ORIGINAL ARTICLE

Evaluation of immediate versus delayed shoulder exercises after breast cancer surgery including lymph node dissection – A randomised controlled trial

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SUMMARY. Two hundred and thirty women who had undergone surgery for breast cancer were randomised to a prospective study, comparing early (group A) and delayed (group B) shoulder exercise. Preoperatively, group A received instructions and an exercise programme supervised by a physiotherapist, whereas group B received written instructions to use the arm normally but to avoid heavy work. Two weeks after surgery both groups were given identical exercise programmes. Shoulder mobility, hand strength and arm volume were measured preoperatively, 1 month, 6 months and 2 years postoperatively. After 2 years 13.8% of the women had lymphoedema, but there were no significant differences between the groups. Grip strength was slightly decreased during the postoperative period in both groups (n.s.). Postoperatively, all movements in both groups were decreased after 2 weeks and 1 month and shoulder elevation and abduction remained decreased at 2 years. Mobility in group A recovered significantly earlier than in group B. © 2002 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Breast cancer is a recognised major health problem. In Sweden, more than 6000 women are affected every year. Fifty per cent of them are under 65 years of age and 20% younger than 50 years. The majority of operations are done with breast-conserving surgery with or without lymph node dissection. When this is performed, it means an extensive axillary dissection which may result in a deterioration of postoperative function, frequently described as symptoms of decreased shoulder and arm mobility and strength, pain, ^{2,3} seroma and lymphoedema.4 Some of these symptoms may lead to permanent dysfunction of the arm. ⁵⁻⁸ The addition of postoperative radiotherapy also increases the risk of arm dysfunction. ^{9–12} To reduce the impairment of strength and mobility and to avoid lymphoedema, shoulder exercises are commonly prescribed. 9,13,14 Previous evaluations of the effects of various kinds of exercises, with immediate or delayed onset, have reported conflicting results regarding seroma frequency and wound exudate. 15–19 However, shoulder mobility seems to return to preoperative values faster with early onset of exercise although only minor differences are seen in the long term. 5,20–24 The development of postoperative lymphoedema may start years after surgery but, when fully developed, it is a source of discomfort, stiffness, heaviness and sometimes even pain. 25–27 Whether early intervention with mobilisation of the arm affects the development of lymphoedema after breast cancer surgery or not has, to our knowledge, not yet been evaluated.

The aim of the study was, in a prospective and randomised trial, to evaluate lymphoedema and shoulder range of motion after immediate shoulder exercises, compared with delayed, in patients undergoing breast cancer surgery including lymph node dissection with or without postoperative radiotherapy.

PATIENTS AND METHODS

The study included a consecutive series of women undergoing radical mastectomy or quadrantectomy including axillary dissection for breast cancer during

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the period from November 1994 until December 1996 at Sahlgrenska Universitetssjukhuset, Göteborg, Sweden. Women fulfilling the following criteria were excluded: age >80 years, senility, bilateral surgery or diseases affecting the outcome, e.g., rheumatoid arthritis or stroke. To avoid patient interference, cluster randomisation was performed to alternate periods of 4 weeks.

During the period 230 patients were included and randomised into two groups, one receiving early (group A) and the other delayed (group B) shoulder exercises. Initially, all patients were followed for a period of 6 months postoperatively. During this period 25 patients dropped out. The causes were: death (five patients), moving from the area (six patients), other diseases (three patients), surgery on the opposite side (three patients) and personal reasons (eight patients). Background data including age, dominant hand, side and type of operation and addition of postoperative radiotherapy to the thoracic wall of the remaining 205 patients, 101 in group A and 104 in group B, are presented in Table 1.

Two years after surgery the patients were asked to participate in a follow-up assessment. At this stage another 24 dropped out of the study. The causes were: death (11 patients), moving from the area (six patients), other diseases (two patients), surgery on the opposite side (one patient) and personal reasons (four patients).

