

Efficacy of orthokinetic orthotics for post-stroke upper extremity hemiparetic motor dysfunction

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Introduction

Problem and objectives

The independence of post-stroke patients is often compromised by neuromuscular impairments of the upper extremity (UE) (Garrison *et al.*, 1988). As stated by Basmajian (1989), 'we must find improved research techniques to enhance stroke management after the immediate post-ictal period . . . helping the patient to achieve an optimal role back in the family and society'. Consonant with this objective, the single-subject (idiographic) research technique for validation of clinical practice utilizing orthokinetic orthotics treatment was developed (Neeman, 1988; Neeman and Neeman, 1993; Payton, 1988). This methodology was addressed to rehabilitation studies of patients with paretic motor dysfunction due to cerebral palsy (Neeman *et al.*, 1988) and to stroke (Neeman *et al.*, 1988a,b; Neeman and Neeman, 1992a,b). This study's purpose was to seek further substantiation of the orthokinetic orthotics method for treatment of patients with central nervous system damage, addressed to the validity of orthokinetic orthotics treatment, its generalizability and specificity.

The single-subject approach (reviewed by Payton, 1988) lends itself to hypothesis testing, with use of statistical analysis (Neeman and Neeman, 1992b; Neeman *et al.*, 1988). This single-subject design provides protection from threats to internal validity (causality), by using single-blind or double-blind procedures, with multiple crossover among non-treatment, placebo treatment, sham treatment, and repeated orthokinetics treatment phases, in counterbalanced time-series (Neeman and Neeman, 1992b; Wood-Dauphinée, 1988). The external validity (generalizability) of the orthokinetics treatment needs to be supported by systematic replications of single-subject experimental studies (Barlow and Hersen, 1984; Neeman, 1988; Neeman and Neeman, 1992b). Accordingly, a systematic replication of two earlier studies (Neeman *et al.*, 1988a,b; Neeman and Neeman, 1992b) is presented. The dependent variable (criterion measure) chosen was active range of motion (AROM), which was also used in the earlier studies.

Method

The method of orthokinetic orthotics has shown pronounced positive outcomes in the treatment of persons with paretic limb musculatures, due to cerebral palsy (Exner and Bonder, 1983; Neeman and Neeman, 1984; Neeman *et al.*, 1988), and to stroke, as was demonstrated in multi-centre clinical studies (Blashy and Fuchs-Neeman, 1959; Whelan, 1964), and in single-subject design efficacy studies (Neeman *et al.*, 1988a,b; Neeman and Neeman, 1992a,b, 1993).

Rationale

Research outcomes on the mechanism of post-stroke movement dysfunctions provide a rationale for rehabilitation of persons with paretic limb musculatures. A study on quantitative electromyographic evaluation of UE muscle co-contraction in patients with hemiparesis, has demonstrated dual impairments of both agonist recruitment and of antagonist inhibition in the hemiparetic forearm (Hammond *et al.*, 1988). It was demonstrated that such pathokinesiology of paresis can serve as a

