Physiotherapy after surgery in patients with subacromial pain

An evaluation of functional outcome and health-related quality of life in the mid- and long-term perspective

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”Every problem is an opportunity in disguise”

Adapted from *Jonathan Livingstone Seagull*, Richard Bach (1970)

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An evaluation of functional outcome and health-related quality of life in the mid- and long-term perspective

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ABSTRACT

Background: No consensus exists regarding physiotherapy treatment after surgery in patients with subacromial pain. There are only a few randomised, controlled studies that evaluate outcome after different physiotherapy treatment protocols. Very few descriptions in terms of work load during exercise or during everyday activities have been presented in the literature. There is a lack of knowledge of patients' clinical course and definitions of attainable goals after surgery and physiotherapy. There is also a lack of knowledge of the long-term results for shoulder function and shoulder-related quality of life. The overall purpose of the thesis was to develop new physiotherapy treatment protocols for patients after surgery for subacromial pain.
Aim: The primary aim was to evaluate if patients after rotator cuff repair or arthroscopic subacromial decompression (ASD) who were treated according to a comprehensive well-defined protocol with a more progressive approach became pain free and attained higher shoulder function at an earlier stage compared with those treated according to a more general approach. The secondary aim was to describe attainable goals in the mid- and long-term perspective.
Patients and methods: In *Study I*, 14 patients were followed until two years after surgery involving full-thickness rotator cuff repair. In *Study II*, 31 patients (32 shoulders) were followed until two years after surgery involving ASD. In both *Study I* and *Study II* physiotherapy treatment protocols with early, specific activation and a more progressive regimen were compared with protocols consisting of a more general, protective regimen. In *Studies III and IV*, 95 patients (105 shoulders) were evaluated 8-11 years after ASD. In the four studies, the patients underwent clinical examinations evaluating pain

during activity and at rest, range of motion and muscle strength. Moreover, instruments evaluating shoulder function and quality of life, as well as patient satisfaction, were used.

Results: In *Study I,* the pain intensity was below VAS 30 mm from six months and, from one year postoperatively, the majority of patients were pain free. At one year, the two groups had attained 150° in flexion, ≥170° in abduction and ≥70° in external rotation. At two years, the Constant Score was ≥77 points. In the Progressive Group 7/7 and in the Traditional 6/7 reported satisfaction with shoulder function at two years. In *Study II*, the pain intensity was below VAS 30 mm from three months postoperatively. At two years, the majority of the patients were pain free and had attained ≥150° in flexion, ≥170° in abduction and ≥75° in external rotation. The Constant Score was 87 points in the Progressive Group and 67 points in the Traditional Group. In the Progressive Group 7/8 and in the Traditional Group 13/18 reported satisfaction with shoulder function. In *Studies III and IV*, the majority of patients attained similar results in terms of range of motion, muscle strength and physical activity as those attained by individuals without shoulder pathology. High shoulder-related quality of life was reported by the majority of patients. Eighty-four per cent stated that they were satisfied with their present shoulder function. The level of pain during activity was the strongest explanatory variable for patient satisfaction. The range of motion in active external rotation in 90º of abduction was the strongest explanatory variable for having a pain-free shoulder during activity. There were no differences between men and women in quality of life, pain during activity, pain at rest or patient satisfaction 8-11 years after ASD.

Conclusion: The principal finding in the intervention studies was that pain decreased by approximately 50% within three months postoperatively. The patients reported that they were pain free one year after rotator cuff repair and two years after ASD. After rotator cuff repair, the more progressive physiotherapy protocol showed as good results as did the more protective protocol while after ASD the progressive protocol was associated with slightly faster recovery of shoulder function and no adverse effects were noted. Early activation using the comprehensive, well-defined and controlled physiotherapy protocols as presented in this thesis may therefore be recommended after rotator cuff repair and ASD. Active external rotation was associated with pain-free activity. Therefore methods to enhance range of motion in external rotation e.g. stretching of the posterior capsule may be recommended. Favourable long-term results were shown after ASD.

Keywords: shoulder pain, impingement, rotator cuff, repair, physiotherapy, rehabilitation, evaluation, patient satisfaction, quality of life, posterior capsule, strength training, gender

THE THESIS

The initial inspiration for Studies I and II was the wide range of undefined postoperative routines after arthroscopic subacromial decompression (ASD) and rotator cuff repair that I noted in clinical day-to-day practice. There was no consensus regarding the time of immobilisation, the timing to return to full shoulder activity after surgery or the concept of physiotherapy treatment. There was also uncertainty and controversy about whether physiotherapy treatment should be carried out. It was difficult for me and my colleagues to give any trustworthy answer to concerned patients' questions about the planning of physiotherapy treatment and return to work or to sport activities or about other future expectations.

During the world congress on Shoulder and Elbow Surgery in Helsinki in 1995, I listened to many reports on the outcome after shoulder surgery. They often stated that physiotherapy accounted for 50% of the final outcome. Only one presentation described physiotherapy after shoulder surgery. The speaker said that only the cold, and the cold provided by a table fan, had been proven to be effective as a physiotherapy treatment modality. My colleague and I did not agree! We also felt a responsibility to evaluate other physiotherapy treatment interventions.

Prior to starting work on the prospective studies, a retrospective study was conducted to establish the level of functional deficits in patients undergoing full-thickness rotator cuff repair, 16 (9-33) months after surgery at our clinic. This was also regarded as a pilot study to test the feasibility of the assessment procedure.

The two progressive protocols were based on the evidence available in the literature at the time. The progressive protocols were to be evaluated and the results were intended to provide evidence in order to reach consensus at the clinic and thereby tailor new, specific treatment protocols. The main concern was to guarantee uniformity and to secure the patients' postoperative course. Secure in this context meant preventing a re-tear in patients undergoing rotator cuff repair. Another reason was to facilitate the everyday work for physiotherapists treating this often difficult syndrome of subacromial pain.

Since 2003, new treatment protocols for patients undergoing rotator cuff repair and arthroscopic subacromial decompression have been implemented at the orthopaedic clinic at Sahlgrenska University Hospital and have been spread to primary care units in the western part of Sweden, where the physiotherapy treatment is also often carried out.

Physiotherapy, including exercise, education and regimens and individually graded strengthening programmes in patients with subacromial pain, should be carried out before surgery is considered. The achievable goals in terms of range of motion, strength and pain reduction after ASD in the long-term perspective were not well described in the literature. From the patient's angle, this information is important when it comes to deciding between continuing physiotherapy or proceeding to surgical treatment with ASD. The physiotherapist is often involved in this decision-making process and should be provided with solid, sound evidence to be able to contribute trustworthy advice.

LIST OF STUDIES

I. Hultenheim Klintberg I, Gunnarsson A-C, Svantesson U, Styf J, Karlsson J. Early loading in physiotherapy treatment after full-thickness rotator cuff repair: a prospective randomized pilot study with a two-year follow-up. Clinical Rehabilitation, 2009;23:622-638

II. Hultenheim Klintberg I, Gunnarsson A-C, Svantesson U, Styf J, Karlsson J. Early activation or a more protective regime after arthroscopic subacromial decompression – a description of clinical changes with two different physiotherapy treatment protocols – a prospective, randomized pilot study with a two-year follow-up. Clinical Rehabilitation, 2008;22:951-965

III. Hultenheim Klintberg I, Svantesson U, Karlsson J. Long-term patient satisfaction and functional outcome 8-11 years after arthroscopic subacromial decompression. Knee Surgery, Sports Traumatology, Arthroscopy, 2010;18:394-403

IV. Hultenheim Klintberg I, Karlsson J, Svantesson U. Health-related quality of life, patient satisfaction and physical activity 8-11 years after arthroscopic subacromial decompression. Submitted

CONTENT

ABBREVIATIONS

ASD	Arthroscopic Subacromial Decompression
CI	Confidence Interval
EQ-5D	European Quality of Life in 5 Dimensions questionnaire
FIS	Functional Index of the Shoulder questionnaire
HIB	Hand In Back functional test
HIN	Hand In Neck functional test
ICC	Intra Class Correlation
ICF	International Classification of Functioning, Disability and Health
IPAQ	International Physical Activity Questionnaire
NRS	Numeric Rating Scale
PG	Progressive Group
POP	Pour out of a Pot functional test
RCT	Randomised Controlled Trial
ROM	Range of Motion
TG	Traditional Group
VAS	Visual Analogue Scale
VRS	Verbal Rating Scale
WOOS	Western Ontario Osteoarthritis Shoulder index

DEFINITIONS IN SHORT

Change score	Term used for the difference in the results in an item or instrument between two follow-up assessments, e.g. 6 weeks values subtracted from preoperative values.
Intention-to-treat analysis	A strategy for analysing data from a randomised controlled trial. All the participants are included in the arm to which they were allocated, whether or not they received (or completed) the intervention given to that arm. Intention-to-treat analysis prevents bias caused by the loss of participants, which may disrupt the baseline equivalence established by randomisation and which may reflect non-adherence to the protocol.
Likert Scale	Corresponds to a psychometric scale commonly used in questionnaires and is a widely used scale in survey research. When responding to a Likert questionnaire item, respondents specify their level of agreement with a statement. The scale is named after its inventor, Rensis Likert (psychologist).
Nociception	This is the neural process of coding harmful stimuli initiated by pain receptors (nociceptors). These receptors are able to detect mechanical, thermal or chemical changes above a set threshold.

Reliability	The degree to which an item or instrument is free from errors of measurement. Other terms that are similar to reliability are accuracy, stability and consistency.
Responsiveness	The extent to which practically or theoretically significant changes in the subject's state are reflected in substantive changes in observed values. The term is equivalent to "sensitivity to change".
Test–retest	This is the approach for determining the reliability of an item or instrument by taking repeated measurements in to the same individuals over a specified time interval. In this way stability or consistency items or instruments can be evaluated.
Validity	This relates to the extent to which an instrument measures what it is intended to measure. Validity is the meaningfulness and utility of an application of a measurement. It is a quality associated with the way in which test results are used. Instruments are usually used to evaluate, discriminate or predict.
Work	The product of the force and the distance through which the body moves, expressed in joules (J).