During the whole study period each patient was seen by one of four specialised physiotherapists preoperatively and at 2 weeks, 1 month, 6 months and 2 years postoperatively. All patients included in group A received preoperatively a shoulder/arm exercise programme to be started on the first postoperative day. On the first and the second day the exercise programme included intermittent hand contractions with a ball in the hand, elbow flexion/extension and hand pro- and supination in supine position with the arm resting on a wedge pillow. From day 3 the exercises were increased to include arm elevation and abduction to 90° with bent elbow in the sitting position. From day 8 also arm elevation and abduction to 90° with straight elbows as well as internal rotation with the hand on the back trying to reach as high as possible were included.

Preoperatively, the patients included in group B only received instructions to follow after operation, they were advised to use the arm as much as comfortable but to avoid lifting and carrying heavier items and to avoid forced movements for 14 days. Postoperatively, no further information was given during hospital stay.

After 14 days, in the outpatient clinic, patients from both groups received an exercise programme including the following exercises in the sitting position:

- arm elevation to 180° with straight elbows,
- internal rotation with the hand on the back trying to reach as high as possible,
- abduction with the fingertips on the shoulders,
- elbows together and apart with the hands behind the neck,
- lift the right and left shoulder as high as possible with the arms elevated to 180°.

And the following exercises in the standing position:

- arm extension with a stick held horizontally behind the back,
- shoulders forward, backwards, upwards and downwards,
- shoulder circles with the fingertips on the shoulder,
- arm elevation standing in a corner with the back of the hand gliding along the wall.

Patients were told to perform each exercise 5 times in every set and repeat the session 3 times daily.

The volume of the arm was measured voluminometrically. The arm was put into a water-filled cylinder and overflowing water was measured. Both arms were measured and the quotient between the parameters was calculated.²⁸ A correction between the dominant and the non-dominant hand was made.²⁹ The volume was calculated in per cent, thus:²⁸

$$\frac{(\mathrm{OA}_{\mathrm{postop}} - \mathrm{NA}_{\mathrm{postop}}) - (\mathrm{OA}_{\mathrm{preop}} - \mathrm{NA}_{\mathrm{preop}})}{\mathrm{OA}_{\mathrm{p}}\mathrm{ostop}} \times 100,$$

where OA_{postop} is the volume of arm on the operated side postoperatively, NA_{postop} the volume of arm on the non-operated side postoperatively, OA_{preop} the volume

Table 1 Age, dominant hand, side and type of surgery and radiotherapy treatment. Number of patients or mean $(\pm S.D.)$ and differences between the groups

	Group A $N=101$	Group B $N=104$	P-Value	
Age, years	58(11)	58 (11)	n.s.	
Dominant hand (right/left)	97/4	99/5	n.s.	
Operation side (right/left)	39/62	60/44	P < 0.01	
Mastectomy only	31	22	n.s.	
Incl. radiotherapy	5	7		
Quadrant resection only	20	23	n.s.	
Incl. radiotherapy	45	52		

of arm on the operated side preoperatively, and $NA_{\rm preop}$ the volume of arm on the non-operated side preoperatively.

Lymphoedema was defined as more than a 10% increase in volume on the operated side compared with the non-operated arm and corrected for preoperative differences. Arm flexion, abduction and rotation were measured in the supine position using a goniometer. Hand strength was measured with a Vigorimeter (Geboüder Martin, Tuttingen, Germany). A subjective estimation of pain, heaviness and tension in the operated arm were measured by means of a visual analogue scale. Estimations between 1 and 3 were graded as mild, 3–5 as moderate and >5 severe. All measurements were performed preoperatively and at 2 weeks, 1 month, 6 months and 2 years postoperatively except for volume measurements which was excluded at 2 weeks.

At inclusion, all patients were given written and verbal information about the aim of the study. The study was approved by the research ethics committee of Göteborg University.

Statistics

Results are reported as mean and standard deviation (S.D.) or range. Differences within and between the groups were analysed with Pitman's non-parametric permutation test for groups and for matched pairs. Differences between proportions in each group were calculated on using Fisher's exact test. Probability values less than 0.05 were considered significant.