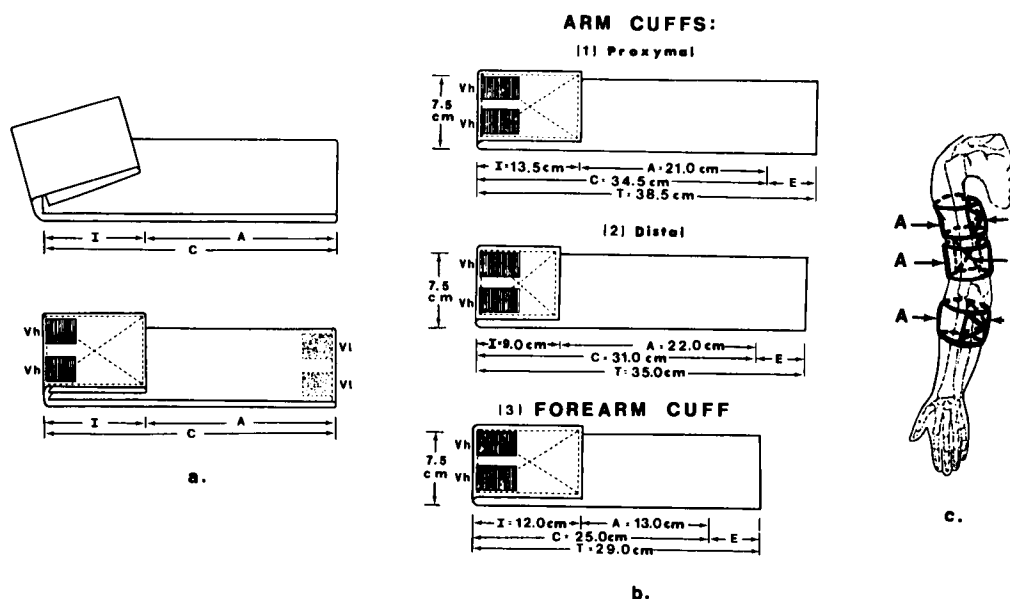


Fig. 1. Fabrication of orthokinetic orthoses (cuffs) by the continuous foldover process: (a) from elastic roller bandage material; (b) from ribbed elastic material (with measurements of cuffs used for the patient in this study); (c) application of orthokinetic cuffs to the patient's upper extremity in orthokinetics treatment phases B1 and B2 (posterior view of the supinated left UE).

A = active field, I = inactive field, C = circumference of limb at placement site of the orthosis, E = extension allowance for overlap closure of cuffs, T = total cuff length, Vh = velcro hook patches on inactive field I, V1 = velcro loop patches underneath active field A.

Note: velcro loop patches are optional when fabricating orthokinetic cuffs (b) from material which is adherent to velcro hook.

target for therapy by orthokinetic orthoses, applied to persons with disabling movement dysfunctions of the paretic limb (Neeman and Neeman, 1992a,b).

Definitions

The term *orthokinetic orthosis* describes a cuff-shaped dynamic orthopaedic appliance (Fig. 1), which does not include rigid polymer or metal components. It does not apply any extraneous modulating mechanical force or constraint, in contrast to the typical splint, which 'serves as the external force to counteract the imbalances of the internal forces' (Duncan, 1989). The orthokinetic cuff was designed (Blashy and Fuchs-Neeman, 1959; Neeman, 1971, 1973, 1988; Neeman *et al.*, 1988a,b) to obviate the adverse effects of muscle disuse through immobility (Halar and Bell, 1988). In contrast to application of external force (Duncan, 1989), the action of orthokinetic orthoses is exerted through internal restoration of neuromuscular balance between agonist and antagonist musculatures, by input of mild neural stimuli to mechanoreceptors in specifically targeted skin areas. Orthokinetics treatment is applied to persons with muscle weakness, muscle paresis and resulting agonist-antagonist imbalance. The input of constant stimuli of mild friction to cutaneous low-threshold, slowly adapting mechanoreceptors (e.g., Merkel's disks, Iggo and Muir, 1969) is effected by close skin contact with the orthokinetic cuff surface. The neurophysiological mechanism of the orthokinesis effect, invoking differential activation of paretic agonist musculatures, and

reciprocal inhibition of antagonist musculatures, was proposed in recent publications (Neeman and Neeman, 1992a,b, 1993).

Subject

The patient, a 49-year-old man with right dominance, 171 cm tall, weighing 81 kg, was referred for orthokinetics treatment of left hemiparesis 26 months following a right thrombotic cerebral vascular accident (CVA). For 6 weeks post-CVA, the patient had received inpatient treatment of physiotherapy and occupational therapy, with balance and transfer training, and retraining in activities of daily living. He continued in outpatient physiotherapy for 6 months, when treatment outcomes had reached a plateau, with no functional control of the paretic UE.

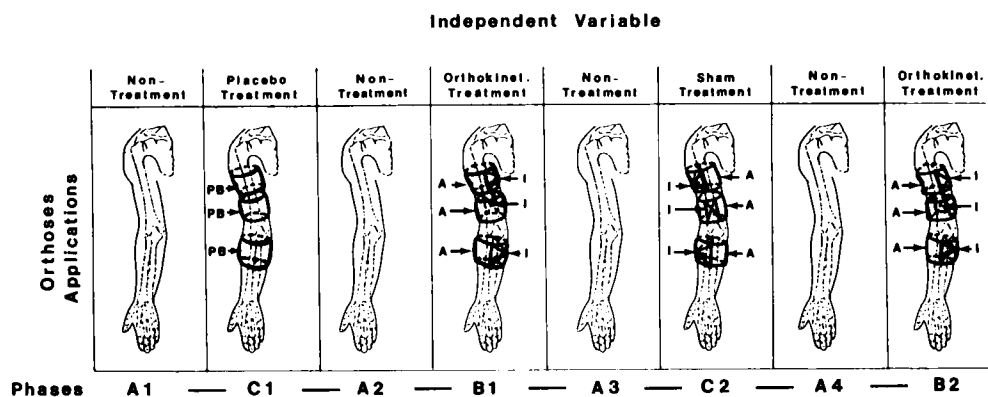


Fig. 2. Independent variable in the pilot study of single-subject design A1–C1–A2–B1–A3–C2–A4–B2. Posterior view of the patient's supinated left UE (A = active field, I = inactive field, PB = plain bandage).