1 INTRODUCTION

The shoulder is the functional link that permits an individual to perform the desired tasks with his/her hand throughout space. Shoulder pain and dysfunction affect activities of daily living as well as the perception of health. Subacromial pain, or as it is often called impingement syndrome, is considered to be one of the most common forms of shoulder pathology.[8,167] In a Swedish survey Bergman et al. reported that the prevalence of chronic regional pain in the shoulder and/or upper arm pain was 8.5% in women and 10.5% in men.[8] In their study, the definition of chronic regional pain was: "*persistent or regularly recurrent pain for more than 3 months over the last 12 months"*.[8] When including patients with chronic widespread pain, when pain was present in both the left and right sides of the body, as well as above and below the waist, the prevalence of pain in the shoulder and upper arm was even higher, i.e. 23.8% in women and 15.4% in men. Several studies indicate that the prevalence increases with age.[8,109] In the UK, the incidence of adults consulting for shoulder conditions peaked at an age of 50 years and then remained stable at around 2%.[109] Nygren et al. reported that 20% of all disability payments for musculoskeletal disorders in Sweden were related to shoulder disorders.[131] In the UK, the estimated percentage of people consulting for treatment for shoulder conditions in the general practice setting is between 20-50%.[109] In the region of Gothenburg approximately 200 patients undergo arthroscopic subacromial decompression and approximately 80 patients undergo rotator cuff repair every year. In Sweden the number of patients who undergo surgery for subacromial pain has increased considerably in the recent years. In 2005, 2,287 patients (1,403 men and 884 women) and in 2008, 7,959 patients (4,853 men and 3,106 women) underwent surgery for subacromial pain according to statistics from the Swedish Board of Health and Welfare (Socialstyrelsen).

1.1 Pathogenesis and aetiology of subacromial pain

The pathology in subacromial pain has a wide spectrum of severity, ranging from inflammation to degenerative changes within the subacromial bursa and the rotator cuff tendons. In the long-term perspective full-thickness rotator cuff tear and degenerative joint diseases may also develop.[21,126] The original classification of the three stages of subacromial pain (impingement syndrome) according to Neer is presented in Table 1.[126,127]

The subacromial space is defined inferiorly by the humerus and limited superiorly by the coracoacromial arch, consisting of the undersurface of the acromion, the coracoacromial ligament and the acromioclavicular joint.[126] The subacromial space is occupied by the subacromial bursa, the tendons of the rotator cuff, most predominantly the supraspinatus,[126] the tendon of the long head of the biceps brachii and the capsule of the shoulder joint.[121]

The phenomenon of painful arc in the shoulder was originally described by Kessel and Watson.[90] Painful arc corresponds to pain during active motion during abduction or elevation in the plane of the scapula in the range between 60º to 120º. These findings were supported by the work of Flatow et al.[47] who in a cadaveric study measured the distance between the acromion and the humeral head. With the arm at the side, 0º of elevation, the distance was 11 mm (SD 11 mm).[47] In nine young healthy volunteers Solem-Bertoft et al. [157] found that the distance was between 11-15 mm. The humerus and acromion are in the closest position in the range of 60º to 120º. After 90º the distance gradually increases again. The point of contact is the undersurface of the antero-lateral edge of the acromion. On the humeral side, both the tendon of the long head of the biceps and the tendon of the supraspinatus displayed points of contact. With an internally rotated humerus the area of contact is larger.[47] The highest values for intramuscular pressure of the supraspinatus muscle were identified in the position with the arm at 90º of elevation in the plane of the scapula.[80] This may lead to the compression of the blood vessels and thereby compromise the blood supply to the rotator cuff tendons. It has been speculated that this is one of the factors contributing to the more frequent subacromial pain seen in patients with heavy overhead loads at work or during leisure or sporting activities.[69,78,80]

Table 1. *Original classification of impingement syndrome according to Neer.*[127]

	Patho-anatomical characteristics	**Typical age**	**Clinical course**	**Treatment**
Stage I	Oedema and haemorrhage	<25	Reversible	Conservative
Stage II	Fibrosis and tendinitis	25-40	Recurrent pain with activity	Consider bursectomy; C/A ligament devision
Stage III	Bone spurs and tendon rupture	>40	Progressive disability	Anterior acromioplasty; rotator cuff repair

Over time a change in the morphology of the antero-inferior edge of the acromion has been identified. Three types have been graded and described; I – flat, II – curved and III – hooked.[129] Compressive forces on the subacromial bursa and the tendons within the rotator cuff and long head of the biceps are larger in patients with acromion type III. These higher compressions are thought to contribute to the larger number of the rotator cuff tears, seen in patients with type III acromion.[47,134]

1.1.1 Pain mechanism of the shoulder

During tendon healing there is a continuous process of neovessels growing into the damaged tissue.[79,99] These neovessels are accompanied by free nerve endings and they are thought to be involved in the nociceptive transmission.[74,99]

The sources of pain are considered to be the subacromial bursa and the musculo-tendinous rotator cuff as well as the coraco-acromial ligament (Figure 1).

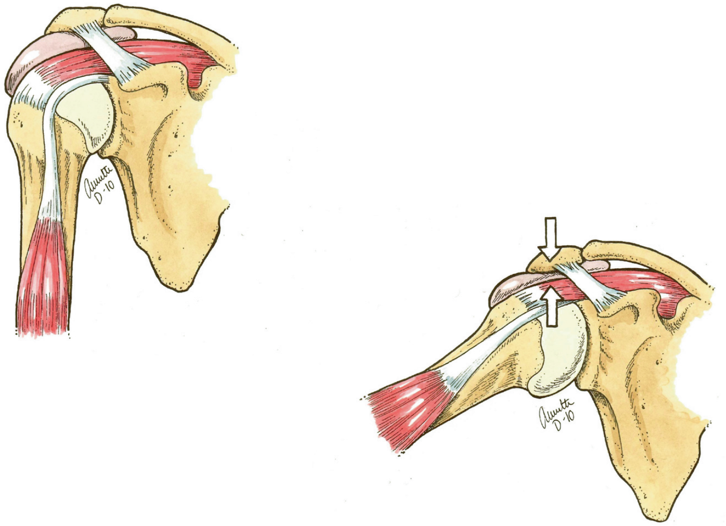

Figure 1. Impingement of the subacromial bursa, the supraspinatus tendon and the tendon of the long head of the biceps with the arm elevated.

The subacromial bursa is the largest bursa in the human body.[74] The role of the subacromial bursa is to reduce friction between primarily the supraspinatus tendon and the undersurface of the acromion during shoulder motions.[106] The subacromial bursa is innervated by the supra-scapular nerve and the lateral pectoral nerve providing proprioception and nociception.[74] The subacromial bursa may thereby also contribute to the kinaesthetic sense and mechano-reception of the shoulder.[74] These mechano-receptors are thought to contribute by a reflex system to a more efficient stabilising muscle action within the rotator cuff.[74] The primary source of pain within the shoulder is thought to be the subacromial bursa.[18,68,106] The source of pain may also be chemical; a correlation has been found between concentrations of neuropeptide substance-P in the bursa and shoulder pain.[55,91]

Pain may be elicited from the tendons of the rotator cuff and the tendon of the long head of the biceps.[106] Supraspinatus pain is typically located in the region of the anterior deltoid muscle.[18]

Free nerve endings and neovascularity identified in the coracoacromial ligament suggests that the ligament may also be a source of shoulder pain.[158]

1.1.2 The consequence of subacromial pain

Subacromial pain is associated with limitations, such as the loss of muscle strength and endurance. External rotation and abduction are particularly affected.[18,115,168] Range of motion is often reduced in patients with subacromial pain.[58,113,114] The largest reduction is often seen in internal rotation.[32 ,65,165,168] External rotation, flexion and abduction are reduced, but to a lesser degree.[168] Patients with a rotator cuff tear are usually affected by pain, limitations in range of motion and strength to a more severe degree than patients with subacromial pain but no tear.[155]

These limitations are often associated with dysfunction and limitations in activity and participation, in patients both with and without a rotator cuff tear. The limitations are expressed in particular by patients being unable to lift a weight above their head, working full time in their normal profession or being unable to participate at the desired level in sports and leisure activities.[27] Patients are often affected by disturbed sleep.[155] They also experience a significant reduction in their quality of life.[27] Tucking in the shirt at the back was reported to be a problem by the majority of patients with rotator cuff tears.[155]

1.2 Shoulder-related quality of life

Chipchase et al.[27] compared SF-36 data in a patient group with subacromial pain with Australian normative data. All health concepts of quality of life were significantly lower in the patient group.

In 1948, the World Health Organisation declared that health was *"a state of complete physical, mental and social well-being, and not merely the absence of disease"*. Health is a far wider concept than that of the absence of illness or disability. According to Pörn,[138] having good health means being able to live your life according to your intentions. Good health comprises three dimensions:

- the person's wish and purpose
- the person's interpersonal resources
- the person's environments

Traditionally, when evaluating outcome, clinician-based measures such as range of motion and strength have been used as primary outcomes. These measures are defined at the level of "Body function and structure", according to the International Classification of Functioning, Disability and Health (ICF).[171] These measures have been considered to be objective and reliable. In recent years, a change towards a whole-person perspective in the evaluation of treatment has been taken into practice in orthopaedic and physiotherapy interventions. Information about the patients' ability during "Activities" and "Participation" must also be addressed.[122,147] For this purpose, both generic and disease-specific, health-related quality of life measurement tools should be used in order to capture the patients' overall perception of health[7,122] and may be addressed under "Participation" according to the ICF.

