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RECOVERY OF ISOMETRIC GRIP STRENGTH AFTER COLLES' FRACTURE: A PROSPECTIVE TWO-YEAR STUDY

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ABSTRACT. Grip strength during short and sustained maximal voluntary isometric contractions was measured in 28 females and 5 males with displaced Colles' fracture involving the distal radio-ulnar joint. The patients were randomized into two groups, treated either through immobilization with plaster cast or with external fixation. The recovery of isometric grip strength was followed over a two-year period. A significant difference was registered between women with plaster casts and women with external fixators six weeks after the fracture. Regaining of grip strength occurred up to one year after the fracture. The pattern of recovery was slower for women with primary external fixation. Neither the dominant nor the non-dominant injured side regained short or sustained maximal voluntary isometric contraction. The dominant injured side showed no significant difference between sides but the non-dominant injured side remained significantly weaker. It is thus important to identify hand dominance. Pain during measurements was reduced after two years, but about one-fifth of the patients still perceived pain. The present findings may serve as guidance in physiotherapy for these patients.

Key words: Colles' fracture; randomized trial; long-term follow-up; isometric grip strength; physiotherapy; recovery; laterality.

INTRODUCTION

Fractures of the distal end of the radius are among the most common fractures (18). During 1988 the incidence of distal radius fractures was 3.8 per 1,000 inhabitants in the city of Bergen (5). The age-specific incidence was highest for women between 60 and 69 years (13.7/year/1,000 inhabitants). Colles' fracture constituted 87% out of the 609 distal radius fractures (5). Colles' fracture is usually caused by a fall on the outstretched arm, the wrist being in dorsi-flexion. It involves a fracture of the distal metaphysis of the radius, which occurs within 2–3 cm proximally to the articular surface, and might extend into the radio-carpal joint, the distal radio-ulnar joint, or into both these joints. An accompanying fracture of the ulnar styloid may occur (4). Dorsal angulation, dorsal displacement, radial angulation, radial displacement, radial shortening and supination of the distal fragment may be present (10). Patients with Colles' fracture are often referred to physiotherapy in the rehabilitation period.

Grip strength is an important function in daily life activities, and has been reported in studies on the functional outcome after Colles' fracture (7, 11, 15, 17, 19).

The aims of the investigation were (i) to study differences in grip strength between patients immobilized with plaster cast or with external fixation after Colles' fracture, and (ii) to follow the course of recovery of isometric grip strength of the injured side compared to the uninjured side during two years. These aims are of importance in determining timing and need of physiotherapy.

MATERIAL AND METHODS

Criteria for inclusion

The target sample included 68 consecutive patients, 45 to 75 years of age, with displaced intra-articular Colles' fractures involving the distal radio-ulnar joint. The required degree of displacement was $\geq$3 mm shortening, $\geq$10° dorsal, and/or $\geq$10° radial angulation of the radius. The fractures should clinically be feasible to immobilize either with a cylindrical below-elbow plaster cast (P-group) or with a light-weighted, non-cylindrical AO External Fixator® made from chrome-cobolt (E-group). Patients with medical conditions or language difficulties that might interfere with the results of the investigation were excluded.

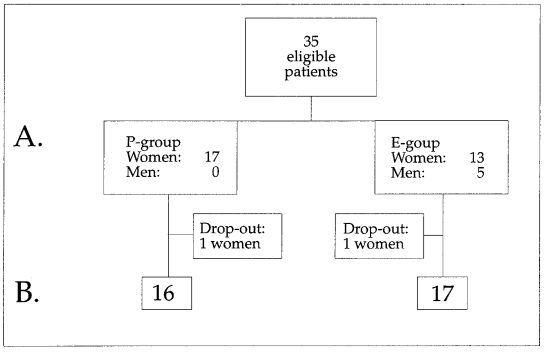

Fig. 1. The number of patients with Colles' fracture after randomization (A) and participating (B). P-group = patients immobilized with plaster cast. E-group = patients immobilized with external fixator.

