4cm) up and down as fast as possible. Drawing big lines required fast elbow flexion and extension movements. The target variable was frequency. Dimensions were measured in movement periods per second.

To reduce the number of target variables, we converted them into a score. Because of the different dimensions of the target variables, transformation into variables without dimensions was mandatory. Individual absolute values were transformed into relative values by applying the formula:

$$\text{M\_relative} = \text{M\_indiv} - \text{M\_worst}/\text{M\_best} - \text{M\_worst},$$

where M_relative is the relative improvement of the value of target variable M, M_indiv is the individual result of the target variable at a certain measurement point, M_worst is the worst result of the target variable being measured within the total sample, and M_best is the best result of the specified target variable being measured within the total sample. This means that the worst individual result measured during the study was 0.00, whereas the best result was 1.00. By relating the individual measured value to the worst and to the best measured values, the data properties—for example, the distances between each value—could be maintained (no ranking) and the results on the different tasks with different dimensions could be compared and averaged. Then, we matched the M_relative values from all tests (1−9) into 2 scores. First, the average of M_relative1 to M_relative4 of the target variables from tests 1 through 4 was converted into a score (elementary hand functions). M_relative5 to M_relative9 of target variables of the tests 5 through 9 were converted into another score (coordinative hand functions). The distinction between "elementary" and "coordinative" hand functions was made on the basis of concepts reported in the literature. Maximum grip strength and maximum movement velocity are performance measures directly linked to the primary cortex function and corticospinal integrity (compare with Muller and Homberg[27]), whereas other areas are involved in coordinative functions such as grip-lift-synergy (coordination of force and movement) while manipulating an object (lifting, moving, drawing).[28-30] Therefore, grip strength, finger and hand tapping, and fastest isometric force changes were assigned to elementary motor functions, whereas the tests involving object manipulation and sensorimotor integration (aiming) were assigned to coordinative motor functions.

If a child was unable to perform a test (eg, unable to hold a pencil), his/her test performance was marked as the worst result of all measurements in the total sample.

To assess the children's competence in the ADLs, we applied the M-ADL questionnaire to a subgroup of 33 children who entered the study in its second half.[31]

The domains of the M-ADL questionnaire are manual ability, eating and drinking, dressing and washing, bladder and bowel management, and mobility. These domains are rated twice within 2 sections.

In section 1, parents give a global estimation of from 0 (complete support) to 10 (complete independence) for each domain according to their "internal standards" (appendix 1). These ratings were summarized in a first total score (TS1).

In section 2, parents are given scales on items characterizing the above-mentioned domains (see appendix 1). A score (range, 0–10) is obtained for each domain. These ratings, based on preset graded scales ("external standards") constitute the total score of section 2 (TS2).

We divided each total score by the maximum total score to obtain the standardized total score of from 0.00 to 1.00 for both sections.

We compared the section 1 scores with section 2 scores to estimate the "subjective bias" of parents, for example, over- or underestimating their children's abilities and their changes with conductive education.

Statistical Analysis

The statistical analysis was performed with SPSS.[e] We calculated means and standard deviations (SDs) in data with normal distributions. The data with skewed distributions were log-transformed. Changes during the B phases, before (t0−t1) and after (t2−t3) phase A, were averaged and then compared with changes within phase A (t1−t2). These changes were adjusted to the time interval between measurements. As in B-A-B designs, a systematic confounding variable is age, and therapeutic changes may possibly be dependent on age, we averaged the B phases before and after phase A. This led to average ages during phases A and B that were statistically the same.

For comparison purposes we used a *t* test for dependent samples. The differences are presented as means and 95% confidence intervals (CIs). *P* values are also presented. The conventional ($<.05$) required α levels were divided by 4 to account for the objective outcome measures for 4 tests (Bonferroni adjustment) and by 2 for the ADL outcomes (2 tests). Interdependencies between the children's ages, baseline measurements before conductive education (impairment at the beginning of the study), parental education, and therapeutic effects were assessed using Spearman correlation coefficients.

RESULTS

Descriptive Statistics

Sixty-seven children (41 males, 26 females; mean age ± SD, 52.0±9.6mo) of 143 who applied for the study met the inclusion criteria. Fifty-nine children had bilateral spastic CP (31 with more impairment on 1 side), 3 were hemiparetic, 2 had a dyskinetic, and 3 had a cerebellar type of CP. Three of the 67 participants were excluded from the analysis: one was withdrawn by his parents before the beginning of conductive education and the other 2 had an additional conductive education block within phase A. Sixteen children were at GMFCS level II, 38 were at level III, and 10 were at level IV. The mean intellectual abilities of the 64 children was 86±13 on the K-ABC.

