

# EFFECTS OF CO<sub>2</sub>-BATHS IN THE COMBINED CONCEPT OF THE EARLY FUNCTIONAL THERAPY IN CASES OF REFLEX SYMPATHETIC DYSTROPHY

**ABSTRACT: Objective:** The effects of the application of CO<sub>2</sub>-baths for the purposes of the specific early functional combined therapy in cases of reflex sympathetic dystrophy should be differentiated.

**Subjects:** Forty patients suffering from acute post-traumatic reflex sympathetic dystrophy in the hand.

**Design:** A four weeks' omission test was carried out in group B. The results were contrasted to group A. The relevant parameters in the process of regeneration were statistically calculated as a chronological serial analysis.

**Results:** In regard of the multi-variable design the results demonstrated highly significant group differences in the case of the progression of regeneration, at which group A was definitely superior to group B. Group B displayed an additional effect of delay.

**Conclusion:** The potential influences with regard to the effects of the CO<sub>2</sub>-bath are: better organisation of the exercises and superior progression of regeneration. Obviously there are beneficial effects of the combination therapy.

**KEY WORDS:** REFLEX SYMPATHETIC DYSTROPHY, FUNCTIONAL THERAPY, CO<sub>2</sub>-BATHS, THERAPEUTIC EFFECTS.

## INTRODUCTION

Reflex sympathetic dystrophy (Algodystrophy, Complex regional pain syndrome) is a painful neuropathic disorder that may develop as a disproportionate consequence of minor trauma affecting the limbs, a bone fracture or a remote process like stroke or myocardial infarction. The characteristic clinical features are spontaneous pain, hyperalgesia, impairment of motor function, swelling, changes in sweating and vascular abnormalities. These features usually occur in a single extremity. An overt nerve lesion is not detectable. Regardless of the site of the precipitating event, the abnormalities show a spreading tendency with a generalized distal distribution that is not confined with innervation territories of peripheral nerves or roots. Physiotherapy addresses the symptom-complex

of pain, hyperaemia, oedema formation and limitation of movement.

A concept for early functional treatment of acute reflex sympathetic dystrophy was developed taking the following into account:

- Steinbrocker's (1968) stipulation with regard to the prophylaxis of the development of reflex sympathetic dystrophy in order to avoid pain-induced immobilization,
- a distinct reduction in the incidence of reflex sympathetic dystrophies can be achieved by introducing early mobilization,
- pain and immobilization promote sympathetic dystrophic reflex mechanisms and lead to local vascular dysfunction with development of oedema, displacements of electrolytes into the interstitium as well as intensified nociception (Figure 1):
- the time-dependent manifestation of familiar clinical symptoms in conjunction with morphological findings due to immobilization.

The combination treatment that was designed consisted of CO<sub>2</sub> baths before exercises adapted to the symptoms and the clinical findings with regard to the criteria which are summarized in Table 1.

In contrast to other local applications, the CO<sub>2</sub> bath is tolerated even in highly acute reflex sympathetic dystrophy. By analogy to the numerous objective effects observed (Ernst et al, 1984; Hartmann et al, 1991; Ito et al, 1989; Koles-r et al, 1984; Komoto et al, 1988; Kwant et al, 1988) modulation of oedema and pain as well as vasomotor stimulation is inferred. In numerous observational and prospective comparison studies, the efficacy of this combination therapy could be documented (Mucha, 1987, 1988; Mucha and Zysno, 1984). This applies to reflex sympathetic dystrophies of traumatic and nontraumatic etiology as well as the shoulder-hand syndrome.

This study was designed to evaluate the specific effect of the CO<sub>2</sub> bath in the combination concept with exercise therapy.

## SUBJECTS AND METHODS

Patients with acute reflex sympathetic dystrophy of the hand were assigned to two test groups on a random basis. Group A (n = 20) received the reference treatment as a combination therapy of CO<sub>2</sub> baths and exercise treatment. Patients in group B (n = 20) exclusively underwent exercise as monotherapy for

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the first four weeks and thereafter the same combination treatment as in group A.