RESULTS

Values of the voluminometric tests before and after surgery are given in Table 2. The differences between the groups were not significant but the postoperative volume was significantly higher than the preoperative value during the whole postoperative period in group B and at 6 months and 2 years postoperatively in group A. The percentages of patients that developed an increased

volume above 10% compared with the non-operated arm, corrected for preoperative differences, are presented in Table 3.

Range of motion before and after surgery is presented in Table 4. The postoperative changes, presented as per cent of preoperative values, in arm elevation and abduction in patients participating during the whole postoperative period of 2 years are presented in Figs 1 and 2. All movements in both groups were decreased 2 weeks and 1 month postoperatively. In both groups, shoulder flexion and abduction were still significantly reduced at 2 years after surgery (P < 0.05) compared to preoperative value. Significant differences between the groups still remained after 2 years for flexion and abduction (P < 0.05)

There were no significant differences in either volume of the arm or arm mobility between patients who received radiotherapy and those who did not undergo such treatment.

The reduction in grip strength was minor but significant during the postoperative period compared with preoperative period (Table 5). The differences between the groups were not significant but there were significant differences between postoperative and preoperative values within each group both at the check-up at 2 weeks and 2 years postoperatively.

Estimates of pain, heaviness and stiffness measured by a visual analogue scale³² are reported in Table 6. None of the patients graded any of their symptoms as severe and the most common symptom was pain.

DISCUSSION

The aim of this study was to evaluate whether it is necessary to start rehabilitation immediately after breast cancer surgery, including lymph node dissection, or if a delayed start is preferable. The results of the study indicate that the benefits of an early exercise start are marginal in most respects, including arm volume increase and grip strength. However, the mobility in arm flexion and abduction is significantly better with an

Table 2 Differences in arm volumes (operated versus. non-operated side) preoperatively and postoperatively according to Swedborg's calculation described in the text²⁸ Mean (\pm S.D.)

Volume, %		Group A, $N=101$	Group B, $N = 104$	<i>P</i> -Value between the groups
	Preoperatively 1 month 6 months	99.6(4.4) 100.7 (5.5) 102.3 (6.1)*	100.6 (4.7) 102.4 (5.9)* 103.0 (5.3)*	n.s. n.s. n.s.
	2 years†	103.7 (7.6)*	104.5 (7.2)*	n.s.

[†] Number of patients 2 years postoperatively group A 85, group B 96.

^{*}Indicates a statistically significant difference between preoperative and postoperative values within the groups on the P < 0.001 level.

Table 3 Percentage of patients in each group who developed lymphoedema (volume on the operated side > 10% increased compared with the non-operated side)

Number of patients	Group A	Group B	<i>P</i> -Value between the groups
1 month postoperatively, % 6 months postoperatively, % 2 years postoperatively, %	1	3	n.s.
	5	4	n.s.
	13	12	n.s.

Table 4 Range of shoulder motion before and after breast cancer surgery. Mean (±standard deviation)

		Group A, $N=101$	Group B, $N=104$	P-Value between the groups
Flexion, [†]	Preoperatively	170 (11)	169 (13)	n.s.
,	2 weeks	123 (19)***	111 (19)***	< 0.001
	1 month	145 (14)***	138 (15)***	< 0.01
	6 months	164 (11)***	159 (14)***	< 0.01
	2 years [‡]	167 (11)*	164 (14)***	< 0.05
Abduction, [†]	Preoperatively	161 (21)	155 (27)	n.s.
ŕ	2 weeks	89 (21)***	79 (19)***	< 0.001
	1 month	115 (22)***	109 (25)***	n.s.
	6 months	147 (25)***	141 (29)***	n.s.
	2 years [‡]	154 (25)***	145 (29)***	< 0.05
External rotation, [†]	Preoperatively	89 (12)	91 (10)	n.s.
	2 weeks	72 (15)***	67 (18)***	< 0.05
	1 month	81 (13)***	80 (13)***	n.s.
	6 months	86 (11)***	87 (12)***	n.s.
	2 years [‡]	88 (11)	88 (11)*	n.s.
Internal rotation, [†]	Preoperatively	71 (11)	71 (12)	n.s.
,	2 weeks	67 (12)***	64 (13)***	< 0.05
	1 month	68 (9)**	68 (11)***	n.s.
	6 months	70 (10)	68 (12)***	n.s.
	2 years [‡]	70 (10)	70 (11)	n.s.