The use of the coding system, terms and constructs provided by the ICF is intended to facilitate communication between different professional groups involved in the treatment and handling of the patient.[60] A common language used in the description of a patient's functional capacity, the limitation and overall state of health is of basic interest in the collaboration between physiotherapists, orthopaedic surgeons, proxy persons/relatives, the social security system and assurance companies. The recommendation today is to link treatment interventions, measures and instruments in scientific reports to the ICF.[60]

1.3 Biomechanics of the shoulder

Scapulohumeral rhythm occurs concurrently and is inseparable in all four shoulder joints.[83] The four joints are the sternoclavicular, acromioclavicular, scapulothoracic and glenohumeral articulations. Scapulohumeral rhythm is often described as *the relationship between elevation at the glenohumeral joint and scapular upward rotation*.[13]

1.3.1 Glenohumeral joint kinematics

During glenohumeral elevation of the arm, the humerus concomitantly rotates externally.[17,47] External rotation of the humeral head is important for clearance of the greater tuberosity and the subacromial soft tissue as it passes under the coracoacromial arch. At the same time, the capsular and ligamentous restraints are relaxed to allow maximum glenohumeral elevation.[17,47]

1.3.2 Scapulothoracic articulation kinematics

During elevation of the arm the scapula moves in a three-dimensional fashion:[13,121,166]

- Upward rotation occurring around an anterior-posterior axis with the inferior angle of the scapula moving laterally (Figure 2a and b)

- Posterior tilt occurring around a medial-lateral axis with the inferior angle of the scapula moving anteriorly (Figure 3a and b)

- External rotation occurring around a superio-inferior axis with the lateral border of the scapula moving posteriorly and the inferior angle of the scapula moving into the body wall (Figure 4a and b)

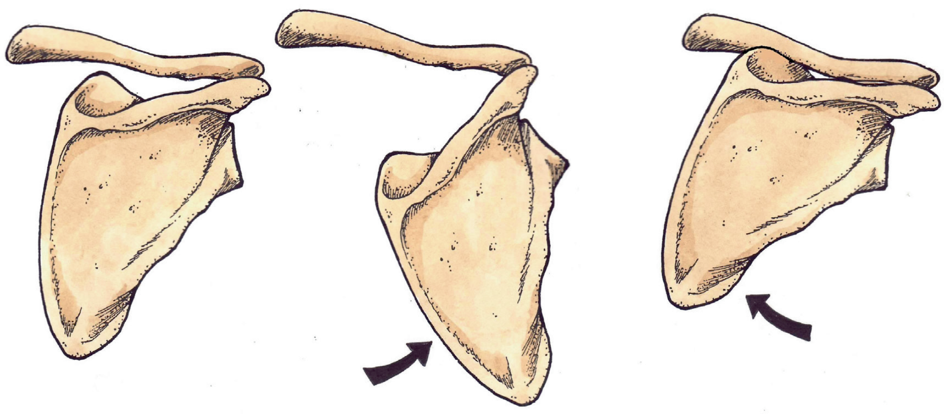

Figure 2. a) Scapular neutral position, posterior view of the right shoulder. b) Scapular upward rotation. With increased upward rotation, the glenoid articular surface rotates upwardly and the acromion is elevated. c) Scapular downward rotation. With increased downward rotation, the glenoid articular surface rotates downward and the acromion is lowered.

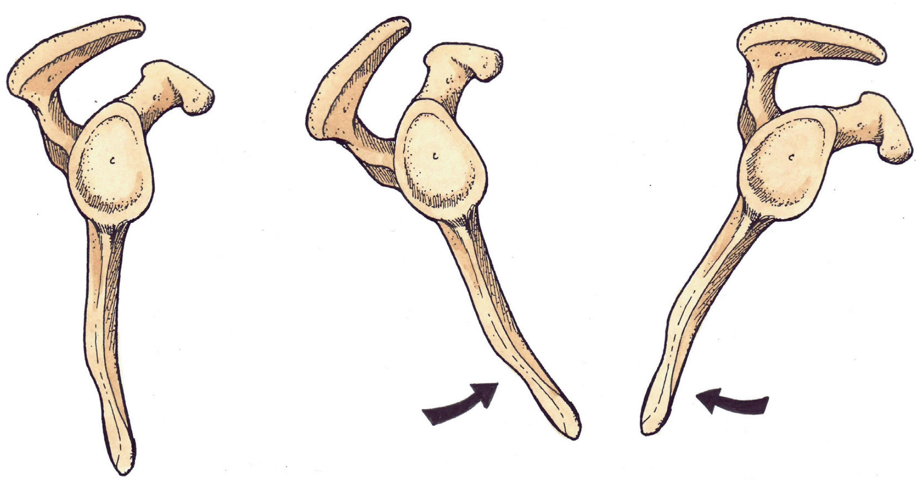

Figure 3. a) Scapular neutral position, lateral view of the right shoulder. b) Scapular posterior tilting. With increased posterior tilting, the glenoid rotates posteriorly and the acromion is elevated at the same time by posterior rotation. c) Scapular anterior tilting. With increased anterior tilting, the glenoid rotates downwards and the acromion in lowered.

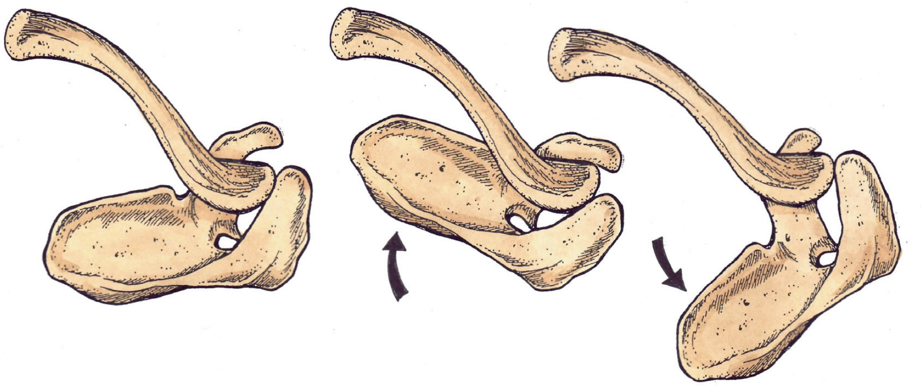

Figure 4. a) Scapular neutral position, superior view of the right shoulder. b) Scapular external rotation. With increased external rotation, the glenoid rotates externally c) Scapular internal rotation. With increased internal rotation the glenoid and the acromion rotates internally.

During glenohumeral elevation, the predominant motion of the scapula is the upward rotation that results in the elevation of the acromion.[121] During the first 30º to 60º of humeral flexion or abduction, the scapula tends to find a position of stability and there is very little upward rotation of the scapula during this period of motion. From 80º to 140º of shoulder elevation is the range in which most of the scapular upward rotation occurs.[5]
The posterior tilting of the scapula further elevates the antero-lateral edge of the acromion.[22] These motions prevent the subacromial soft tissue from being impinged.[47] Shoulder retraction also results in the posterior tilt of the scapula and further increases the area of the subacromial space as compared to shoulder protraction.[157] As the subacromial space is small, even a subtle change in dimension can result in the compression of the subacromial tissues.[47]

Scapular movement is also the result of clavicular elevation and rotation. These motions are the prerequisite for clearance of the antero-lateral aspect of the acromion, as well as of the acromio-clavicular joint during elevation of the arm.

1.3.3 Posterior glenohumeral joint capsule

In the normal shoulder, the width of the capsule and integrated ligaments allow the humeral head to rotate downwards in the glenoid fossa during motion.[65] The impingement syndrome is almost always associated with the physical finding of posterior capsular tightness.[15,25,32,65,83,124,168] The tightness of the posterior portion of the capsule forces the humeral head to superior migration and occurs during glenohumeral flexion and also in cross-body movements.[65]

In a cadaveric study, where posterior capsular tightness was surgically induced, there was an increase in the superior and anterior translation of the humeral head during passive glenohumeral flexion.[65] The superior glide leads to the increased mechanical compression of the subacromial bursa and the tendons of the rotator cuff.[47]

The tightness of the posterior capsule may be due to reactive fibrosis tissue in the capsule in some patients as a result of repetitive microtrauma.[168]

The flexibility of the posterior glenohumeral capsule can be evaluated by measuring the range of motion in internal rotation and cross-chest adduction.[168]

1.3.4 Muscle biomechanics of the shoulder

The functional use of the arm consists most often of motions between the plane of forward flexion and elevation in the plane of the scapula. Howell [70] showed that the supraspinatus and deltoid muscles are equally responsible for the muscle strength in motions ranging from 15º to 150º of flexion and/or elevation.

The rotator cuff

The rotator cuff comprises the supraspinatus, subscapularis, infraspinatus and teres minor muscles (Figure 5). They originate from the scapula and form a confluent aponeurotic tendon that surrounds the humeral head and contributes to the movement, stability and sensory motor control of the glenohumeral joint.[150]

The role of the **supraspinatus** muscle is multifactorial, but has not as yet been fully clarified. The sole capacity of the supraspinatus muscle to depress the humeral head is uncertain.[154]

The suprapinatus contributes mainly to abduction,[100] the compression of the humeral head into the glenoid fossa [70] but also to external rotation.[100] During abduction, suprapinatus activity reaches its peak value at 60º.[100]

Up to 30º of abduction, the supraspinatus is activated at a higher level than the deltoid.[2,100] Poppen and Walker[135] proposed that the supraspinatus is more important than the deltoid in initiating abduction up to 30º because of its longer moment arm compared with the deltoid.

In healthy shoulders, Poppen and Walker[135] found that the first 3 mm of superior glide of the humeral head occured during the first 30º. An additional 1-2 mm may occur in some individuals up to 60º elevation in the plane of the scapula. This superior glide of the humeral head is due to the pull of the deltoid muscle and the anterior translation by the pectoralis major and latissimus dorsi. This undesirable motion must be counteracted to prevent injury.[154,163] In the simultaneous activation of the deltoid and the four muscles within the rotator cuff, superior humeral head migration was significantly less than without activity of the rotator cuff.[154] On the other hand, the supraspinatus was not able by itself to prevent superior humeral head migration. The addition of the supraspinatus to the other three muscles of the rotator cuff did not contribute to reduced humeral head migration.[154]

Implication: Exercises for the supraspinatus muscle should be performed in the lower degrees of elevation in the plane of the scapula.

The **infraspinatus** has been shown to contribute most to the glenohumeral external rotation.[2,100,101] The infraspinatus reaches the peak value at approximately 40º of external rotation regardless of the level of abduction.[100] The infraspinatus also contributes to abduction, and to a greater extent than supraspinatus, in the range between 90º and 180º.[100,110] Although it has a shorter lever arm than the supraspinatus, the infraspinatus has a larger physiological cross-sectional area and its contribution to abduction is therefore important.[110]

Alpert et al.[2] found the highest activity in the infraspinatus in the range between 30º-60º when evaluating rotator cuff function under varying loads and speeds during elevation of the arm in the plane of the scapula. The infraspinatus has also been shown to have a high level of activity during flexion, higher than the supraspinatus.[100]

The contribution of the infraspinatus to external rotation tends to decrease with a higher degree of abduction.[2,45,143]

Implication: Exercises for the infraspinatus should be performed at different angles of shoulder range of motion.