In order to identify the factors influencing the course of the disease and regeneration as precisely as possible, the following inclusion criteria were applied to include patients in the test groups: confirmed high-activity reflex sympathetic dystrophy of the hand (also external) of exclusively post-traumatic genesis, no other diseases; no signs of regression of existing symptoms and findings (unexplained diffuse pain, difference in skin color and skin temperature relative to the other limb, diffuse oedema, limited active range of motion) with a manifestation period of at least two and at most six weeks.

The treatment was administered under the same standardized conditions as those already described in detail in earlier investigations (Mucha, 1980; Mucha et al, 1984; Zysno and Mucha, 1984). Pharmacotherapy was not used and was discontinued at the commencement of treatment and investigation in the patients concerned.

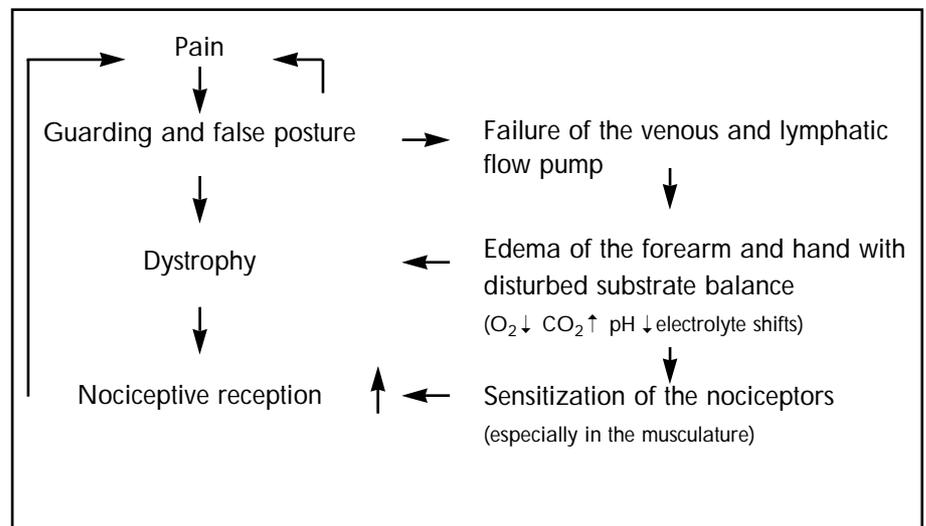
The CO<sub>2</sub> bath was physically prepared with a CO<sub>2</sub> content of 800 - 1200 mg/l CO<sub>2</sub>. The duration of immersion was 12 min at a water temperature of 32°C - 33°C. A resting phase of 30 - 45 min ensued with non-dependent functional positioning of the limb concerned. In the subsequent exercise treatment, activities were performed at the shoulder, fol-

lowed by the elbow and forearm, and at last gentle active-assistive exercises were performed with the wrist and joints of the fingers. The intensity was adapted chronologically: on the one hand, it accorded with regressions of pain symptoms; on the other hand, it was adapted additively to the development of functional abilities. To improve strength, innervation and mobility of the hand had to be normalized. Exercise was performed five times a week.

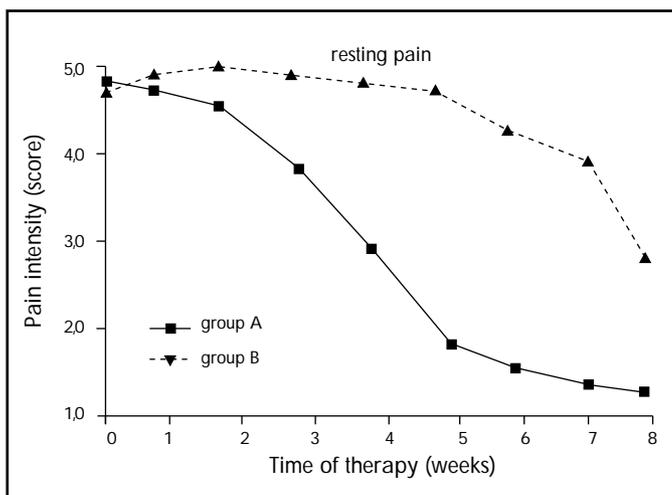
On commencement of treatment, the following control parameters were measured twice a week during the course of the treatment: differences in circumference as a volume comparison: of the wrist; metacarpophalangeal joints