[†]Indicates differences between preoperative and postoperative values within each group. *P < 0.05, **P < 0.01 and ***P < 0.001.

[‡]Number of patients 2 years postoperatively group A 85, group B 96.

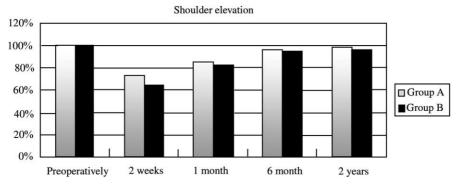


Fig. 1 The postoperative changes presented as percentage of preoperative values in arm elevation in patients participating during the whole postoperative period of 2 years.

early exercise start (Tables 2–6). At 2 weeks arm elevation is decreased to approximately 73% of the preoperative value in the early exercise group compared with approximately 55% in the delayed group (P<0.001). The corresponding figures for abduction are 65% in group A and 50% in group B (P>0.001). Therefore, in the early postoperative phase, the most

important exercises seem to be elevation and abduction of the arm. Internal as well as external rotation are also significantly decreased at the 2-week visit postoperatively (P < 0.05) but seem to return rapidly irrespective of study group.

Previous studies have reported the postoperative frequency of lymphoedema to vary between 8% and

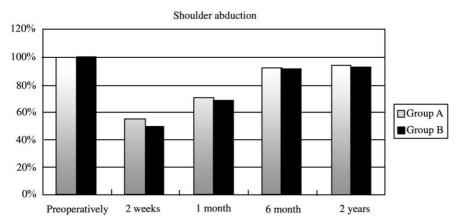


Fig. 2 The postoperative changes presented as percentage of preoperative values in arm abduction in patients participating during the whole postoperative period of 2 years.

Table 5 Grip strength, measured with a Vigortmeter, before and after breast cancer surgery. Mean (±S.D.)

		Group A, N= 100	Group B, N= 104	<i>P</i> -Value between the groups
Grip strength [†]	Preoperatively	75.6 (18.1)	78.0 (18.4)	n.s.
	2 weeks	72.3 (19.7)**	75.8 (17.6)*	n.s.
	1 month	75.0 (18.9)	77.2 (17.2)	n.s.
	6 months	77.0 (17.7)	77.4 (18.6)	n.s.
	2 years [‡]	73.1 (16.6)***	72.6 (18.1)***	n.s.

[†]Indicates differences between preoperative and postoperative values within each group. *P < 0.05, **P < 0.01 and ***P < 0.001.

Table 6 Estimates of pain, heaviness and stiffness measured by a visual analogue scale before and after surgery. Percentage of patients with mild (VAS 1-3) or moderate (VAS 3-5) symptoms. The differences between the groups were not significant

		Group A		Group B	
		Mild	Moderate	Mild	Moderate
Pain	Preoperatively	2	2	3	0
	2 weeks	12	11	15	8
	1 month	10	5	8	4
	6 months	7	5	3	4
	2 years*	9	3	11	1
Heaviness	Preoperatively	1	0	2	0
	2 weeks	5	5	10	6
	1 month	7	2	5	6
	6 months	5	4	6	4
	2 years*	5	7	8	2
Tension	Preoperatively	1	2	0	2
	2 weeks	7	4	13	7
	1 month	4	5	4	3
	6 months	6	3	2	3
	2 years*	5	1	4	2

^{*}Number of patients 2 years postoperatively group A 85, group B 96.

38%. This wide range may be explained by different methods of measuring and criteria for assessing the oedema. The mean value of the incidence of lymphoedema in patients in this study is 6.5% at 6 months and 13.8% at 2 years measured volumetrically.