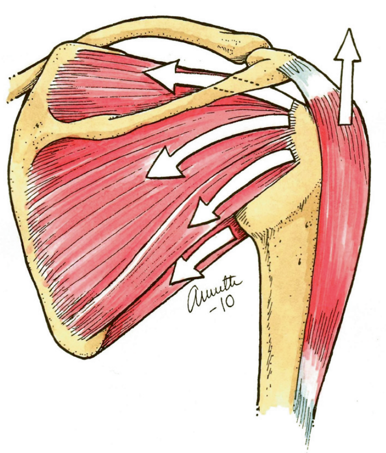

Figure 5. Illustration of the rotator cuff and the deltoid muscle with indication of direction of force generation.

The **teres minor** contributes to glenohumeral external rotation together with the infraspinatus.[2,45,101,143] Teres minor maintains its contribution to external rotation strength throughout the whole range of motion of abduction. The abduction angle does not affect the contribution to external rotation by the teres minor. Teres minor activity is similar at 0º, 45º and 90º of abduction and is increased in the arc of 120º-150º.[2] The contribution to external rotation tends to increase at higher angles.[2,101]

In favour of the insertion of the teres minor, away from the antero-lateral aspect of the acromion, the teres minor tendon is seldom affected by the pathology in subacromial pain.[177] It is therefore seldom affected by pain during or after exercise. The main part of its muscle fibres are situated distally to the centre of rotation of the humeral head and it is therefore an effective depressor[150] and plays a strategic role in achieving pain-free shoulder function.

Implication: Exercises for the teres minor should be performed from 45º and gradually up to increased angles of shoulder range of motion.

The primary role of the **Subscapularis** is to contribute to the internal rotation. This contribution has a tendency to decrease as the angle of glenohumeral elevation increases. The subscapularis is also active during abduction and flexion throughout the range of motion but to a lesser degree compared with the supraspinatus and infraspinatus.[100] Liu et al. [110] found that the subscapularis changes from being an abductor to an adductor at approximately 60º of glenohumeral elevation. A major part of the muscle fibres are situated distally to the centre of rotation of the humeral head, like the teres minor, and may therefore contribute substantially to humeral head depression.[2,154]

Implication: Exercises for the subscapularis should be performed at different angles but mainly in the lower angles of shoulder range of motion.

The long head of the biceps contributes to glenohumeral flexion, abduction and external rotation.[151] The long head of the biceps also stabilises the head of the humerus anteriorly and superiorly and thereby helps to reduce the pressure in the subacromial space.[178] In a cadaveric study, the long head of the biceps has been shown to limit excessive internal and external rotation as well as the posterior translation of the humeral head within the glenoid fossa.[178] The long head of the biceps appears to centre the humeral rotation on the glenoid fossa at the extremes of internal and external rotation.[178] The long head of the biceps is documented as a humeral head depressor, as well as a humeral head compressor.[93,178]

Implication: Exercises for the long head of the biceps should be performed by flexion at the glenohumeral joint with a straight elbow and the forearm in the position of supination.

Dysfunctional or weak rotator cuff musculature has been well documented in patients with subacromial pain.[19,149,168] A reduction of 30% or more in initial muscle strength in the rotator cuff appears to be enough to result in a more superiorly positioned humeral head.[149]

The scapular stabilisers and rotators

The upper part of the **serratus anterior,** together with the mid-portion of the trapezius and rhomboids are considered to be the main scapular stabilisers. The inferior part of the serratus anterior is the most important upward rotator of the scapula and by keeping the width of the subacromial space it permits the subacromial tissue to pass under the subacromial arch without being impinged (Figure 6).[44,86,135]

Implication: Exercises for the serratus anterior should be performed to create the optimal upward rotation of the scapula, preferably by unilateral scapular protraction.

The **upper trapezius** pulls the acromion upwards and medially. The **lower trapezius** plays an important role in the last phase of elevation. By pulling the upper third of the medial board of the scapula downwards, it completes the upward rotation of the scapula (Figure 6).[86] Exercises to restore scapular stability should put the emphasis on low activity in the upper trapezius in combination with high activity in the mid and lower portions of the trapezius.[33,44]

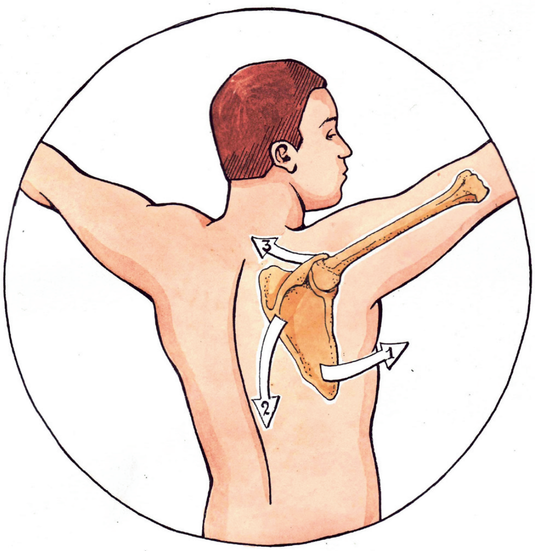

Figure 6. Illustration of scapular rotators with indications of direction of force generation: 1) serratus anterior 2) lower trapezius 3) upper trapezius.

Implication: Exercises for the lower trapezius should be performed to create the optimal upward rotation of the scapula by elevating the arm in the line of the muscle fibres of the lower trapezius, starting from angles close to 90° up to optimal range of motion.

The role of the scapular stabilisers and scapular rotators is multiple. They make the scapula a stable basis for the rotator cuff muscles to act from. The concurrent motions adjust the position of the glenoid fossa in relation to the humeral head to provide an optimal length tension position for the rotator cuff muscles to be most effective.[34,83]

1.3.5 Body posture

An erect body posture has been shown by several authors to be important in preventing shoulder muscle overuse[58] and impingement of the subacromial tissue.[35,88,114] A slouched thoracic position was associated with significantly less posterior tilt of the scapula and thereby a decrease in active range of motion in elevation and in abduction.[88] Moreover, Lewis et al.[107] showed, in patients with subacromial pain, that the pain was experienced at a higher range of active shoulder elevation when maintaining an erect upper body position compared with a slouched position. A taping procedure was used on the thoracic wall and scapula to enhance an erect upper body and retracted scapula.[107]

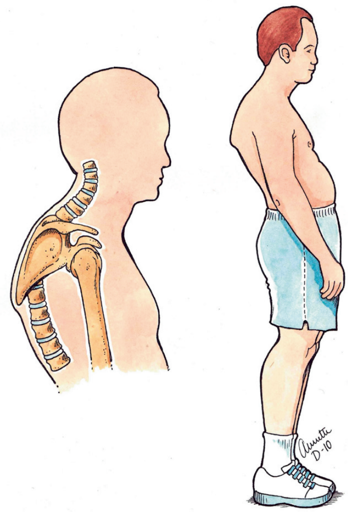

Figure 7. Illustration of scapular position in a slouched body position.

Muscle force has also been seen to be reduced by 16% in a slouched body position. The slouched position is thought to put the scapula in downward rotation, anterior tilt and internal rotation (Figure 2c, 3c 4c and Figure 7). Consequently, the muscles around the scapula and the glenohumeral joint are put in a position of active insufficiency.[88,95]

1.4 Alterations in shoulder joint kinematics

Because of the complex interrelationships in biomechanics between the scapula and the glenohumeral joint motions, scapular dyskinesis may lead to a spectrum of pathological alterations.[22,34,113]

Healthy persons,[160] as well as patients with impingement syndrome [149] exhibit superior humeral head migration during elevation of the arm in the plane of the scapula. When evaluating the position of the humerus in the glenoid fossa after individuals had completed a heavy training programme to fatigue the rotator cuff, the position of the humeral head was seen to be significantly higher up and more superior in the glenoid fossa compared with the pre-fatigue position. The position of the humerus in patients with impingement was even more superior compared with healthy volunteers in Teyhen's report.[149,160] The narrower subacromial space in the state of fatigue may help to explain the pathomechanics that may lead to impingement of the subacromial structures during movement.[149]

Increased winging of the scapula has been identified in patients with shoulder pain compared with healthy controls.[169] A protracted position of the scapula was identified by Greenfield et al.[58] in patients with shoulder overuse syndrome. Winging and protraction are characterised by the internal rotation (Figure 4c) and anterior tilt (Figure 3c) of the scapula, thereby causing a decrease in the subacromial space.[58,113]

Shoulder pain is often followed by a shortened pectoralis minor muscle. It has been shown that this may result in the internal rotation of the scapula, thereby pulling the acromion downwards (Figure 4c).[22]

A protracted shoulder position and a slouched posture are often seen in patients with subacromial pain.[25] Examination of the subacromial space by Magnetic Resonance Imaging (MRI) in healthy individuals revealed that the space is narrowed by protraction and widened by retraction of the scapula.[157]

Scapular muscle imbalance, such as relatively higher activity in the upper trapezius compared with the serratus anterior and the lower trapezius has been proposed as one factor contributing to scapular dyskinesia.[33] On the other hand, it appears that the serratus anterior and the lower trapezius are more susceptible to inhibition by painful conditions.[54]

Dysfunction as a result of fatigue and/or the delayed onset of muscle contraction can also lead to changes in scapular kinematics, such as less scapular posterior tilt[22,34,94], less upward rotation by the serratus anterior and inappropriate temporal sequencing of the scapula-thoracic muscles.[34,83,113]

In Sharkey and Marder's[154] cadaveric study of shoulder joint elevation, any deficit in stimulated activity in the infraspinatus, teres minor or subscapularis resulted in increased superior migration of the humeral head. These observations support the idea that muscle imbalance or fatigue play important etiological roles in subacromial pain.[149,160]

It is uncertain if impingement syndrome causes dysfunctional muscle performance secondary to subacromial compression or if the weakness causes the impingement syndrome to develop, or if it is a combination of both.[149,154,160,168]

1.5 Tendinopathy of the rotator cuff

The aetiology of rotator cuff injury is thought to be multifactorial. Lewis[106] gives the following definition of tendinopathy*"a generic term without aetiological, biochemical or histological implications used to describe pathology in and pain arising from a tendon"*.