(MCP) and distal interphalangeal joints (DIP); joint functions with the neutral (0) method (forearm, joints of hands and fingers) and the compression strength of the hand with a hand dynamometer (firm Bettendorf) in relation to that of the healthy side (= 100%). The difference in skin temperature, measured with an infrared thermometer (Diatek), was interpreted as a positive finding where a difference of more than + 0.8°C was manifested compared to that of the back of the healthy hand. Existing pain was differentiated qualitatively and registered quantitatively with a graphical analogue scale and given a corresponding score. The following initial definitions were applied:

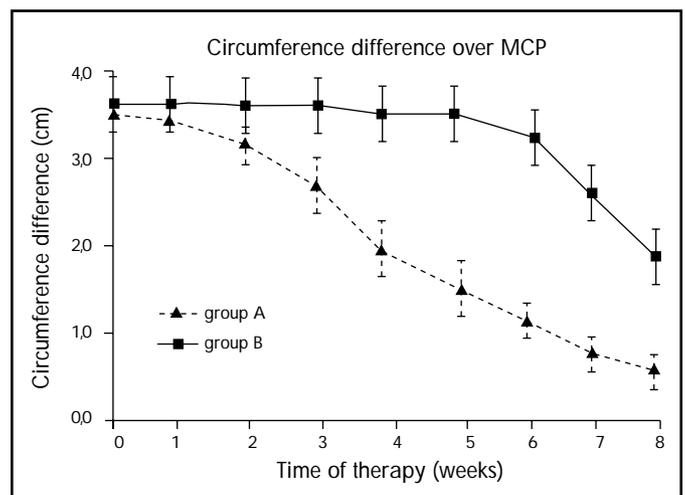
**Figure 1: Pain and immobilization in the pathogenesis of reflex sympathetic dystrophy.**



**Figure 2: Resting pain in the course of the initial 8 weeks in the therapy groups (group A: n=20, group B: n=20).**



**Figure 3: Development of oedema caused circumference increase over MCP in the course of the therapy groups.**



**Table 1: Main Criteria in Early Functional Therapy of Reflex Sympathetic Dystrophy.**

1.	to bring in relief position
2.	start with consentient exercises
3.	analytical differentiation of assistive and active exercises
4.	centrifugal and additive development of movements
5.	dosage of intensity with regard to manifestation of pain and development of local performance

**Table 2: Results of the Multivariate Tests (Wilks Roys) for Pain Parameters.**

Variable	Effect	F	DF	sig.of F
<b>Pain Score</b>				
Night's rest	time	246,81	8/31	0,000
	group / time	33,55	8/31	0,000
Resting conditions	time	187,85	8/31	0,000
	group / time	78,14	8/31	0,000
Spontaneous movement	time	81,94	8/31	0,000
	group / time	28,55	8/31	0,000

**Table 3: Summary of Multivariate Tests (Wilks Roys) for Differences of Circumferences.**

Variable	Effect	F	DF	sig.of F
<b>Differences of Circumferences</b>				
Wrist	time	494,90	8/31	0,000
	group / time	171,18	8/31	0,000
MCP	time	496,52	8/31	0,000
	group / time	321,28	8/31	0,000
PIP	time	271,08	8/31	0,000
	group / time	139,12	8/31	0,000

- i) for nocturnal positional pain, pain which interrupts sleep at least once,
- ii) for resting pain that can definitely interfere with patient's daily personal hygiene; and
- iii) For movement pain, pain that accompanies any attempt at voluntary movement with persistent intensification of the pain.