The programs used in the conductive education intervention were as follows: standing and walking programs (14.9% of the total therapy time), hand programs (16.8%), cognitive programs (6.9%), movement programs while lying down (22.1%), and individual programs (39.3%) adjusted for each child's needs. The motor parts of the programs—as assessed from the reported activities on the basis of minute-by-minute protocols by 2 physicians and 2 psychologists—were estimated to constitute 52.6% of the time; 28.8% of the time was dedicated to ADLs and 18.6% to cognitive education.

Effects on Hand Functions

Conductive education significantly improved the coordinative hand functions score for the preferred hand by .10 (95% CI, .086−.114), from .38 to .48, which corresponds to a 25% improvement from baseline in comparison with no improvement during special education (table 1). The observed P value .000 was still significant on the Bonferroni-adjusted α level of .05/4=.0125. The .10 improvement was related to a scale of from 0.00 (worst performance) to 1.00 (best performance of all values measured). There was a similar improvement by .076 (95% CI, .034–.116), from .39 to .47, which corresponds to a 20% improvement from baseline for the nonpreferred hand compared with no improvement during special education. Because of the higher variability, and because fewer children were able to perform the tests at each measurement point with their nonpreferred hands, the observed P value of .03 was not significant on the Bonferroni-adjusted α level of .0125.

Analysis of variance (ANOVA) and Bonferroni post hoc testing showed that improvements in the preferred hand did not differ significantly between children at the different GMFCS levels. The mean difference between level II and level III was −.06 (95% CI, −.17 to .05); between II and level IV it was −.03 (95% CI, −.18 to .12); and between level III and level IV it was .03 (95% CI, −.10 to .16). The highest improvements were seen in children in the level III group (mean difference, .12 vs level II; mean difference, .06 vs level IV, mean difference, .09). ANOVA and Bonferroni post hoc testing found similar results for the nonpreferred hand: the mean difference between level II and level III was −.16 (95% CI, −.38 to .06); between level II and level IV it was −.06 (95% CI, −.35 to .24); and between level III and level IV it was .10 (95% CI, −.16 to .37). Again, the relatively best improvements were among children in level III.

Elementary hand motor functions (eg, maximum grip force, tapping) did not change (see table 1).

Effects on ADLs

A parallel improvement in ADLs was also shown in the subgroup of children who were tested with the M-ADL questionnaire. Conductive education also improved ADL competence on the section-scaled ratings in the M-ADL questionnaire by .11 (95% CI, .070–.149), from .50 to .61, which corresponds to an improvement of 20% from baseline compared with no significant improvement under special education (mean, .039; 95% CI, −.005 to .068) (table 2) as rated by parents. The observed P value of .015 was significant on the Bonferroni-adjusted α level of .05/2=.025. On the section general estimation in the M-ADL questionnaire, the children improved by .126 (95% CI, .074–.177), from .60 to .72, which also corresponds to an improvement of about 20% from baseline compared with no significant improvement under special education (mean, .007; 95% CI, −.026 to .041; $P< 0.01$). The observed P value of less than .001 was still significant on the Bonferroni-adjusted α level of .05/2=.025.

In accord with the objective findings, parents described main improvements in manipulative skills and in use of a pen in the manual ability subscale (data not shown).

There were no consistent significant interdependencies between a child's age, severity (GMFCS level) baseline measurement at the beginning of the study, parental education, and therapeutic effects (table 3).

DISCUSSION

Our objective in this study was to confirm or refute the hypothesis that a conductive education block intervention improves manipulative hand functions relevant to daily living. The data show significant improvements of coordinative hand functions (eg, grip-lift synergy during lifting objects, aiming). The effects were achieved during relatively short intensive intervention periods (3×4wk within a 9-mo period). As shown in a subgroup, ADLs assessed through a parent questionnaire also improved significantly during this block conductive education intervention.