Design and patients

In this prospective investigation the same material was used as in the study by Lagerström et al. (8). Thirty-five consecutive patients were allotted to the treatment groups by a computer-based random assignment within 6-unit blocks (Fig. 1). One woman in the P-group and one in the E-group discontinued the follow-up measurements, and were excluded, leaving 16 women in the P-group and 12 women and 5 men in the E-group. Because of redisplacement within 10 days, five women with plaster casts were re-reduced and immobilized with an external fixator (PE-group). After the first measurement occasion six weeks after the fracture, one woman (E-group) refractured, and another woman (P-group) did not want to participate.

Twenty-nine fractures were similarly distributed in classes VI–VIII, according to the Frykman classification system (4). Four fractures belonged to class V. There were no significant differences between the women in the two groups concerning age (mean: 58.0, range: 45–72 years), height (mean: 163.8, range: 153–173 cm), or weight (mean: 66.2, range: 50–94 kg), nor any difference in age between the men (mean: 60, range 45–72 years) and the women. The men were significantly taller (mean: 174.8, range: 170–182 cm) and heavier (mean: 80.6, range: 73–94 kg) than the women (8). According to the method described by Saltin & Grimby (16), the patients reported light to moderate workloads and spare-time activities. All patients with the exception of one woman in the plaster-group were self-reported right-hand dominant (8).

Treatment

Surgical treatment. Disregarding the immobilization method, treatment was standardized and equal concerning primary orthopaedic treatment, and clinical follow-ups. The immobilization period was six weeks from the day the fracture was finally treated.

Physiotherapy started the same day or the day after the fracture had been immobilized. The therapists were specially trained in managing the programme. The programme, consisting of basic information and active exercises, was identical for all patients ($n = 33$). Briefly, the physiotherapy contained the following principal elements: information about the fracture and the expected course of recovery, and an exercise programme for prevention of post-traumatic oedema and for maintaining range of motion of the free joints of the injured upper extremity. Early after the surgical treatment, patients were taught gradually to increase the use of their injured side in activities of daily living. When the immobilization device was removed, mobility training for the wrist and forearm joints was started. During the first 14 weeks after the fracture, the time and the number of treatments were standardized. Additional physiotherapy was applied as indicated by the patients' individual needs.

Measurement procedures

Grip strength measurements. Short and sustained maximal voluntary isometric contraction (MVC, SMVC) were measured bilaterally with the Grippit® (9, 12, 13), a device consisting of an elliptical handle with electronic transducers based on strain gauges, and a wooden base on which an arm guide is mounted. Grip strength (Newton, N) was recorded every half-second, and connected to a computer, grip versus time curves could be visualized. Calibration of the Grippit® and the measurement procedure were carried out as previously described (8, 9). Immediately after each measurement session, the patients were asked to report any pain or discomfort in connection with the grip strength measurement. The intensity of pain was measured with a 10-cm visual analogue scale (6, 8).

All measurements were performed by the same investigator (C. L.) on six occasions starting on the same day as the immobilization device was removed: 6, 10, 14, 18 weeks and 1 and 2 years after the fracture.

Statistical analysis

Missing values for injured and uninjured sides were substituted by interpolation for 9 patients (MVC: 16 values; SMVC = area: 11 values; perceived pain: 9 values).

As the grip strength values of this sample were fairly normally distributed, parametric statistics were performed. Descriptive statistics, correlation coefficients, paired and unpaired *t*-tests and analyses of variance were calculated according to standard routines. Differences were considered significant if the *p*-value was < 0.05.

RESULTS

The maximal values of all three trials were chosen to represent the patients' MVC (Newton, N) in all analyses. SMVC was expressed as the area below the grip versus time curve (Newtonseconds, Ns) (8). One plaster casted and 12 externally fixated patients were not able to perform the SMVC test for the injured side on the day the immobilization device was removed. Therefore, the results from this measurement occasion were not analysed (8).