All initial parameters above and beyond the inclusion criteria such as demographic data and the side affected were registered at the commencement of the treatment.

The following were the criteria for conclusion of treatment:

- i) individual function in the affected movement system that were equivalent on each side, and
- ii) unrestricted performance of everyday chores.

Radiological findings were recorded but not included in the evaluation, since adequate quantitative changes such as those found in earlier investigations (Mucha, 1987; Mucha et al, 1984; Mucha and Zysno, 1984) were not to be expected in these patients in view of the

chronologically stringent inclusion and progress criteria (Veldman et al, 1993).

The course of treatment and all findings were recorded and the data obtained were analyzed statistically after conclusion of the investigation. As a test of homogeneity, initial qualitative data were analyzed with the chi-square test. The progress data were calculated with an analysis of variance test series and documented graphically in the course. Quantitative data was only recorded once and checked by means of univariate analysis of variance. The probabilities of error of 5% ( $p < 0.5^*$ ) and 1% ( $p < 0.01^{**}$ ) were relevant levels of significance criteria.

**RESULTS**

The age distribution showed a peak between 47 and 56 years (range 20-74). Statistical testing revealed a homogeneous distribution in the groups compared. This also applied to gender distribution ( $\chi^2_{(1)} = 0.1$ , nonsignificant). Women predominated in the two groups of 20: there were 13 women in group A and 11 women in group B.

The pain development during the first eight weeks of treatment in the two groups is illustrated in Figure 2. It was clearly discernible that the decrease in pain occurred very much earlier under resting conditions than under spontaneous movement. Both the time-dependent decrease in intensity in the two groups and the group differentiation show highly significant changes in all qualities of pain in the observation period (Table 2). With homogeneous initial conditions, the group difference shows a highly significant difference as early as the second week of treatment with regard to resting pain, and in the fifth week of treatment with regard to movement pain. Group A shows a more rapid and thus better pain reduction up to the eighth week of treatment.

The latter also applies to the course of the decrease in volume and circumference difference over the individual points of measurement (Figure 3; Table 3). In addition, a topographical right shift became evident which reflects a decrease in progression from proximal (wrist) to distal (DIP). The contraction remobilization of the wrist and its

progressive development in the groups is shown in Figure 4. A highly significant development of regeneration over the observation period of eight weeks of therapy in the two groups was also manifested here as well as a significant difference in progression between the groups with unequivocal superiority of group A (Table 4). Moreover, it is apparent that there was a malposition in flexion and accordingly a greater extension deficit with difficult regeneration (Figure 4). The same also applies to the radial abduction compared to ulnar abduction.

The development of regeneration in the finger joints is apparent from Figures 5 and 6. In general, it was more rapidly attained in the joints of the thumb than in the long fingers. The overall course and the differences in progress between the groups are adequately demonstrated by the study design. Statistically, these differences are also highly significant (Table 4).

Figure 7 shows the number of patients with the differences between sides for the skin temperature of the hand in the therapy groups and their changes in the course of observation. There is a continuous decrease of this finding only from the third week of therapy in group A and from the fifth week of treatment in group B. There are significant differences between the fourth and eighth week of treatment (Table 5).

In contrast to the control parameters listed referred to so far, the regeneration

**Table 4: Summary of Multivariate Tests (Wilks Roys) Results for Mobilisation Parameters of the Hand.**

Variable	Effect	F	DF	sig.of F
Flexion	time	373,22	8/31	0,000
	group / time	56,77	8/31	0,000
Extension	time	140,11	8/31	0,000
	group / time	23,63	8/31	0,000
Radial Abduction	time	119,09	8/31	0,000
	group / time	21,91	8/31	0,000
Ulnar Abduction	time	196,15	8/31	0,000
	group / time	46,17	8/31	0,000
Thumb Opposition	time	1299,91	8/31	0,000
	group / time	339,24	8/31	0,000
Fist Difference	time	191,57	8/31	0,000
	group / time	63,87	8/31	0,000

of the compression strength shows the slowest course. However, in statistical terms group A is once more unequivocally superior to group B.