Theories behind rotator cuff tendinopathy describe intrinsic and extrinsic factors, with an overlap of mechanisms leading to the progression of the pathology.[112] Intrinsic factors, originating within the tendon, are usually a consequence of overuse, overload or compression within the ageing tendon or microvascular bloodsupply.[106,112]

Extrinsic factors are described as a combination of compression and friction from the inferior aspect of the acromion and the coraco-acromial ligament on the subacromial bursa and rotator cuff tendons, as described earlier.[47,126,127]

The inflammation in the early stage of the pathology leads to fibrotic changes within the tendon and bursa. The fibrotic changes lead to thickening or hypertrophy of the bursa and/or the rotator cuff tendons, potentially leading to increased compression of the tissues against the borders of the subacromial space.[9,83,121]

In the review by Lewis,[106] it is concluded that the actual state in the literature consists of conflicting theories about the pathogenesis of rotator cuff tendinopathy. Nor is the available literature able to clarify whether changes in vascularity occur within the rotator cuff tendon with ageing or are associated with rotator cuff pathology.[106]

It has been proposed that degenerative changes within the rotator cuff tendons can already be seen in more than 70% of the population already at 40 years of age.[18,80] On the other hand, Longo et al.[112] found no degenerative changes in tendons from persons 70 years of age presenting no previous history of shoulder pain. They discussed the possibility that the significant differences found in ruptured tendons must be the result of mechanical stress.[112]

The rotator cuff tendons specialise in accommodating high tensile stresses, up to 100 N/mm. However, compressive and shear forces are less well tolerated.[124] It has been suggested that different strain levels within the supraspinatus tendon at the articular and the bursal sides lead to shear forces within the tendon that exceed the strength. The strain level is already high on the articular side of the tendon already with the arm in a neutral position, in 0º of abduction. During glenohumeral abduction, the differences in strain levels gradually increase. This is thought to result in intra-tendinous micro-tears and also is thought to be one of the reasons for the propagation of partial tears into full-thickness tears.[142]

Meister and Andrews[119] described five different modes of rotator cuff failure; primary compressive disease, secondary compressive disease, primary tensile overload, secondary tensile overload and macro-traumatic injuries. Secondary compression or secondary tensile overload are referred to as glenohumeral instability, scapulothoracic instability or functional overload.[119] The loss of rotator cuff function, from either fatigue or frank tears, can lead to the superior translation of the humeral head during arm elevation, as the deltoid muscle is unopposed.[135,136,154]

Several authors have shown that the degenerative process is accelerated by repetitive stress and especially by overhead activities either from high working demands or during sports.[69,78,80] Rotator cuff tears in younger patients are believed to be related to an eccentric overload of the rotator cuff, during racket sports or throwing activities for example.[119]

Partial tears may create a tension overload on the remaining fibres of the tendon. Over time this may lead to full-thickness rotator cuff failure.[124] The natural course of rotator cuff pathology is not well known. Some patients with rotator cuff tear are asymptomatic.[177] However, shoulder pain has been shown to develop within 5 years in 50% of the patients with asymptomatic rotator cuff tears.[28,177]

Rotator cuff tears may also occur as a consequence of gleno-humeral dislocation.[128] With age, the elasticity of the soft tissues decreases.[97] During a traumatic dislocation of the humeral head, the tension within the rotator cuff and mainly the supraspinatus may exceed the strength of the tissue. The risk of a concomitant rotator cuff tear is more frequently seen in older patients and should always be considered in an event of shoulder dislocation in patients older than 40 years of age.[128]

A full-thickness or complete tear is considered when the full depth of the tendon is injured. The supraspinatus is almost always involved and is the first tendon to rupture. The rupture extends posteriorly to the infraspinatus.[64] The involvement of the teres minor or subscapularis tendons is less frequent.[64,177]

The prevalence of rotator cuff tears increases with age. Yamaguchi et al.[177] found that the average age of patients with no tears was 48.7 years, in patients with unilateral tear 58.7 years while it was 67.8 years for those with bilateral tears. A 50% likelihood of bilateral tears after the age of 66 years was observed.[177]

There is no current standard classification of rotator cuff tears.[37] The classification by De Orio and Cofield[38] was used in Study II (Table 2). They define the size of the rupture by the anterior to posterior length.

Table 2. *The classification by De Orio and Cofield.*

Small tear	≤1 cm
Medium tear	1-3 cm
Large tear	3-5 cm
Massive tear	>5 cm

Furthermore, the retraction, i.e. the gap of the tear, has been shown to be important to define. The grade of retraction in addition to the length may affect the probability of a repair with mechanical sustainable strength.[37]

1.5.1 Tendon healing

Tendon is a dynamic, mechano-responsive tissue.[92] When there are loads above the tolerance level of the tissue, there is a stimulus through mechanotransduction so that the body adapts by increasing protein synthesis and adding tissue where possible.[92] Tendons can respond favourably to controlled loading after injury.[81,92] However, the metabolic turnover in tendon tissue is slower compared with muscle tissue due to poor circulation.[84]

Normal tendon tissue undergoes continuous remodelling. The tendon healing process after acute injury or tendon repair is divided into three phases[79]:

- Acute inflammatory phase; 0-7 days
- Proliferative phase; 8-21 days
- Maturation and remodeling phase; 21 days and thereafter

Immobilisation and the lack of mechanical loading have been shown to negatively influence the turnover of extracellular matrix and thereby accelerate collagen breakdown. Analyses have shown that the breakdown begins just after three days of immobilisation. This collagen breakdown can be partially prevented by tensile loads on the tendon.[97]Activity appears to improve the tensile mechanical properties of tendon and muscle tissue, in contrast to immobilisation or disuse.[84,85,176]

In the proliferative phase, the granulation tissue replaces the original fibrin clot with more scaffolding and more permanent repair tissue. Initially, type III collagen is arranged haphazardly in the absence of cross-linking and glycosaminoglycans. As a result of the tensile forces applied to the tissue, immature type III collagen is replaced by aligned mature type I collagen fibres. Type III collagen is less able to sustain stress than type I collagen. The process gradually transforms to maturation during the remodelling phase and the organisation of scar tissue.[79]

The time needed to reach final tensile strength has not been fully established.[176] Exercise and training induce collagen turnover and may contribute to the acceleration of collagen biosynthesis.[103]

In the muscle tissue, the benefits of loading include the improved alignment of regenerating myotubes that mature into myofibres, as well as the faster and more complete regeneration and minimisation of hypotrophy.[82,85]

Fyfe and Stanish[48] speculated whether eccentric exercises generate greater forces than concentric exercises and thereby greater remodelling stimulus. There is evidence to suggest eccentric exercise can develop greater forces in muscles during dynamic movements, but this evidence does not extend to the specific exercises in the Fyfe and Stanish eccentric exercise protocols.[141]

Recent studies have shown that the mechanical stimuli during eccentric and concentric loading are fundamentally different - not in terms of force magnitude but in the frequency of force fluctuations. These fluctuations are thought to be important in order to successfully stimulate tendon healing.[141]

The potential for spontaneous tendon healing or natural course after rotator cuff injury has not been established.[112]

The phenomenon of ”fatty infiltration” in the torn and retracted rotator cuff was presented by Goutallier et al.[56] It was estimated that the irreversible degeneration made it impossible to restore the muscle function of the supraspinatus. The muscle-tendon unit could be regarded as a passive, ligament-like structure with no dynamic role. In contrast, in patients with full-thickness rotator cuff tear, Einarsson et al.[43] found no difference in muscle morphology or quality compared with the ipsilateral deltoid muscle indicating that muscle function may be reversible.

The risk of tendon rupture as well as tendon healing is also influenced by smoking, diabetes, prior surgery, medication, age, nutritional status and co-morbidities such as systemic disease.[97,124]

1.5.2 Immobilisation after rotator cuff repair

To prevent stress on the repair that may exceed the mechanical strength of the tissue, the arm is immobilised in a brace after rotator cuff repair. A duration of 4 to 6 weeks of immobilisation is often suggested, using a brace with the arm at the side.[53,66]

1.5.3 Implications for surgery in subacromial pain

In the Cochrane systematic review, comprising surgery for rotator cuff disease, thirteen randomised and controlled trials (RCT) were included.[28] Eleven trials included patients with impingement and two trials included patients with rotator cuff tears. No study met all the methodological criteria and minimal pooling could thus be performed. Heterogeneous interventions, poorly described inclusion criteria as well as poor descriptions of patients' characteristics made an appropriate interpretation of the results difficult.[28] Marx et al.[116] also point out, in a recent review, the lack of clear consensus regarding indications for rotator cuff repair in the literature.

Three studies in the Cochrane review[28] compared open or arthroscopic subacromial decompression with active non-surgical treatment (physiotherapy including exercise, education and regimens or individually graded strengthening programmes). In one of them, patients were classified into impingement stage II according to the Neer criteria.[127] No significant difference between surgery and active physiotherapy was shown.[28] Brox et al.[20] included placebo (detuned soft laser) in a third research arm. This arm was halted prematurely after interim analysis at six months. The analysis showed that patients with active treatment, surgery or exercise programmes, improved significantly more than those who received placebo at six months. [20]

In the two RCT studies of rotator cuff repair, one compared arthroscopic rotator cuff repair with or without acromioplasty and the other compared different suture techniques.[28] There were no randomised controlled trials comparing active non-surgical treatment with surgery. Many surgical techniques have been described in the literature, but evidence of their efficacy comes mainly from retrospective or prospective case series.[28]

The indication for surgery for rotator cuff repair at our clinic was marked weakness in humeral abduction, combined with functional impairment, especially pain.

1.5.4 Implications for exercise in subacromial pain

Evidence in favour of the efficacy of physiotherapy interventions for shoulder disorders, i.e. conservative treatment, was reviewed by the Cochrane collaboration.[57] Green et al.[57] found evidence that exercise was effective in both the short and long term. The combination of mobilisation with exercises resulted in additional benefits when compared with exercise alone for rotator cuff disease. The authors of the review are concerned by the small sample sizes, the heterogeneity in terms of the population groups that were studied, the interventions that were used and the length of follow-up. The low methodological quality in the available studies results in little overall evidence to guide treatment for shoulder pain.[57]

From the studies published up to the date of the review, it is not possible to conclude whether supervised physiotherapy is equally effective compared with a prescribed home training programme, or if one is superior to the other.[57]

In the review by Michener et al.,[123] the scope of a systematic search of the literature was limited to studies evaluating physiotherapy in patients with subacromial impingement/pain syndrome. Michener et al. stated that the current literature supports the use of therapeutic exercises to strengthen the rotator cuff and scapular muscles. They also found evidence to suggest that manual therapy in combination with exercises produced a better outcome. Manual therapy primarily included glenohumeral joint mobilisation but also the stretching of soft tissue in the shoulder girdle and mobilisation of the thoracic and cervical spine.[123]

In a recent review by Kuhn,[102] the data demonstrate that exercise has significant effects on pain reduction and improves function.