Absolute values and differences between uninjured and injured sides for MVC and area were used for analysis of differences between treatment groups, and

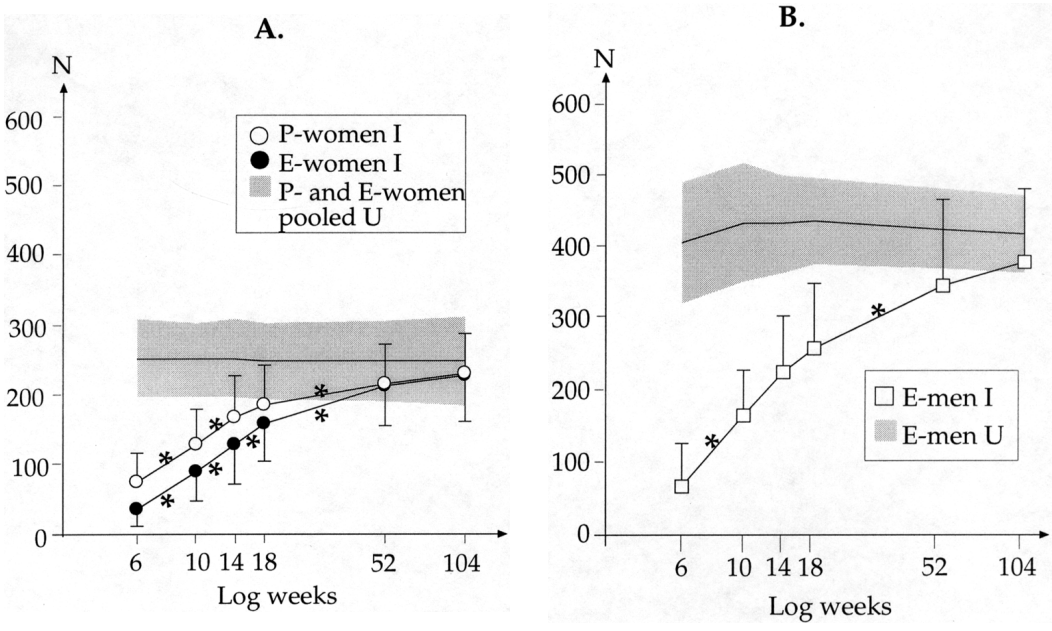

Fig. 2. Recovery of maximal voluntary isometric contraction (MVC; N) between 6 and 104 weeks after Colles' fracture. A: Women immobilized with plaster cast (P-women; $n = 11$) and primary external fixation (E-women; $n = 12$). B: Five men with primary external fixation (E-men). Shaded fields represent uninjured side (U). I = injured side. Mean ± SD for U and I. $*p < 0.05$.

of changes over time within groups. The rate of recovery was expected to vary during the two-year follow-up. Therefore, separate analyses were performed for short- and long-term changes, between 6 and 18 weeks and between 18 weeks and 2 years, respectively.

Comparisons of women and men immobilized with primary external fixation

All men were randomized to immobilization with the external fixator. Comparisons of grip strength were made between them and the women with primary external fixation. The gradual regains and levels of MVC and area in absolute values are presented in Figs. 2A and B, and 3A and B. There was no significant interaction between the courses of recovery.

Women immobilized with plaster cast or with external fixation

Differences between groups. Analyses of differences in MVC and area between treatment groups were performed per protocol [women who remained in their treatment group according to the randomization (plaster-casted women: $n = 11$; women with primary external fixation: $n = 12$)].

For the uninjured side there were no significant differences in MVC between the plaster casted and the externally fixated women during the two-year follow-up. For the injured side the women with plaster casts showed significantly higher MVC than the women with primary external fixation on the day the immobilization device was removed (difference: 38.4 N). No other significant differences in MVC or area were found between the two groups.

Regaining grip strength over time. Comparisons of MVC and area, expressed in absolute values, showed similar courses of the uninjured sides for the two groups and were pooled. Figs. 2A and 3A illustrate the gradual regains and the levels of MVC and area compared with the uninjured side. Analyses using the differences between uninjured and injured sides showed the same rate of recovery except for the area of the women with an external fixator, where the increase was not significant between 10 and 14 weeks. MVC and area covariated significantly for both groups on all measurement occasions for the injured and for the uninjured sides (ranges: injured side: $r = 0.85$–0.97; uninjured side: $r = 0.76$–0.95).