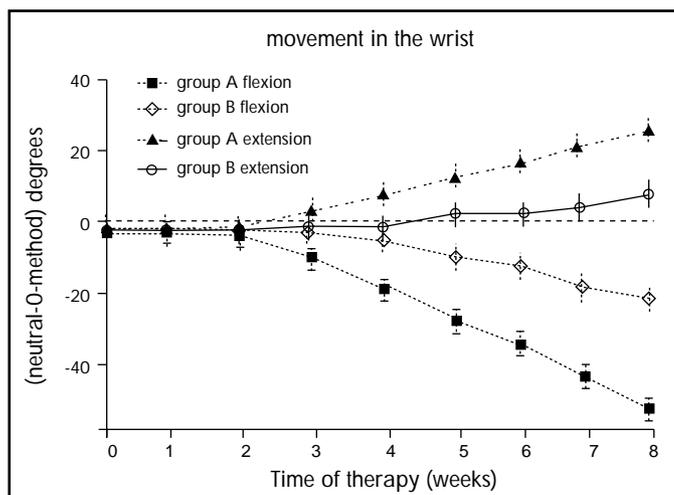
On average, the prospectively defined conclusion criteria were fulfilled by patients of group A after  $9.4 \pm 1.4$  weeks and by patients of group B only after  $16.6 \pm 1.7$  weeks. The differences between the groups are highly significant ( $F_{(1.38)} = 221.38^{***}$ ).

#### DISCUSSION

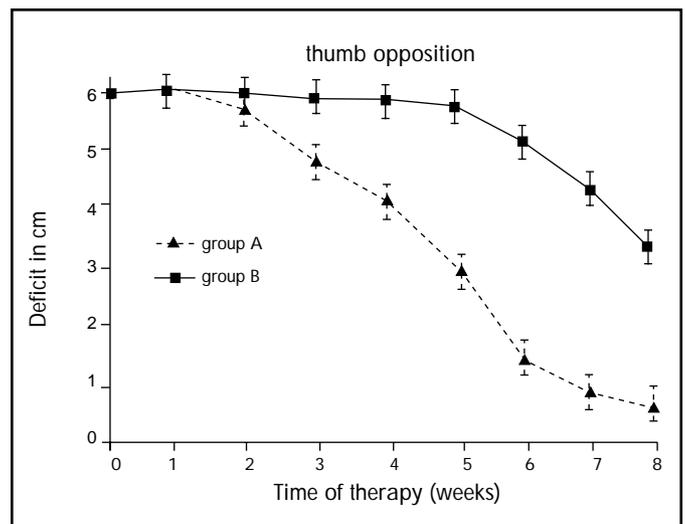
The treatment concept applied was developed in a large number of preli-

minary investigations and its efficacy is documented (Mucha, 1980, 1987; Mucha et al, 1984; Mucha and Zysno, 1984). It was clearly shown that the efficiency and the duration of treatment required are crucially dependent on early application in the course of the disease and are also affected by topography. Owing to the specific objective of this investigation, criteria that influenced the manifestation and thus pre-treatment duration as well as the location, were defined. Some authors (Bossnew, 1977; Weber et al, 2002) also assume different progress characteristics when

**Figure 4: Development of remobilisation of hand contraction in the therapy groups (group A: n=20, group B: n=20)**



**Figure 5: Development of the thumb function in the course of therapy.**



**Table 5: Number of Patients with the Differences (>0,8°C) between Sides for the Skin Temperature of the Hand in the Therapy Groups and their Changes in the Course of Eight Weeks**