A1 through A4 = non-treatment phases; C1 = placebo treatment phase; C2 = sham treatment phase; B1 and B2 = orthokinetics treatment phases. For details, see text.

Orthokinetic orthotics treatment

In the first stage, a short-duration pilot study was carried out to assess the patient's responsiveness to orthokinetics treatment. The experimental single-subject pilot study comprised double-blind application of three orthokinetic cuffs to the affected UE paretic musculatures, designed to compensate for impairments both of agonist recruitment, and antagonist inhibition (Figs 1c and 2). The pilot study used a counterbalanced interrupted time-series design, which included non-treatment, placebo treatment, sham treatment, and two orthokinetics treatment phases (Figs 2 and 3). The positive outcomes on the criterion measure of elbow AROM, were tested (i) by Bartlett's test for variance homogeneity, and (ii) by *t*-test comparing means of contiguous phases, two at a time. All phases showed absence of significant serial dependency on test (i). Hence, test (ii) was appropriate (Barlow and Hersen, 1984; Payton, 1988). It showed no significant differences on AROM between placebo phase C1 and non-treatment phases A1 and A2 (i.e. placebo effect). In contrast, the differences on AROM between orthokinetics treatment phases B1 and B2 versus contiguous non-treatment phases were statistically significant ($p < 0.01$), and hence supported specificity and causality (internal validity) of the orthokinetic orthotics treatment for this patient. These inferences led to the clinical decision to implement, in the second stage, a course of clinical treatment for one hour twice weekly, which was based on the orthokinetics technique in the pilot

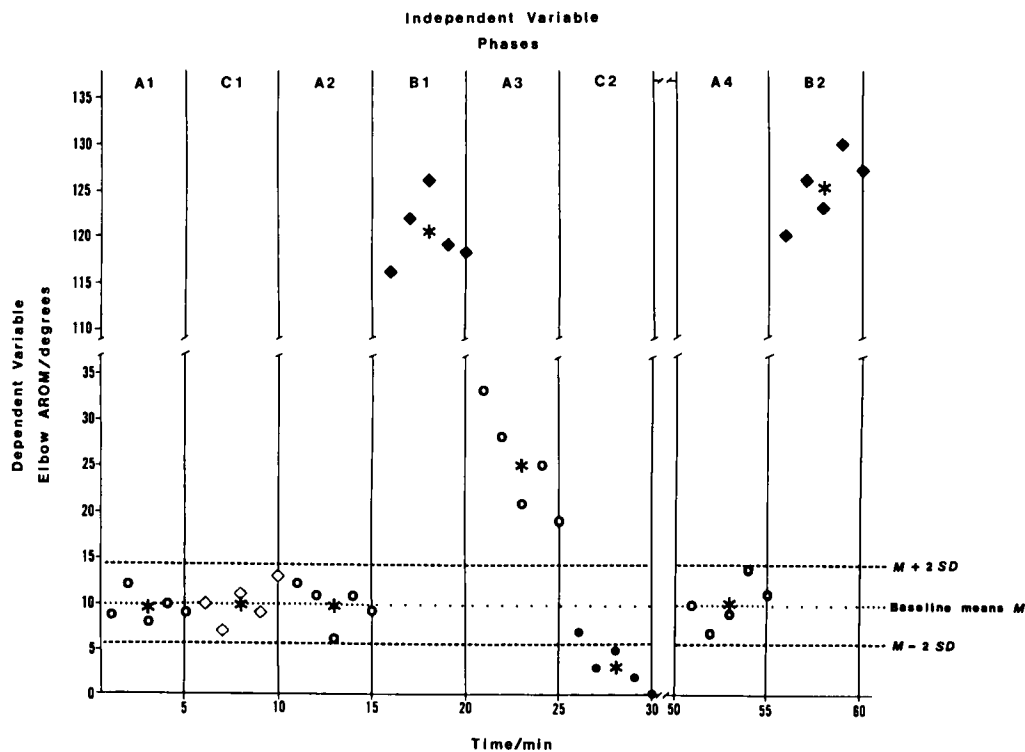


Fig. 3. Treatment of the patient's paretic left UE in single-subject design time-series A1-C1-A2-B1-A3-C2-A4-B2. ○ = non-treatment phases A1-A4; ◇ = placebo treatment phase C1; ● = sham treatment phase C2; and ◆ = orthokinetics treatment phases B1 and B2; * = mean *M* of AROM in each phase.