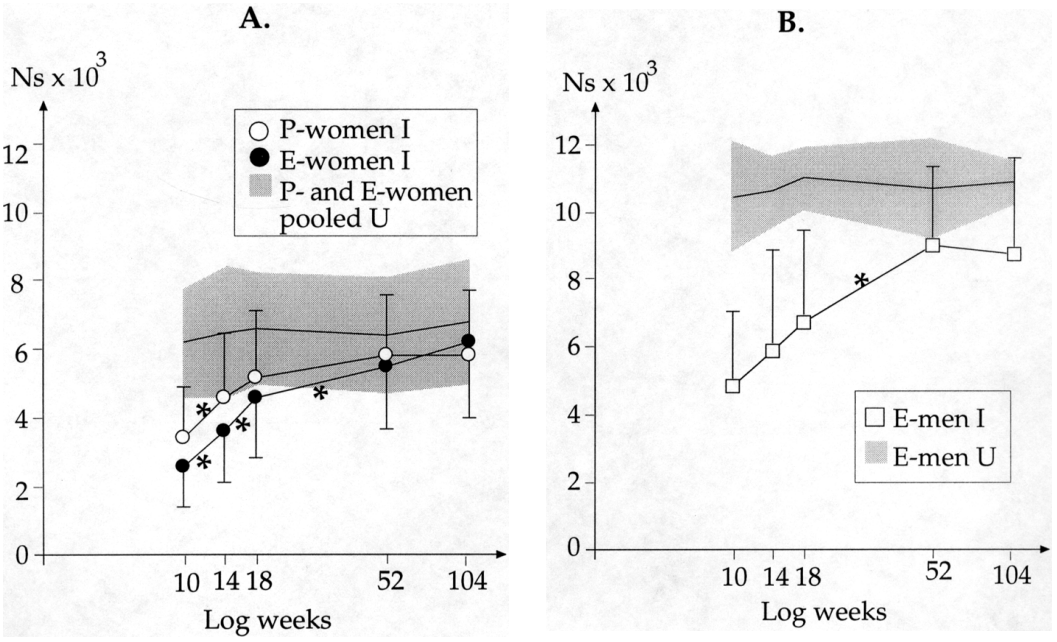

Fig. 3. Recovery of area (Ns) between 10 and 104 weeks after Colles' fracture. A: Women immobilized with plaster cast (P-women; $n = 10$) and primary external fixation (E-women; $n = 11$). B: Five men with primary external fixation (E-men). Shaded fields represent uninjured side (U). I = injured side. Mean ± SD for U and I. * $p < 0.05$.

*Women with secondary external fixation (*n = *5)*

For the uninjured side, there were no differences in MVC or area between women with secondary external fixation compared with the women with plaster cast and with primary external fixation. The regain in MVC and area, expressed as the difference between uninjured and injured side, for the three groups of women is presented in Table I. The women with secondary external fixation showed greater differences between sides for both variables on all measurement occasions except for MVC on the day the immobilization device was removed.

Grip strength and laterality

The relations of grip strength (MVC and area) between the uninjured and injured side two years after the fracture, and the distribution of fractures on hand dominance were analysed (Table II). When laterality was not taken into account, the differences between sides in the combined women-group ($n = 26$) were higher compared with the women with the dominant sides injured ($n = 14$), and lower compared with the women with the non-dominant sides injured ($n = 12$). Regarding MVC and area, the injured non-dominant side was ≥20% weaker than the uninjured dominant side. The injured dominant side was equal with the uninjured non-dominant side. Four men had injured their non-dominant side. The injured side was 16% weaker than the uninjured side in the men.

Perceived pain during grip strength measurements

There were no significant differences concerning perceived pain between women with plaster cast and primary external fixation. Therefore, they were pooled for the subsequent analyses of pain. Fig. 4 shows the numbers and ratios of patients perceiving pain (ratio = number of patients with pain divided by total number of patients). Perceived pain during MVC and SMVC measurements at 6 and 104 weeks after the fracture is presented in Table III. The pain was most pronounced on the day the immobilization device was removed, and decreased gradually over time. The women with secondary external fixation had less pain than the other groups.