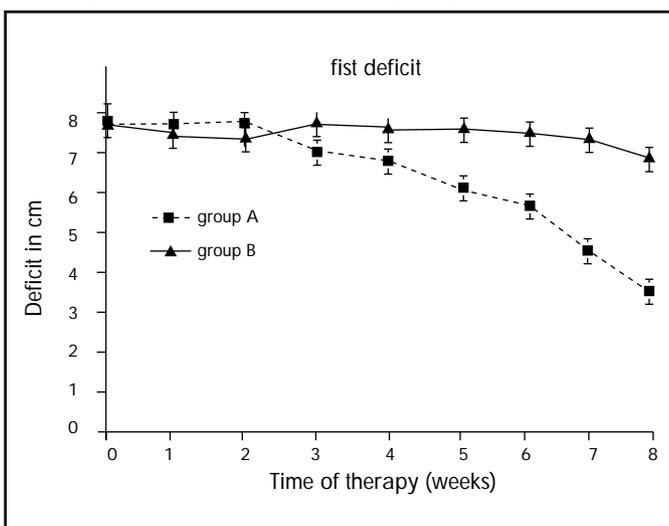
Weeks of Therapy	Increase of Skin Temperature > 0,8° C	Group A		Group B		Chi <sup>2</sup> (1)
		Abs.	%	Abs.	%	
0	+	19	95	17	85	0,27
	-	1	5	3	15	
1	+	18	90	18	90	0,00
	-	2	10	2	10	
2	+	17	85	16	80	0,00
	-	3	15	4	20	
3	+	12	60	17	85	2,00
	-	8	40	3	15	
4	+	11	55	17	85	4,28*
	-	9	45	3	15	
5	+	9	45	15	75	3,75*
	-	11	55	5	25	
6	+	6	30	14	70	6,40*
	-	14	70	6	30	
7	+	4	20	12	60	6,66**
	-	16	80	8	40	
8	+	1	5	9	45	8,53**
	-	19	95	11	55	

the triggering cause is different. The present study focused on highly acute post-traumatic reflex sympathetic dystrophies of the hand. It can thus be assumed that initial conditions were largely homogeneous in this patient population. This also applied to the results for the age and gender distribution in the groups compared. The two groups in the present study also showed the age peak in the fourth and sixth decade of life and the more frequent manifestation in women that have also been reported in other investigations (Bossnew, 1977; Weber et al, 2002).

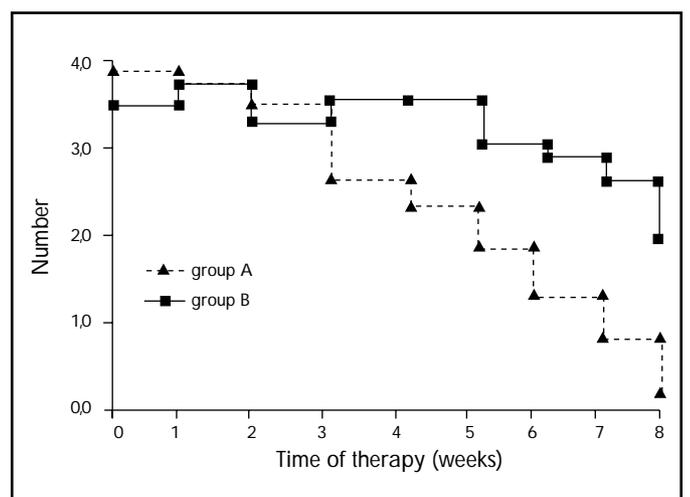
On the basis of previous treatment experience and the inclusion criteria, functional parameters which reflected full regeneration and at the same time the end point of the treatment could be chosen as criteria that would indicate the completion of treatment in the study population. Since there are usually individual differences in the endpoint, all progress checks were carried out until the criteria of treatment completion were fulfilled. However, after completion of the study and in the statistical analysis of the data, a representative period of eight weeks of therapy was laid down since both comparison groups were complete at this time. The individual progress parameters were the same as in the preliminary investigations, not least in order to attain indirect comparability via the progress design.