This method measures the exact arm volume directly in millilitres. 8,26,28,33 The procedure may seem somewhat cumbersome as it requires the use of water and special equipment and other methods are therefore sometimes preferred. The most common is to measure arm

[‡]Number of patients 2 years postoperatively group A 85, group B 96.

circumference or girth, which is significantly quicker and easier to do.^{3,7} However, no volume can be calculated from these figures and the accuracy of such a method depends on how many circumferences are measured. Between two and five circumferences have been used in other studies. 13,16,34 A volume estimate can be calculated measuring the intervals reducing 4cm, as described by Kuhnke.35 The arm is divided into segments with 4cm intervals and the volume of each segment is calculated and added to achieve an estimate of the full arm volume. It should be remembered that measurements of circumference are highly biased by variations in the degree of firmness and the contour of the limb, by the tension placed on it, by the tape measure or by the fact that the swelling of the soft tissue is not uniform.³³ In comparison with other measurements, voluminometry seems to be the most reliable method.³⁴

When surgery is combined with radiotherapy, the damage to tissue is increased as well as the risk of permanent disability. 9-12 Approximately, 50% of the patients included in this study also received radiotherapy and the proportions of patients in groups A and B were comparable. In spite of the fact that every second person received radiotherapy, it did not affect the outcome and there was no higher degree of morbidity among these patients. The reason for the contradictory results in this study compared with others could be the differences in how the radiotherapy was performed.³⁶ The radiotherapy in this study was concentrated only to the chest wall. It is the radiation to the axilla that increases the risk of long-term complications regarding arm mobility and the development of lymphoedema. 8,9,12,37,38 It should also be noted that in some of the above-mentioned studies women did not receive any physiotherapy after radiotherapy, which may also affect the results. 8,11,12,38

More than 200 patients were included in this study and patients were randomised to one of the two groups according to a 4-week schedule. This is not the optimal way to perform the randomisation, but as patients are mobile on the wards, it would have been inappropriate to treat some and not others during the same period and, moreover, the results could be affected by contacts between patients in the two groups. Although scientifically correct, this randomisation has unfortunately resulted in a higher proportion of patients in group A having surgery on their left side than in group B, where the patients to a higher extent had surgery on their right side (P < 0.01). The groups are therefore not fully comparable. This is of minor importance for the results of the range of motion and grip strength as the differences are calculated on preoperative versus postoperative values of the same arm and not the actual differences between the arms. However, the uneven randomisation has an impact on the results of arm volume. To only compare preoperative and postoperative values would have been incorrect as gain and loss of weight also affect arm volume. It is possible that the patient's weight may change during a period of 2 years, in some patients so much that the volume of the arms will not be comparable when calculating the extent of lymphoedema. Furthermore, the volume of the arm is dependent on which hand is dominant. The dominant arm is slightly larger than the opposite arm.²⁹ To avoid this error, the results of the arm volume measurement were corrected for the natural asymmetry according to Godal and Swedborg.²⁹ This correction adjusts for most of the differences but the groups are still not fully comparable.

Several studies present a more marked reduction in arm mobility compared with the results found in our patients. 3,4,8,26 The differences may be explained by different study designs. Two studies were performed without randomisation between groups of patients who either had early mobilisation or a delay until after the sutures were removed. 14,39 There are also studies comparing early versus delayed onset of exercise of only 5–7 days after surgery compared with 14 days in this study. 15,17,20,22,23 Another aspect is the length of hospitalisation; patients in our trial stayed for only 2 days, compared with Wingate et al., who reported hospitalisation up to 10 days. 13,21

In many studies, great importance is attached to measuring the amount of drainage and development of seromas. ^{18,19} In our study, this was impossible because of the short hospital stay. Patients were discharged with drainage and were thereafter taken care of by a nurse at the local health centre.

In order to reduce seroma and avoid development of lymphoedema, many surgeons introduce different kinds of exercise regimens. Women in this study had neither fixation of the arm to stop movement nor were they forbidden to mobilise, whereas in some studies delayed exercise means fixation with a sling, 4 a thoracic bandage 16 or a collar and cuff shoulder immobilisation. 19 The absence of fixation may partly explain the small differences between the groups in this study.