Table I. *Maximal voluntary isometric contraction (MVC; N) and area (Ns) for women immobilized with plaster cast (P-women) and with external fixation primarily (E-women) or secondarily (PE-women). Differences between uninjured and injured sides on six and five measurement occasions, respectively*

		P-women			E-women			PE-women		
	Wks	*n*	Mean	SD	*n*	Mean	SD	*N*	Mean	SD
MVC (N)	6	11	190.7***	49.0	12	206.7***	77.5	2	193.0	18.4
	10	10	126.4**	48.8	11	155.6**	59.6	4	182.5	51.9
	14	10	91.3	39.8	11	110.1*	65.5	5	162.4*	66.2
	18	10	67.4*	42.5	11	86.9**	50.1	5	119.2*	59.4
	52	10	32.6	38.1	11	34.2*	35.0	5	44.4	62.2
	104	10	16.2	31.7	11	21.3	48.9	5	42.4	61.1
Area (Ns)	10	10	2,953.4**	1,183.8	11	3,420.6	1,604.3	4	3,622.3	1,032.6
	14	10	1,937.1	1,323.2	11	2,918.0**	1,552.2	5	3,407.0	1,576.9
	18	10	1,501.5*	921.5	11	1,932.0*	1,166.4	5	2,558.2	1,478.2
	52	10	621.6	813.0	11	880.4	1,164.0	5	1,019.6	1,323.6
	104	9	635.3	825.5	10	636.5	1,453.7	5	762.8	1,263.3

Wks = no. of weeks after fracture.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

DISCUSSION

Differences between women and men immobilized with primary external fixation

The differences in grip strength between the externally fixated women and men were obvious (Figs. 2A and B, and 3A and B). As expected, the men had higher MVC and area than the women on both sides on all measurement occasions, except for MVC in the injured side on the day the external fixator was removed. The men also showed bigger differences between uninjured and injured sides for MVC and area than the women, particularly during the early follow-up period. The men, however, tended to regain both MVC and area more slowly than the women (Figs. 2A and B, and 3A and B).

Differences between women immobilized with plaster cast or with external fixation

The women with external fixation showed significantly lower MVC than the women with plaster casts on the day the immobilization device was removed. The patterns of regaining MVC and area were similar for the two groups up to 18 weeks after the fracture, the plaster-casted women remaining stronger (Figs. 2A, and 3A). They showed a

Table II. *Relations between uninjured and injured sides for maximal voluntary isometric contraction (MVC; N) and area (Ns), and distribution of fractures on hand dominance 2 years after the fracture. Female group, immobilized with plaster cast or with external fixation primarily or secondarily*

	Injured side					
	Dominant or non-dominant		Dominant		Non-dominant	
	MVC ($n = 26$)	Area ($n = 24$)●	MVC ($n = 14$)	Area ($n = 14$)	MVC ($n = 12$)	Area ($n = 10$)●
U–I side	23.4 N *	662.4 Ns *	0.3 N	129.9 Ns	50.3 N ***	1,407.9 Ns ***
Ratio I/U	91.1%	90.0%	100.0%	98.1%	79.6%	77.9%

U = uninjured side; I = injured side; N = Newton; Ns = Newtonseconds.
● Two women could not complete the measurements of sustained maximal voluntary isometric contraction.
* $p < 0.05$; *** $p < 0.001$.