Nowadays, physiotherapy usually follows ASD and rotator cuff repair.[75,124] When physiotherapy after surgery is described in research, large differences between studies are presented when it comes to the progression of resistance during rehabilitation and load during other activities,[139,172] as well as after rotator cuff repair.[51,66,67,104]

In two more recent articles, current concepts in physiotherapy after surgery for subacromial pain are described in detail. After ASD, Jackins[75] proposes active assisted range of motion exercises in all directions directly after surgery, performed five times per day. Full flexibility is first to be accomplished, after which attention is paid to restoring the capacity and recruitment pattern of the rotator cuff muscles and the scapular stabilisers.[75]

After rotator cuff repair, Millet et al.[124] propose 4-6 weeks of immobilisation. They describe four phases during rehabilitation: Phase 1, passive exercises; Phase 2, active exercises that gradually transfer loads onto the healing tissue; Phase 3, strengthening exercises focusing on restoring power and endurance to the healed rotator cuff muscles, and Phase 4; improving muscular strength, power and endurance, as well as a gradual return to full functional activities.[124]

Kelly et al.[89] showed that, in aquatic training, there is significantly less muscle activation during elevation in the scapular plane compared with when it is performed on land. The supra-, infraspinatus and subscapularis muscles were tested at a speed of 30º/s and 45º/s. Kelly et al. thereby conclude that aquatic training allows for earlier active motion in the postoperative period without compromising safety after rotator cuff repair.[89]

The partial discharge of loading during aquatic training facilitates the re-learning of a normal movement pattern throughout a range of motion in patients after rotator cuff repair and ASD.[124] Motions with the affected arm at shoulder level with straight elbows and with a proper movement pattern are possible to perform at a much earlier point in time in water than on land.[89]

There is evidence to indicate that short periods of exercise interspersed over the day are more effective than one long daily session to prevent the negative effects of inactivity.[161] Intermittent bouts of aerobic activities or exercises are more effective in maintaining protein synthesis rates within tendons and muscles. The specificity of exercises is very important when adaptation of the metabolic process is to be enhanced.[161]

The restoration of muscular function during physiotherapy, in terms of the type of exercise, loading, sets and number of repetitions, should be modified, depending on the clinical progress of the individual patient.[15,124,172]

1.5.5 Monitoring subacromial pain

Brewster and Schwab[15] pointed out the importance of painfree activities and caution with activities leading to tensile or compressive overload on the rotator cuff after surgery in patients with subacromial pain and particularly after rotator cuff repair. Pain inhibition by muscular activity may have a detrimental effect on the restoration of normal muscle performance.

To allow pain-free performance, exercises should be modified by the number of repetitions, the length of rest between sets, the degree of range of motion during dynamic exercises, the load and the speed of the exercises.[15]

Patients must modify or refrain from work or leisure activities that provoke the experience of pain.[15]

1.6 Summary of problem areas presented in the thesis

This thesis will cover physiotherapy after surgery in patients with subacromial pain caused by primary, mechanical impingement as described by Neer.[126,127] Patients in Study I were classified as stage III according to Neer. Patients in Studies II, III and IV were classified as stage II and early stage III according to Neer. Impingement secondary to instability, outlet or internal derangement will not be discussed.

The specific problem areas covered in this thesis are as follows:

- There was a lack of evidence in favour of physiotherapy treatment for patients after surgery in patients with subacromial pain.
- The description of progression in terms of intensity of workload during exercise or during every day activities had been scarcely presented after rotator cuff repair or ASD.
- There was a lack of prospective, randomised studies evaluating different physiotherapy strategies after ASD and rotator cuff repair.
- There was a lack of knowledge of patients' clinical course and definition of attainable goals after ASD and rotator cuff repair both in mid- and long-term perspectives.
- There was a lack of knowledge of the long-term results for shoulder function and quality of life in relation to shoulder function.

2 AIM

The overall purpose of this thesis was to develop new physiotherapy treatment protocols after full-thickness rotator cuff repair and after arthroscopic subacromial decompression (ASD).

The primary aim was to evaluate if patients after rotator cuff repair or ASD, who were treated according to a comprehensive protocol with graded exercises and a more progressive approach became pain free and attained higher shoulder function at an earlier stage compared with those who were treated according to a more general approach. The aim was also to describe attainable goals both in the mid- and long-term perspective.

The specific aims were:

Study I: To evaluate the outcome and describe clinical changes produced by two different physiotherapy treatment protocols in patients with full-thickness rotator cuff repair up to two years after surgery.

Study II: To evaluate the outcome and describe clinical changes produced by two different physiotherapy treatment protocols in patients treated with ASD until two years after surgery. A second aim was to test the test-retest reliability of the Functional Index of the Shoulder (FIS).

Study III: To evaluate patient satisfaction in the long-term perspective after ASD and, moreover, the functional outcome in terms of range of motion, muscle strength, pain during activity and at rest, and the Constant Score. A second aim was to analyse the correlation between patient satisfaction and the different functional items.

Study IV: To describe health-related quality of life, patient satisfaction with present shoulder function, and physical activity 8-11 years after ASD in patients with primary impingement syndrome stage II and early stage III. A second aim was to analyse the relationship between the outcome instruments used in this study.

3 PATIENTS AND METHODS

3.1 Patients

A total of 144 patients were included in the four studies (Table 3). In Study I, 16 patients listed for rotator cuff repair were included. In Study II, 33 patients listed for arthroscopic subacromial decompression were included. Ninety-five patients who had undergone arthroscopic subacromial decompression (ASD) comprised the study group in both Studies III and IV.

Table 3. *Description of patients included in the four studies. Percentages of women and age at inclusion are presented.*

Study	Patients included	Men/women (%)	Age, mean, (SD, range)	Comments
I	16	11/5 (31%)	54.5 (6.8, 40-64)	*
II	33	20/13 (39%)	46 (7.0, 31-56)	1 man operated bilaterally n= 34 shoulders
III and IV	95	52/43 (45%)	54 (9.2, 26-69)	10 patients operated bilaterally, n= 105 shoulders

Eighteen patients who were included in Study II participated in the long-term follow-up in Studies III and IV. Another 6 patients who were allocated to the Home-training Group in Study II attended the long-term follow-up evaluation. This third group was excluded from the analysis in Study II due to the small number of patients included and because only four patients were found to fulfil the inclusion criteria post-operatively.

Studies I and II were approved by the Human Ethics Committee at the University of Gothenburg. Studies III and IV were approved by the Regional Ethical Review Board, Gothenburg, Sweden.

Information about patients being allocated to surgery (full-thickness rotator cuff repair or ASD) was given in Studies I and II by the nurse coordinating the surgery schedule at Sahlgrenska University Hospital/Östra. The patients were contacted by telephone and asked if they agreed to participate. Patients who agreed to participate were contacted by the independent research therapist by telephone and the pre-operative evaluation was performed between 1 and 14 days before surgery. All patients signed the written informed consent before being included in the studies. During surgery, randomisation was performed using sealed envelopes. The allocation was performed according to a computerised table of random numbers. The surgeons were not informed of patient allocation at any point in time. After rotator cuff surgery, the patients stayed in hospital for two or three days after surgery. Patients undergoing ASD were discharged on the day of surgery.

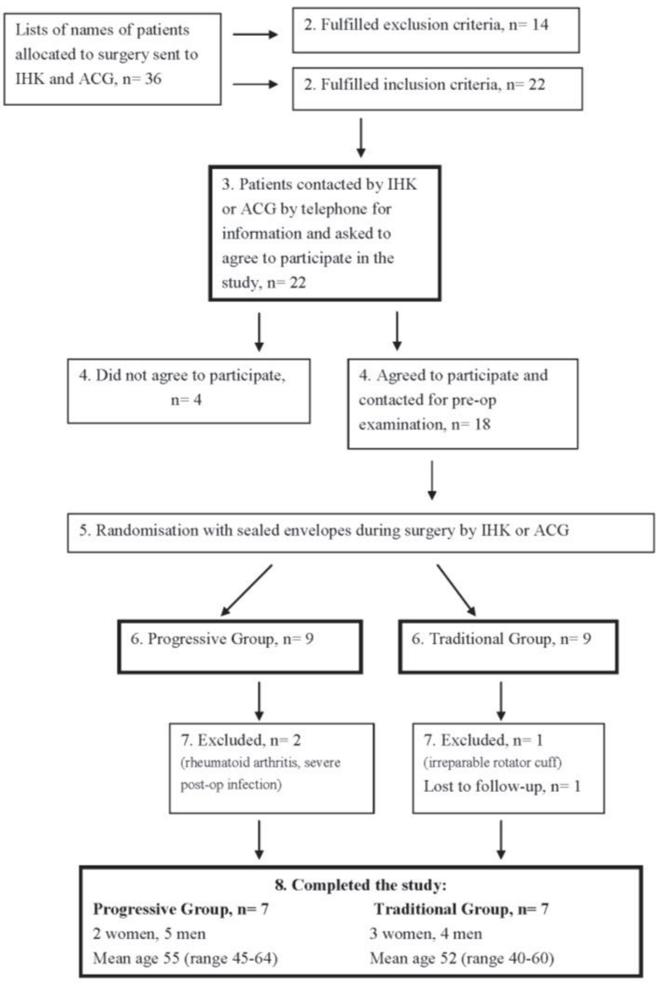

Figure 8. Flow-chart showing inclusion process of patients in Study I.

3.1.1 Study I

Inclusion in the study was performed in a consecutive manner when patients were allocated for surgery. A flow chart showing the inclusion process is shown in Figure 8.

The exclusion criteria were no previous rotator cuff repair to the involved shoulder, other diagnoses that could interfere with the treatment or shoulder function, e.g. rheumatoid arthritis, diabetes, neurological or psychological diseases, as well as difficulty reading and writing in Swedish.

The patients were randomised into two groups. In the Progressive Group, there were four patients, and in the Traditional Group there were five patients who had ruptured the rotator cuff as a result of a trauma. No patients had a concomitant rupture of the long head of the biceps.

The timing of the instruments used in clinical evaluation is shown in Table 4.