Until recently, studies have reported conflicting results concerning the effects of conductive education. Odman and Oberg[32] found no major differences in outcome and expectations between conductive education and conventional training

Table 1: Effects of Conductive Education on Kinematic and Kinetic Measures of Hand Motor Functions

	Coordinative Hand Function Score (changes in mean scores[†])				Elementary Hand Function Score (changes in mean scores[†])			
Hand	N*	Change (Mean)	95% CI	P	N*	Change (Mean)	95% CI	P
Preferred hand								
No conductive education	62	−.013	−.035 to .017	<.001[‡]	58	.042	.017 to .067	NS
Conductive education	62	.100[§]	.086 to .114		58	.063	.050 to .075	
Nonpreferred hand								
No conductive education	42	−.085	−.135 to −.035	<.05[‡]	42	−.007	−.033 to .021	NS
Conductive education	42	.075[§]	.034 to .116		42	.037	.021 to .053	

NOTE. Combined scores of kinetic and kinematic tests for coordinative hand functions and for elementary hand functions under conductive education versus baseline intervention (*t* test for dependent samples).

Abbreviation: NS, not significant.

[*] Valid number of children with all measurements.

[†] Total range of the scores: 0.000 to 1.000. Positive (negative) changes of mean scores indicate improvements (impairments) between measurement points.

[‡] Main outcome criteria coordinative hand function score on the preferred hand: $P<.001$ was still significant on the Bonferroni-adjusted α level of .05/4=.0125; coordinative hand function score on the nonpreferred hand: $P=.03$, not significant on the Bonferroni-adjusted α level of .0125.

[§] Preferred hand: improvement from .38 to .48 (about 25%); non-preferred hand: improvement from .39 to .47 (about 20%) under conductive education.

Table 2: Effect of Conductive Education on ADLs

	Standardized Total Score of Global Ratings (sTS2)[†]				Standardized Total Score of Global Ratings (sTS1)[†]			
Intervention	N*	Change (mean) of TS2	95% CI	P	N	Change (mean) of TS1	95% CI	P
No conductive education	31*	.032	−.005 to .068	<.05[‡]	33	.001	−.026 to .041	<.001[‡]
Conductive education	31*	.109[§]	.070 to .149		33	.126[§]	.074 to .177	

NOTE. Total score of scales rated by parents and total score of global estimation by parents (t test for dependent samples).
*Two cases had to be excluded because the questionnaires were not completed properly.
[†] Total range of sTS1 and of sTS2: 0.00 to 1.00. Positive (negative) changes of mean scores indicate improvements (impairments) between measurement points t0, t1, t2, and t3; this means measurements at the beginning or end of each treatment phase.
[‡] P=.015, significant on the Bonferroni-adjusted α level of .05/2=.025; P<.001, significant on the Bonferroni-adjusted α level of .025.
[§] Effect size: sTS2: improvement ranged from .50 to .61 (≈20%); sTS1: improvement ranged from .60 to .72 (≈20%).

programs in Sweden. Conventional training programs in Sweden, however, are different from those in Germany. Further, Odman and Oberg's clinical measures were largely addressed to gross motor functions or mobility.

Liberty[15] examined developmental skills in functional contexts in small children with multiple handicaps and found that young children with motor dysfunction, concomitant disorders, and severe developmental delay may benefit from conductive education.

Neither Odman and Oberg nor Liberty specifically examined hand motor function. The observed improvements of coordinative hand functions indicate relevant improvements.

The coordinative hand motor functions represented in our score imply discrete force and movement tuning during object manipulation and/or hand-eye coordination (eg, aiming task).[16] These coordinative abilities are relevant for using cutlery, for dressing, for cleaning, and for playing with toys.

Because specific training of maximum forces or velocities is rarely practiced in conductive education, it is not surprising that there were no improvements in elementary hand functions during the conductive education intervention.

The discordant effects of conductive education on coordinative and on elementary hand motor functions can also be explained from a neurobiologic background. Elementary hand motor functions—for example, maximum frequency of finger or hand tapping or the fastest isometric force changes—are highly related to the integrity of the pyramidal tract and of the primary motor cortex. The pyramidal tract is usually impaired in children with spasticity because of periventricular leucomalacia.[27] Further, it is known from studies of adults with cortical lesions that the primary motor cortex has much less plasticity than the secondary and tertiary cortex being more responsible for planning and coordination of motor action.[33] Therefore, elementary hand motor functions that are associated more with the primary, and partially the supplementary, cortex, may be less susceptible to training effects. In contrast, coordinative hand functions are supposed to be more associated with the secondary and tertiary motor cortex and subcortical structures[34] and these may be more susceptible to training.