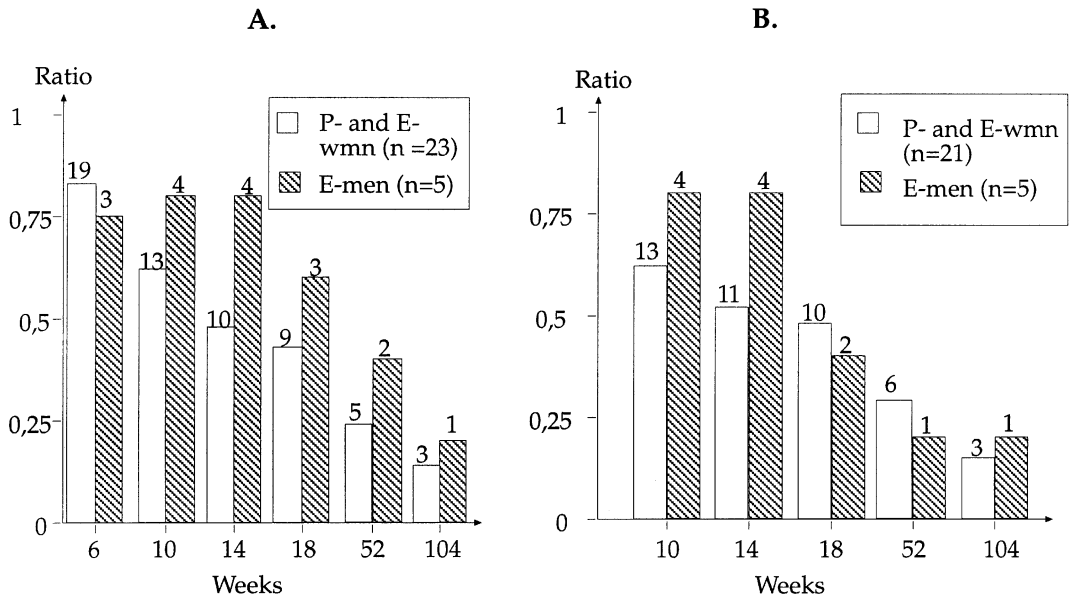

Fig. 4. Pain during measurements of short (A) and sustained (B) maximal voluntary isometric contractions after Colles' fracture in six and five measurement occasions, respectively. Numbers and ratios of patients perceiving pain. Ratio = number of patients with pain divided by total number of patients. Women with plaster cast (P-women; $n = 11$) and with primary external fixation ($n = 12$) pooled, and five men with primary external fixation (E-men).

faster rate of recovery than those with external fixation, which could be due to firmer immobilization in the external fixator. Within 18 weeks and one year the women with external fixation had recovered to the same grip strength (MVC and area) as the plaster-casted women. No difference was found after one year. The results, thus, indicate early intervention with physiotherapy after Colles' fracture, especially with externally fixated women. The rather high correlation between area and MVC shows that either could be used for evaluation of these patients.

Women with secondary external fixation compared with women with plaster cast and with primary external fixation

Compared with the women immobilized with primary external fixation or plaster cast, the women with secondary external fixation showed lower MVC and area during the whole follow-up period, and a tendency to slower recovery (Table I). The extended immobilization period for the women with secondary external fixation may have contributed to these findings. This might indicate the need for early

Table III. *Perceived pain (visual analogue scale; cm) during measurements of short and sustained maximal voluntary isometric contractions (MVC; SMVC). Women immobilized with plaster cast and with primary external fixation, and men with primary external fixation*

		Women				Men			
	Wks	*n*	Mean	Md	Range	*n*	Mean	Md	Range
MVC	6	23	2.2	1.5	0–7.0	4	2.6	1.6	0–7.0
	104	21	0.4	0	0–5.0	5	0.5	0	0–2.7
SMVC	10	21	0.9	0.1	0–3.9	5	1.8	0.7	0–6.6
	104	20	0.2	0	0–2.0	5	0.5	0	0–2.5

Wks = no. of weeks after fracture.

intervention with physiotherapy for patients secondarily immobilized with an external fixator.

Laterality

For the combined group of women ($n = 26$) there were still significant differences in MVC and area between the uninjured and the injured sides two years after the fracture. Laterality was then not taken into account (Table II). Petersen et al. (14) concluded that the 10% difference in MVC between dominant and non-dominant sides, stated by Bechtol (1), was valid only for right-handed healthy individuals. For left-handed individuals MVC should be considered equivalent in both hands (1). These results were supported by Crosby et al. (2), while Nordenskiöld & Grimby (13) reported a side difference in MVC of less than 10% in healthy right-handed men and women. In the present investigation the relations between uninjured and injured sides varied when laterality was taken into account. The non-dominant injured side was significantly ($p < 0.001$) weaker. In contrast, the dominant injured side showed no significant difference between sides. Neither the injured dominant nor non-dominant side regained MVC or area within the two-year follow-up, implying the 10% rule (14). It thus seems important to identify hand dominance when evaluating grip strength.

Pain

About 25% of patients with distal radius fracture have residual dysfunction (4), including decreased grip strength and/or pain when exerting grip strength (3). In our study the pain measurements showed a rather low intensity of pain (Table III), but 19% of the patients had persistent pain during measurements after two years. The pain may have influenced the results of MVC and area, particularly in the early follow-ups. By means of pain measurements, the magnitude of the pain is known in this investigation. The effect of the pain might thus be evaluated, for instance, by comparison with the influence of pain on daily life activities.

Physiotherapy

The investigation shows significant differences in the early course of recovery of grip strength. This implies the need for specific early physiotherapy regarding grip strength. Furthermore, the differences between uninjured and injured sides were still in evidence after two years, which also indicates the need for physiotherapy up to at least two years.

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