Table 4. *Instruments used in clinical evaluation preoperatively and at follow-ups in patients who underwent full-thickness rotator cuff repair.*

	Pre-op	3 m	6 m	12 m	24 m
Pain during activity	x	x	x	x	x
Pain at rest	x	x	x	x	x
Range of motion	x		x	x	x[4]
Isometric muscle strength[1] Isobex®	x		x	x	x
Isometric muscle strength[2] KinCom®	x		x	x	
Isokinetic muscle strength[3] KinCom®	x		x	x	
Constant score	x		x	x	x
HIN	x		x	x	x
HIB	x		x	x	x
POP	x		x	x	x
FIS	x		x	x	x

1= elevation at 90° of elevation in the plane of scapula; 2= elevation at 80° of elevation in the plane of scapula; 3= internal rotation and external rotation 4= within the Constant Score

3.1.2 Study II

The inclusion was performed in a consecutive manner when patients were allocated to surgery. A flow chart showing the inclusion process is shown in Figure 9.

The exclusion criteria were no previous surgery to the shoulder, or other diagnoses that could interfere with the treatment or shoulder function, e.g. rheumatoid arthritis, diabetes, neurological and psychological disorders.

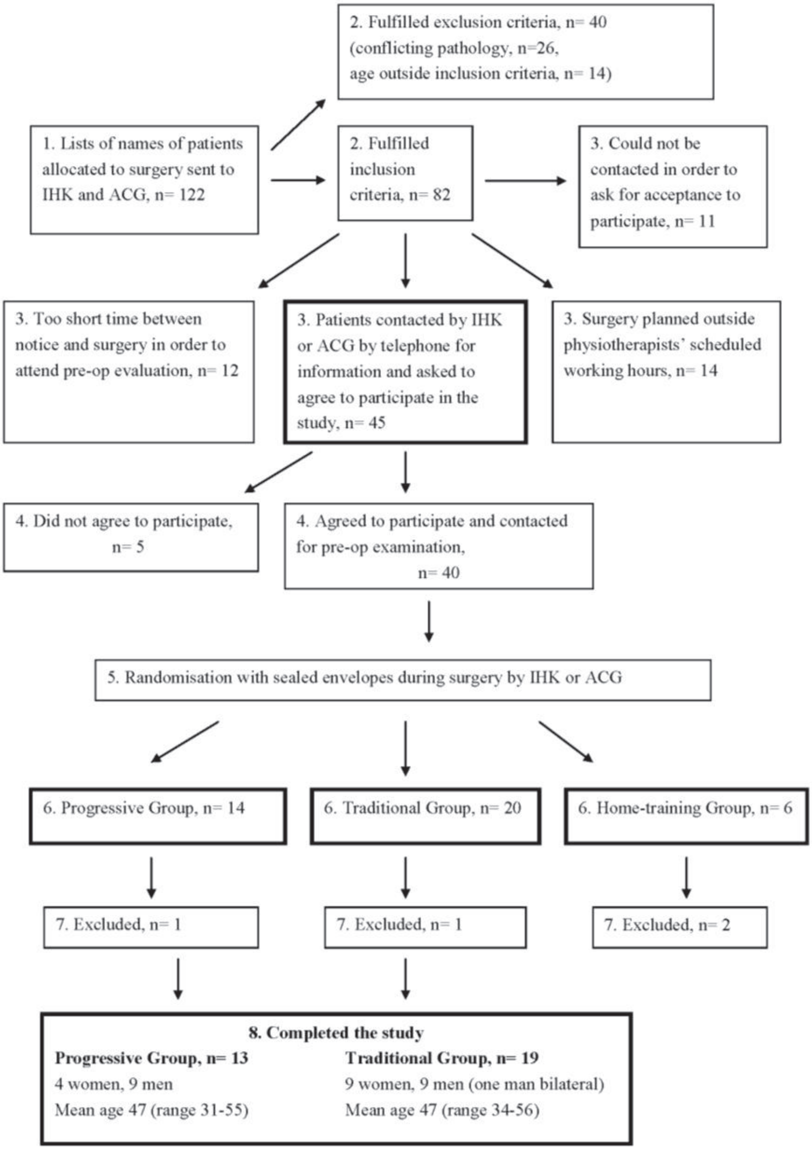

Figure 9. Flow chart showing the inclusion process for patients in Study II.

Patients were randomised into three groups. Due to consecutive randomisation, there were different numbers of patients in each group. The Home-training group, was excluded from the analysis because only four patients fulfilled the inclusion criteria post-operatively.

In the Progressive Group, there was one drop-out, who only attended the first follow-up. There was one drop-out in the Traditional Group, who did not follow the protocol or come to the follow-ups.

The timing of the instruments used in clinical evaluation is shown in Table 5.

Table 5. *Instruments used in clinical evaluation preoperatively and at follow-ups in patients who underwent ASD.*

	Pre-op	6 we	3 m	6 m	12 m	24 m
Pain during activity	x	x	x	x	x	x
Pain at rest	x	x	x	x	x	x
Range of motion	x	x	x	x	x	x
Isometric muscle strength[1] Isobex®	x	x	x	x	x	x
Isokinetic muscle strength[2] KinCom®	x		x	x	x	
Constant score	x	x	x	x	x	x
HIN	x	x	x	x	x	x
POP	x	x	x	x	x	x
FIS	x	x	x	x	x	x

1= elevation at 90° of elevation in the plane of scapula within the Constant Score

2= elevation in the plane of scapula, internal rotation and external rotation

3.1.3 Studies III and IV

Studies III and IV comprised the same study population, but they were evaluated with different instruments. The flow chart shows the inclusion process for the patients in Studies III and IV, Figure 10.

The exclusion criteria were severe medical disorders that could interfere with shoulder function (i.e. severe whiplash-associated disorders, neurological disorders, as well as drug-related problems or psychological disorders), medium-sized full-thickness rotator cuff tears identified during surgery, and patients not speaking Swedish.

Patients with rheumatoid arthritis not diagnosed at the time of surgery, psoriatic arthritis or polyarthritis were included. Patients who were subjected to trauma with proximal humeral or scapular fractures or partial rotator cuff tears, small full-thickness tears or tears of the long head of the biceps prior to surgery were also included in the study.

When presenting the results and in the discussion section, the word “patients” is synonymous with “shoulders”, as ten patients represent two (bilateral) results (n=95 patients; n=105 shoulders).

The surgery, ASD, was performed at the same clinic by five different experienced shoulder surgeons.

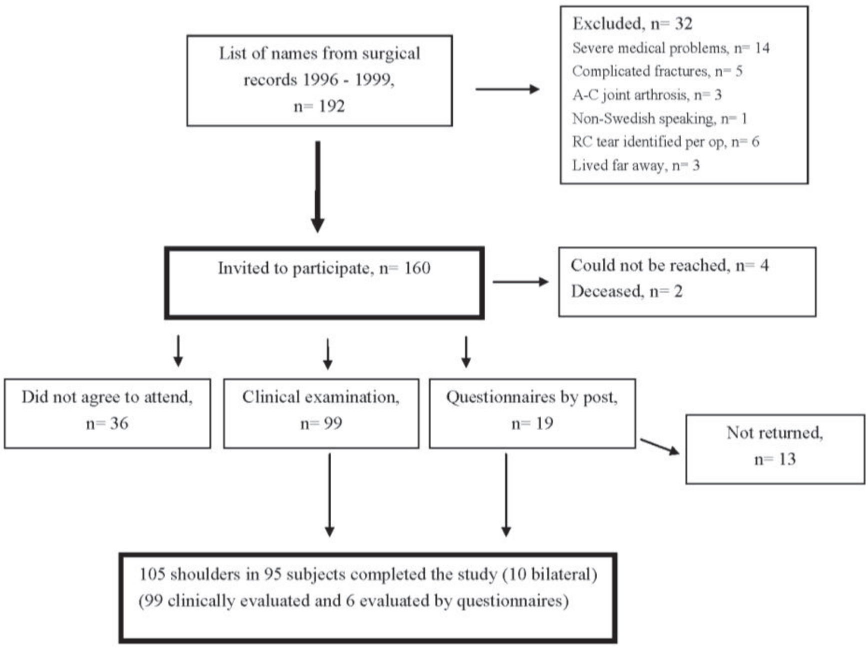

Figure 10. Flow chart showing the inclusion process for patients in Studies III and IV.

3.2 Surgical methods

Study I: Repair of full-thickness rotator cuff tears

All patients underwent a similar surgical procedure.[145] Antero-inferior subacromial decompression as described by Neer[126] was performed prior to the open rotator cuff repair itself.

A vertical antero-lateral incision, approximately 5 cm, was used. The insertion of the deltoid was left intact. The tendon of the deltoid was opened laterally, close to the acromion. The subacromial bursa was excised. The coracoacromial ligament was detached. The tear in the rotator cuff was isolated and debridement of the scarred margins was performed. Side-to-side sutures were made to reduce the area of the defect. The supraspinatus and infraspinatus tendons and muscles were mobilised in order to produce solid soft tissue supporting the sutures. The re-insertions of the medial ends of the torn rotator cuff were sutured to a trough at the junction of the greater tuberosity and the anatomical neck using suture anchors or sutures tied over bone bridges or a combination of both. In all cases non-absorbable sutures and 3-4 Mason-Allen knots were used.

All shoulders were immobilised post-operatively in a brace with the arm at the side.

Study II: Arthroscopic subacromial decompression (ASD)

All patients underwent a similar surgical procedure by four different shoulder surgeons at the same clinic. Standard antero-inferior subacromial decompression was performed using posterior and lateral portals. If a partial tear in the rotator cuff was present, it was mildly debrided.

3.3 Physiotherapy treatment

Patients in the Progressive Group were treated by the authors (IHK and ACG). Patients in the Traditional Group were treated by fellow physiotherapists, who were familiar with the current treatment protocols used at the department and had several years' experience of treating patients with subacromial pain. The other colleagues were not informed about the specific training exercises and treatment modalities used in the Progressive Group.

Strategies for the Progressive Group in Studies I and II

The new physiotherapy treatment protocols in the Progressive Group in Studies I and II were tailored by the two authors (IHK and ACG). The concept was based on the following specific principles.

- Increase metabolic and aerobic capacity in the collagen tissues by activating the rotator cuff muscles
- Restore humeral head depression exerted by the supraspinatus, infraspinatus, teres minor and the long head of the biceps
- Regain normal flexibility of the posterior capsule to allow the humeral head to remain centred in the fossa glenoidale throughout full range of motion
- Regain stability and normal movement patterns of the scapula by activating the serratus anterior, upper trapezius and inferior
- Restore correct thoracic posture and the retracted position of the scapula

After rotator cuff repair, the overall goal was to achieve healing of the rotator cuff tendons and to strengthen the mechanical properties of the repaired tendons while restoring pain-free motion and function. In patients who had undergone ASD, partial rupture of the rotator cuff may have been present and healing was also regarded as an important goal in these patients. The early activation also aimed to achieve an earlier decrease in swelling in the subacromial soft tissue. The swelling was thought to be a consequence of the pathology itself but also of the surgery.