Descriptions of the course of the disease play a special role for analysis

**Figure 6: The development of the fist deficit, representing the function of the long fingers.**



**Figure 7: Number of patients with differences (>+0,8°C) between sides for the skin temperature of the hand in the course of 8 weeks.**



and representation of the effect of treatment in reflex sympathetic dystrophy since this disease can have a spontaneous course between six months and two years. Immediate effects on the disease activity can only be inferred from early regressions of symptoms and findings in the highly active stage of the disease. These are accompanied by simultaneous regeneration of function. Chronological differences represent differences in the effect and efficiency of treatment. The present results clearly show that the four-week omission trial for application of the CO<sub>2</sub> bath in the initial highly active phase of the disease is in some cases accompanied by the absence and in other cases by a substantial restriction in the effectiveness of treatment of the exercise program administered in group B. After commencement of the combination treatment, an adequate advance in progress becomes manifest after the fifth week of treatment. This occurred four weeks earlier in group A. A delaying effect going beyond the four weeks becomes apparent: this is manifested not least in the overall treatment time of  $16.6 \pm 1.7$  weeks in group B compared to  $9.4 \pm 1.4$  weeks of treatment in group A.

The progress characteristics document the efficiency of combination therapy and its indication in the early treatment of highly acute reflex sympathetic dystrophies. It is precisely in this stage of the disease that the CO<sub>2</sub> baths enable application, and the intensity of exercise therapy. In addition, they intensify the parallel effects of the two forms of treatment. The curves representing the decrease of pain (Figure 2), volume (Figure 3) and skin temperature (Figure 7) provide clear indications of this. On the basis of the characteristics of this decrease, the exercise progression is planned and the functional intensity is regulated. The recovery of functional performance therefore becomes evident with an adequate delay. Initially function of the forearm and wrist then that of the thumb and finally the joints of the long fingers are remobilized. Strength deficits are the last parameter that can be compensated which is understandable in terms of the development of regeneration, regulation of treatment and the requisite exercise condition that.

In all variables, there is a parallel and characteristic progress scheme: more pronounced effects of treatment were only shown after an initial latency phase of one to two weeks. In all cases, group A shows a statistically better progression than group B. In group B, striking accelerations of progression are only shown from the fifth to the sixth week of treatment, i.e. in the phase of treatment during which the CO<sub>2</sub> baths were used.

The basis for specific individual effects and the interaction mechanisms of the CO<sub>2</sub> bath cannot be established from the present study. By analogy to the results of other investigations (Hartmann et al, 1991; Koles-r, 1984; Komoto et al, 1988) several influence factors must be discussed: analgesic effects via the cutaneous stimulus compensation by the CO<sub>2</sub> which is tolerable even in the highly active phase, since according to Sato and Schmidt (1973) corresponding deficits maintain reflex dystrophic nociception. Pain intensity is modified by regulatory effects on the painful hypertensive musculature and systemic effects of relaxation (Zysno, 1974). In accordance with the results concerning the relatively rapid decrease in volume (swelling), a good anti-oedematous effect can also be assumed which is likely to take place both via the centralization in the whole-body immersion and the peripheral effect of hydrostatic pressure. Vasomotor effects may also occur as were demonstrated by Komoto et al (1988). The re-adaptation of the dilated vessels in the area affected by the disease evidently abolishes the stasis and promotes resorption of the eodema. There is also likely to be concomitant normalization of skin temperature. The resorption of eodema is accompanied by normalization of substrate exchange and degradation of nociceptive substances.

Parallel effects were aimed for initially by adequate positioning and forms of exercise. Graduated exercise stimuli for re-adaptations of muscle innervation, joint mobilization and ultimately the strength and global function of the hand were used in the chronological dynamic development process. In this way, permanent defects were avoided and full function was rendered possible in a relatively short treatment period of  $9.4 \pm 1.4$  weeks.

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