There was only a slight reduction in grip strength in our patients during the whole study period. Ivens and Hladiuk reported in two different papers^{3,4} that muscle strength was initially reduced but returned to normal values after some months. A study by Aitken reported the same muscle strength despite differences in surgery and other therapies.³⁸

Only a minority of the women reported pain and sensations of heaviness and tension in the arm on the operated side (Table 6), in contrast to Swedborg and Segerström, both of whom have reported higher levels of discomfort.^{5,8} Pain is seldom an isolated symptom but occur in connection with lymphoedema²⁵ or decreased mobility.^{7,8}

During the period of inclusion of patients in this study, the usual length of postoperative hospital stay was as short as 1–2 days. With such a short hospitalisation time the physiotherapists' opportunity to give sufficient treatment, information and instructions are limited. After discharge, 2 weeks postoperatively, each patient visited the physiotherapist individually for half an hour at the outpatient clinic in connection with a visit to the surgeon. One of the questions before the start of the study was if the brief oral instructions with an exercise programme during hospitalisation could be replaced by written instructions, and if the start of exercise could be delayed until the postoperative visit, when patients are also more willing to co-operate. However, the results indicate that early onset of exercises as given in this trial seems preferable.

The conclusion of this study is that an early compared to delayed onset (14 days) of training does not affect the incidence of postoperative lymphoedema but in both short as well as long term early onset of exercises is valuable in avoiding deterioration in range of shoulder motion.

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References

- 1. Cancer incidence in Sweden 1998, Socialstyrelsen.
- Tasmuth T, von Smitten K, Kalso E. Pain and other symptoms during the first year after radical and conservative surgery for breast cancer. Br J Cancer 1996; 74: 2024–2031.
- Ivens D, Hoe A L, Podd T J, Hamilton C R, Taylor I, Royle G T. Assessment of morbidity from complete axillary dissection. Br J Cancer 1992; 66: 136–138.
- Hladiuk M, Huchcroft S, Temple W, Schnurr E. Arm function after axillary dissection for breast cancer. J Surg Oncol 1992: 50: 47–52.
- Swedborg I, Borg G, Sarnelid M. Somatic sensation and discomfort in the arm of post-mastectomy patients. Stand J Rehab Med 1981: 13: 23–29.
- Kissin M W, della Roveret Q, Easton D, Westbury G. Risk of lymphoedema following the treatment of breast cancer. Br J Surg 1986; 73: 580–584.