study, and lasted 26 weeks (Gonella, 1989). The outcomes of this orthokinetics treatment were increase in left elbow AROM to 145°, with carry-over upon removal of the orthokinetic cuffs. Forearm pronation achieved normal limits, with active supination return to the neutral position at 0°. Active wrist extension of 15° was achieved from 15° flexion to 0°; metacarpophalangeal extension of 20° from 90° to 70° in all five fingers, and 15° extension from 90° to 75° at the proximal interphalangeal joints of the 2nd to 5th fingers. This permitted opening the closed left fist to hold and stabilise objects for manipulation with the right hand. Additional gains were demonstrated in active left shoulder flexion to 110°, and abduction to 90° with elbow flexed. Active mobility ranges of horizontal abduction, with elbow extended, of 0° to 80°, and adduction 0° to 30° were attained. The orthokinetics treatment outcomes were partial restoration of voluntary mobility to the patient's paretic UE and assistive functional use in occupation.

Prior to stroke, the patient had operated a florist shop and greenhouse, which continued to be run by his family members. At 18 weeks of rehabilitation treatment, he asked to resume working in the greenhouse. The therapist proposed needed workplace adaptations, allowing the patient to ambulate safely along the plant flats, and to carry out watering, pruning, grafting and transplanting tasks while comfortably seated. The patient was taught safe work techniques, with emphasis on reach, balance and prevention of falls. At 26 weeks, the patient's endurance level in greenhouse work, while wearing orthokinetic cuffs, had reached 5 hours daily. His rehabilitation goals were attained upon resumption of part-time occupation, with assistive functional use of the affected UE.

Discussion

The positive outcome of late postacute rehabilitation with orthokinetics treatment, after a time-lag of over two years since onset of hemiparesis, was not attributable to a maturation effect (Lind, 1982) of spontaneous neural recovery from stroke (Davidoff *et al.*, 1991), and hence causality (internal validity) of the orthokinetics therapy was supported, as well as its specificity. As posited, the theory-based orthokinetics treatment (B1 and B2) resulted in pronounced restoration of agonist-antagonist muscle balance, in contrast to sham treatment (C2), with reverse orientation of the orthokinetic orthoses, which resulted in significant augmentation of muscle imbalance (Figs 2 and 3). These outcomes represent 'direct replication' of orthokinetics treatment in phases B1 and B2, and 'theoretical replication' in phase C2 (Yin, 1989). Thus, comparison of the outcomes of this study with the preceding one (Neeman and Neeman, 1992a,b), showed correspondence in the specificity of internal validity supported by the respective single-subject pilot studies, as well as in the positive rehabilitation outcomes of the two clinical orthokinetics treatment courses, with achievement of each patient's rehabilitation goal.

Conclusions

The two-stage approach of an initial evaluation by a short, scientifically valid pilot trial, is designed to subserve the objectivity of selection criteria for patients' admission to clinical rehabilitation, based on their demonstrated responsiveness to the planned orthokinetics treatment. The double-blind screening of patients, and the consequent gain in objectivity, provides a safeguard for the patient's right to treatment, while also protecting the care provider, and the physician or other professional acting as 'gatekeeper' to the rehabilitation service (Haas, 1988). Selection of patients for rehabilitation by the two-stage approach, has predictive value for the treatment outcome, thus preventing admission of 'cost outliers' who would not benefit from rehabilitative therapy (Osberg *et al.*, 1990). The single-subject paradigm, in a double-blind trial design, may serve the unfilled needs of rehabilitation professionals to validate their own clinical practices in a cost-effective, yet scientifically rigorous manner (Basmajian and Gowland, 1987; Eakin, 1991a,b; Fess, 1992; Gonella, 1989; Neeman and Neeman, 1992a,b, 1993; Payton, 1988; Wood-Dauphinée, 1988).

Implications for further study

This interdisciplinary study, which integrated clinical care by use of orthokinetic orthotics with treatment efficacy studies, is responsive to calls for action in stroke research (Basmajian, 1989; Basmajian and Gowland, 1987). It implies the need for additional, systematic replications, designed to enlarge the scope of applicability of orthokinetic orthotics. In particular, rehabilitation studies are needed on the therapeutic use of orthokinetic orthoses for patients with paretic limb dysfunction, secondary to central nervous system damage in conditions of stroke and head injury, and congenital diseases of the brain and spinal cord (United States Department of Health and Human Services, 1990). Cooperative studies addressed to such issues are under way (Neeman and Neeman, 1992a,b).

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