The strength of our study applying kinetic and kinematic measures for manipulative tasks is that these allow for objective measurements of hand motor functions. Therefore, this is the first study to demonstrate improvements of hand motor functions under conductive education through objective measures. One reason for detecting improvements in relation to CP in this study might be a high sensitivity of the kinetic and kinematic measures. Clinical tests such as the Melbourne Assessment of Unilateral Upper Limb Function, or the Quality of Extremity Skills Test, summarize very different hand motor functions—including elementary hand functions that may be less likely to be changed by nonpharmacologic treatment.[35,36]

This may be one explanation as to why previous studies that used clinical tests failed to identify treatment effects of conductive education on hand motor functions. Further, these studies had insufficient statistical power because of their small sample size,[12,13,37] or a very low therapeutic input (2h/wk per child).[12] The literature on adult stroke rehabilitation has shown that increasing the intensity of therapeutic interventions improves their effect.[38,39] An explanation may be that treatment intensity influences the temporal profile of growth factors involved in neuronal plasticity.[40]

Compared with previous studies on conductive education, this individual cohort study (multiple case-control study) involved the largest number of children with CP studied so far and covers a larger range of severity.

The study design fulfills the criteria for the level of evidence 2.[41] The criterion standard for intervention studies is the randomized double-blind controlled trial (level of evidence 1). We abandoned our plan to carry out a randomized controlled trial for several reasons.

It is recognized that "no CP is like the other." The cases differ with respect to severity, distribution of the lesions, type and

Table 3: Treatment Effects on Coordinative Hand Functions Related to Age, Degree of Impairment Before Treatment, and Educational Level of Parents

Treatment Effect	Age	GMFCS Level	Baseline Measurement (t0)*	Parental Education[†] (father)	Parental Education[†] (mother)
Treatment effect on coordinative hand functions (preferred hand)	.10	.11	.32	.11	.04
Treatment effect on coordinative hand functions (nonpreferred hand)	.17	−.04	.21	.22	−.06
Treatment effect on ADLs (scaled ratings, TS2)	.07	.34[‡]	−.29	.20	.21
Treatment effect on ADLs (global ratings, TS1)	−.17	.35[‡]	−.41[‡]	.12	.20

NOTE. Values are Spearman ρ correlations.
*Measurement at the beginning of the study (t0).
[†] Educational level: 1 lowest level (primary or secondary school) to 3 (high school or university).
[‡] P<.05, on the Bonferroni-adjusted α level of .0025 (not significant).

mixture of the movement disorder, mental functions, behavioral aspects, previous treatment history (intensity and types of treatments), psychosocial factors, socioeconomic status of the parents, etc. To control for confounding that might result from these numerous variables in a randomized trial, a large sample size would have been required. The alternative to a large sample size would have been restricting the trial to children with similar patterns and degrees of severity of CP. This would have reduced the external validity of the results. In addition, we know from the only randomized study[12] on conductive education reported to date that about 50% of the parents were unwilling to be randomized. The level of evidence of randomized controlled trials with dropout rates higher than 20% is regarded as poor, with a level of evidence 2b or lower according to the Oxford Centre for Evidence-based Medicine.[41] With our individual cohort design, there was a high level of compliance by parents, children, and therapists and a very low dropout rate in this group of parents and patients.

The individual cohort design we used may leave room for confounding because of differences in the speed of maturation by age. Some studies[42,43] have found very limited natural maturation of motor functions in children with CP after the age of 3 years. This means the confounding variable of maturation can be regarded as fairly limited in children with CP. Further, we attempted to minimize the bias by averaging the changes within the B phases before and after phase A. This was not necessarily a perfect adjustment, but was the best we could do.

Scherzer[44] concluded that multiple case-control or individual cohort studies are best for carrying out complex nonpharmacologic intervention studies in multiple-handicapped children (especially with the experimental phases lasting over a fairly long period).

The specificity of the conductive education effect may be an issue. It is possible that the conductive education block treatment was perhaps more focused on motor functions and ADLs than conventional special education and treatment blocks were. Therefore, we cannot rule out that similar treatment concepts or therapies involving only some elements of conductive education might be similarly effective. As mentioned in the introduction, some elements of conductive education have been identified as effective for neurorehabilitation in studies with adults. Within conductive education, these elements are embedded in a highly motivating background, for example, by group learning in a child-oriented surrounding and within a natural setting of special education. Because conductive education is a very complex approach, specificity may be an issue. Additionally, the optimal setting in which to deliver conductive education is known. In this study, we examined the original approach of the National Petö Institute and the quality of the intervention was controlled as well as possible by regular and intensive supervision from the directors themselves and by precisely written treatment protocols.