- Sunesson B L. Arm lymphoedema after treatment for breast cancer – a challenge for health professionals. Linköping, Thesis No 21, 1996.
- Segerström K, Bjerke P, Nyström A. Importance of time in assessing arm and hand function after treatment of breast cancer. Stand J Plast Recant Hand Surg 1991; 25: 241–244.
- Sugden E M, Rezvani M, Harrison J M, Hughes L K. Shoulder movement after treatment of early stage breast cancer. Clin Oncol 1998; 10: 173–181.
- Gerber L, Lampert L, Wood C et al. Comparison of pain, motion and edema after modified radical mastectomy vs local excision with axillary dissection and radiation. Breast Cancer Res Treatment 1992; 21: 139–145.
- 11. Brismar B, Ljungdahl I. Postoperative lymphoedema after treatment of breast cancer. Acta Chir Stand 1983; 149: 687–689.
- Swedborg I, Wallgren A. The effect of pre- and postmastectomy radiotherapy on the degree of edema, shoulder-joint mobility and gripping force. Cancer 1981; 47: 877–881.
- 13. Wingate L et al. Rehabilitation of the mastectomy patient: a randomized blind, prospective study. Arch Phys Med Rehab 1989; 70: 21–24.
- Gutman H, Kersz T, Barzilai T, Haddad M, Reiss R. Achievements of physical therapy in patient after modified radical mastectomy compared with quadrantectomy, axillary dissection and radiation for carcinoma of the breast. Arch Surg 1990; 125: 389–391.
- Dawson I, Stam L, Heslinga JM, Karlsbeek HL. Effect of shoulder immobilization of wound seroma and shoulder dysfunction following modified radical mastectomy. Br J Surg 1989; 76: 311– 312.
- Flew T J. Wound drainage following radical mastectomy: the effect of restriction of shoulder movement. Br J Surg 1979: 66: 302–305.
- Schultz I, Barholm M, Gröndal S. Delayed shoulder exercises in reducing seroma frequency after modified radical mastectomy. Ann Surg Oncol 1997; 4: 293–297.
- Petrek J, Peters M, Nori S, Knauer C, Kinne D, Rogatko A. Axillary lymphadenectomy: a prospective randomized trial of 13 factors influencing drainage, including early or delayed arm mobilization. Arch Surg 1990; 125: 378–382.
- Browse D J, Goble D, Jones P A. Axillary node clearance: who wants to immobilize the shoulder? Eur J Surg Onc 1996; 22: 569– 570.
- Jansen RFM, van Geel A, de Groot H, Rottier A, Olthius G, van Putten W. Immediate versus delayed shoulder exercises after axillary lymph node dissection. Am J Surg 1990; 160: 481–484.
- 21. Wingate L. Efficacy of physical therapy for patients who have undergone mastectomy. Phys Ther 1985; 6: 896–900.
- Lotze M, Duncan M, Gerber L, Woltering E, Rosenberg S. Early versus delayed shoulder motion following axillary dissection. Ann Surg 1981; 193: 288–295.
- Van der Horst C H, Kenter J A L, De Jong M T, Keeman J N. Shoulder function following early mobilization of the shoulder after mastectomy and axillary dissection. Neth J Surg 1985; 4: 105– 108.
- Rodier J F et al. Influence of the timing of pysiotherapy upon the lymphatic complications of asillary dissection for breast cancer. Int Surg 1987; 72: 166–169.
- Petlund CF. Prevalence and incidence of chronic lymoedema in a Western European Country. Prog Lymph 1990; XII: 391–394.
- Tengrup I, Tennvall Nittby L, Christiansson I, Laurin M. Armbesvär vanliga efter bröstoperation. Läkartidningen 1999; 46: 5089–5091.
- Hoe A L, Ivens D, Royle G T, Taylor I. Incidence of arm swelling following axillary clearance for breast cancer. Br J Surg 1992; 79: 261–262.
- Swedborg I. Voluminometric estimation of degree of lymphoedema and its therapy by pneumatic compression. Scand J Rehab Med 1977; 9: 131–135.

- 29. Godal R, Swedborg I. A correction for the natural asymmetri of the arms in the determination of the volume of oedema. Stand J Rehab Med 1982; 14: 193-195.
- 30. Riddle D L, Rothstein J M, Lamb R L. Goniometric reliability in a clinical setting. Phys Ther 1987; 5: 668–673.

 31. Öberg T, Öberg U, Karsznia A. Handgrip and fingerpinch
- strength. Phys Ther Theory Practice 1994; 10: 27-34.
- 32. Gift A. Visual Analogue scales: measurement of subjective phenomena. Nurs Res 1989; 38: 286-288.
- 33. Brorson H. Liposuction gives complete reduction of chronic large arm lymphedema after breast cancer. Acta Oncol 2000; 39:
- 34. Gaskin T, LoBuglio A, Kelly P, Doss M, Pizitz N. STRETCH: a rehabiltive program for patients with breast cancer. South Med J 1989; 4: 467–469.

- 35. Kuhnke E. Volumenbestimmung entrundeter Extremitäten aus Umfangsmessungen. Z Lymphol 1978; 2: 37-44.
- 36. Liljegren G, Holmberg L. Arm morbidity after sector resection and axillary dissection with or without radiotherapy in breast cancer. Eur J Cancer 1997; 33: 193-199.
- 37. Christensen SB, Lundgren E. Sequelae of axillary dissection vs axillary sampling with or without irradiation for breast cancer. Acta Chir Scand 1989; 155: 515-520.
- 38. Aitken R J, Gaze M N, Rodgre A, Chetty U, Forrest A P M. Arm morbidity within a trial of mastectomy and either sample with selective radiotherapy of axillary clearance. Br J Surg 1989; 76:
- 39. Pollard R, Callun KG, Altman DG, Bates T. Shoulder movement following mastectomy. Clin Oncol 1976; 2: 343-349.