It could be argued that the effect of the intervention was due to the intensity of the block treatments rather than to specific effects of conductive education. Although treatment intensity in stroke rehabilitation has been associated with improved treatment effects,[38,39] there are data suggesting that increasing the intensity of the interventions per se in children may not necessarily improve intervention effects.[45] Additionally, McHale and Cermak[46] have shown that in elementary schools, 30% to 60% of daily activities are connected with hand motor function. Thus, hand motor functions are also highly involved in conventional education, even in nurseries or in elementary schools. The observed effects of conductive education on hand motor function are therefore probably not only related to an increase in intensity but also to the content of conductive education.

Study Limitations

A possible limitation of our study is that we can provide only a little information about the stability of the treatment effects. On the nonpreferred hand, children lose about the same abilities after they stop conductive education ($-.08$) as they win when using conductive education ($+.08$). The effects on the preferred hand remain stable, perhaps because the gains are sustained through further practice in everyday activities at home. Odman and Oberg[14] did not find any significant effect of 1 additional intensive conductive education training period after 1 year; this may be interpreted that continuous training and/or implementation into everyday life is necessary to maintain its effects. It must, however, be left to further study whether, for example, nonblocked continuous conductive education intervention is superior to blocked conductive education intervention.

This study, by focusing on hand motor functions and using quantitative hand motor testing, closes a gap inasmuch as previous intervention studies with children with CP have neglected hand motor functions. This is surprising because hand functions are important in children's ADLs, including school skills (eg, writing, drawing), and therefore are crucial for integration into later life. A reason for the scarcity of such studies is the unavailability of appropriate objective tests. With this newly developed battery of kinematic and kinetic measures, it was possible to elicit significant and considerable effects of treatment.

CONCLUSIONS

This study provides data on the impact of conductive education block treatment on kinematic and kinetic hand function tests in children with a wide range of severity of CP. In children with mainly spastic types of CP, intensive conductive education with 3- to 4-week blocks embedded in a 9-month period of conventional treatment and special education improved coordinative hand functions to a greater extent than special education with conventional treatment alone. Conductive education had no effect on elementary hand functions, which suggests that the intervention improved coordination, whereas paresis and spasticity persisted. In a subsample of the study population, ADL measurements showed considerable improvements.

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APPENDIX 1: EXAMPLES FOR SECTIONS 1 AND 2 OF THE M-ADL QUESTIONNAIRE

1) General estimation (0 complete care, 10 independence)	
Mobility in everyday life (draw o.s. up, sitting, walking, climbing steps, etc.)	☐
Eating and drinking (use of cutlery, drinking from cup, etc.)	☐
Hand skill in everyday life (use of pens, scissors, objects, etc.)	☐
Toilet training (dry and clean, over the day, at night)	☐
Self-care at home (dress, undress, body care, washing)	☐

2) Rating on preset graded scales (Self-care at home scale) *Self-Care at Home*

Self Care at Home	
Dressing and undressing	0
Cannot yet take any clothes off, no support possible	0
Helps when dressed or undressed, cannot however actively dress or undress	1
Can take off simple pieces of clothes (eg, cap, socks, pullover)	2
Dressing not yet possible (also simple things)	
Can put on simple pieces, undressing with little help almost completely possible	3
Can dress and undress mostly alone, closures still difficult, after dressing often correction is necessary (front/back twisted, bottom of sock on top etc)	4
Dressing and undressing usually secure and skillful, including buttoning	5
Body care	
Body care (combing hair, brushing teeth, etc) not yet possible	0
Brushing teeth, combing hair, creaming skin with support	1
Brushing teeth, combing hair, creaming skin, partly independently, partly with (little) help possible	2
Mostly independent body care	3
Washing	
Does not yet wash himself independently, including hands	0
Independent hand washing; face and body only with help	1
Also washes body, partly with (little) help	2

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Suppliers

a. Euroflex series; RvS Eurovema AB, Box 1179, 141 24 Huddinge, Sweden.
b. Grip force system (GHT); Entwicklungsgruppe Klinische Neuropsychologie, PD Dr. J. Hermsdoerfer, Dachauerstr 164, D-80992 Munich, Germany.
c. Digitizer tablet A3; Wacom Technology Corp, 1311 SE Cardinal Ct, Vancouver, WA 98683.
d. Ultrasound-based movement analysis system; Zebris Medical GmbH, Max-Eyth-Weg 42, D-88316 Isny im Allgäu, Germany.
e. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.