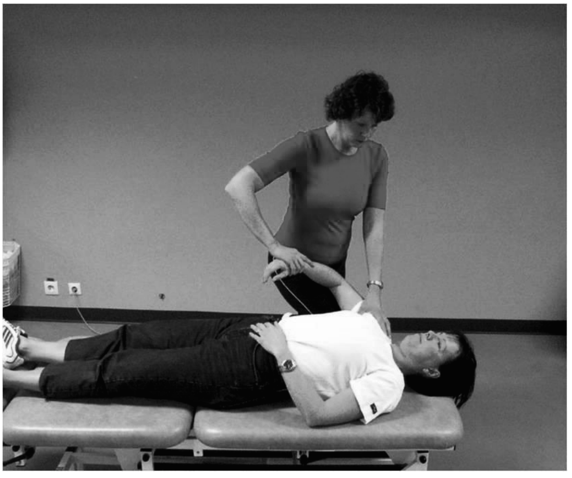

Figure 11. Manual technique to restore internal rotation. The humerus is placed in the plane of scapula. (Photo Gustav Klintberg)

Gentle, manual passive range of motion to restore internal rotation was initiated eight weeks after rotator cuff repair. Gradually, when possible to perform without pain, a manual technique targeting the tissue within the posterior capsule was undertaken. The technique to restore internal rotation is shown in Figure 11. Stretching procedures for the posterior capsule were initiated six weeks after ASD. The manual technique for restoring flexibility in the posterior capsule is shown in Figure 12.

To create the prerequisites for correct upper body posture and retracted scapulas, the pectoralis minor, upper trapezius and levator scapula muscles were stretched manually.

In the Progressive Group in Studies I and II, exercises including eccentric loading (pulley systems or dumbbells) were performed at the physiotherapy department. The patients were instructed to prolong the eccentric phase for the rotator cuff during the exercises. In the home-training programme, using external resistance from elastic rubber bands, the patients were instructed to prolong the eccentric phase.

Figure 12. Stretching to the posterior glenohumeral capsule. (Photo Stefan Pahi)

Exercises for the scapular rotators were not part of the treatment protocols used at the department before this study was initiated and are consequently not part of the protocol for the Traditional Group.

Strategies for all patients in Studies I and II

All patients were instructed to perform the home-training programme in front of a mirror to enhance the quality of performance. All patients filled in a compliance log at each home-training session.

The treatment protocols in both the Traditional and the Progressive Groups were based on strengthening exercises being modified to allow pain-free motion. Advice on how to protect the subacromial tissue from impingement in daily living was given to both groups.

The exercises at the physiotherapy department for both groups were modified depending on the clinical progress of the individual patient with regard to type of exercise, loading, sets and number of repetitions.

According to the protocols, there were no differences between the two groups in the number of visits to the physiotherapy department. Supervised physiotherapy was continued until patients had returned to their previous activity level during work and leisure time, or when no further progress was judged to be possible by the physiotherapist in charge.

3.3.1 Study I

Physiotherapy treatment after rotator cuff repair started for both groups the day after surgery.

The main outlines showing differences (marked in bold) between treatment protocols in the Progressive Group and the Traditional Group are shown in Table 6.

Table 6. Rotator cuff repair: main outlines and differences (marked in bold) in exercises as well as in timing between the physiotherapy treatment protocols in the Progressive Group (PG) and Traditional Group (TG). The PG were instructed using a home-training programme 1(A), 2(A), and 3(A), while the TG were instructed with 1(B), 2(B) and 3(B). In aquatic training, both the PG and TG were instructed using the same programmes.

	Progressive Group, (PG)	**Traditional Group, (TG)**
First day post-op.	Home-training programme 1(A), including **specific activation of the rotator cuff**, performed 3 times per day. Passive ROM, (2-3 times/week), was performed by the physiotherapist throughout the physiotherapy period or until full ROM was achieved.	Home-training programme 1(B), performed 3 times per day. Passive ROM (2-3 times/week), was performed by the physiotherapist throughout the physiotherapy period or until full ROM was achieved.
Four weeks post-op.	**Removal of immobilising brace**. Home-training program 2(A), including exercises with **increased loading for the rotator cuff** and **active, assisted ROM** in flexion and elevation in the plane of the scapula, performed 3 times per day. Supervised physiotherapy on an out-patient basis 2-3 times/week was started. **Aquatic training programme 1**; active assisted exercises performed with the arms in front of the body, once/week.	
Six weeks post-op.	Increased loading of the rotator cuff by the home-training program; isometrics and **active ROM in flexion and abduction with elbows flexed** (short lever arm). Passive ROM with emphasis on **restoring internal rotation** Increase of load during supervised physiotherapy.	**Removal of immobilising brace**. Home-training programme 2(B), including **activation of the internal and external rotators** and **active assisted ROM** in flexion and elevation in the plane of the scapula. Supervised physiotherapy on an out-patient basis 2-3 times/week was started.
Eight weeks post-op.	Home-training program 3(A), **increased load on the rotator cuff by rubber elastic bands**, performed 2 times per day. Dynamic strengthening exercises for the rotator cuff and scapular muscles through-out full ROM during supervised physiotherapy. **Active ROM with elbow straight** (long lever arm).	

10 weeks Post-op.	**Aquatic training program 2**; active, water-resisted exercises performed throughout full range of motion, 2 times/week.	**Aquatic training programme 1**, active assisted exercises performed with the arms in front of the body, once/week.
12 weeks post -op.	**Eccentric load on the rotator cuff** during supervised physiotherapy.	
16 weeks post-op.		Home-training programme 3(B), **increased load on the rotator cuff by rubber elastic bands.** Supervised physical therapy with dynamic strengthening exercises for the rotator cuff and scapular muscles throughout full ROM. **Aquatic training, program 2;** active, water-resisted exercises performed throughout full range of motion, 2 times /week
24 weeks post-op.		**Eccentric load on the rotator cuff** during supervised physiotherapy.

ROM = Range of Motion; Aquatic training was performed in warm water (34°) supervised by a physiotherapist.

Table 7. ASD: Main outlines and differences between the physiotherapy treatment protocols in the Progressive Group (PG) and the Traditional Group (TG). The PG was instructed using home-training programme 1A, 2A and 3A, while the TG was instructed with 1B and 2B.

	Progressive Group (PG)	**Traditional Group (TG)**
Day of surgery	Home-training programme 1A, with light warm-up exercises for the shoulder followed by **specific activation of the rotator cuff, performed every two hours** and active, assisted ROM in flexion, elevation in the plane of the scapula, external and internal rotation performed 3 times/day. Information on how to fill in the compliance log.	Home-training programme 1B, performed 3 times/day, with light warm-up exercises for the shoulder and pendulum exercises followed by active assisted ROM in flexion, elevation in the plane of the scapula, external and internal rotation. Information on how to fill in the compliance log.
Two weeks post-op.	Home-training programme 2A, including light warm-up exercises followed by **gravity-resistant exercises for the rotator cuff performed every two hours**. Exercises to stretch the upper trapezius, pectoralis major and internal rotators, active ROM in flexion and elevation in the plane of the scapula, as well as exercise for scapular adductors lying prone were performed 3 times/day. Patient education on effects of posture and mechanisms behind the syndrome.	Home-training programme 2B, **performed 3 times/day, with activation of internal and external rotators** and scapular adductors lying prone with no external resistance, followed by active, assisted ROM in flexion and elevation in the plane of the scapula and exercises to stretch the upper trapezius, pectoralis major and internal rotators. Patient education on effects of posture and mechanisms behind the syndrome.

Six weeks post-op.	Home-training programme 3A, performed 3 times/day, **with resistance from rubber elastic bands for the rotator cuff with a prolonged eccentric phase and for the scapular adductors**. Programme 2A was performed additionally twice a day. Starting supervised physiotherapy on an out-patient basis 2-3 times/week with **exercises for the rotator cuff and all scapular muscles with external loading from pulley systems and dumbbells**. Passive ROM by PT was initiated and continued to restore full ROM. **Manual passive stretching to the posterior capsule**. Increase in resistance during supervised physiotherapy within pain-free level.	Continued to perform home-training programme 2B three times/day. Starting supervised physiotherapy on an out-patient basis 2-3 times/week with dynamic exercises but without external loading.
Eight weeks post-op.	**Dynamic concentric and eccentric strengthening exercises for the rotator cuff** and scapular muscles throughout full ROM. Gradually increased resistance performed within pain-free performance and correct scapular control. Passive ROM by PT continued to restore full ROM. **Manual passive stretching to the posterior capsule** continued to restore flexibility. Exercises were selected to meet demands of work and vocational activities. Supervised physiotherapy continued to reach dynamic stability throughout the kinetic chain with regard to patient demands.	Supervised physiotherapy with **exercises with external loading from pulley systems and dumbbells.** Resistance was adjusted to individual capacity. Exercises were selected and performed to meet demands of work and vocational activities. Passive ROM by PT continued to restore full ROM. Frequency in visits and duration was set on an individual basis according to the PT's judgement.

ROM = Range of Motion; PT =Physiotherapist

The specific exercises for the rotator cuff, increased loading and aquatic training were introduced six weeks earlier in the Progressive Group.

Home-training programmes including schematic illustrations for each exercise for the Progressive Group and the Traditional Group are shown in Appendix 1.

3.3.2 Study II

Physiotherapy treatment after ASD started on the day of surgery in both groups.

The main outlines showing differences (marked in bold) between treatment protocols in the Progressive Group and the Traditional Group are shown in Table 7.

The specific exercises for the rotator cuff and also the graded strength training were introduced two weeks earlier in the Progressive Group.

Home-training programmes including schematic illustrations for each exercise for the Progressive Group and the Traditional Group, are shown in Appendix 2.

3.4 Instrumentation

3.4.1 Clinical assessment

In Studies I and II, all the clinical evaluations were performed by an experienced research physiotherapist blinded to patient allocation and not involved in the treatment of patients.

In Study III, all the patients were evaluated by the author, who has in-depth experience of shoulder rehabilitation.

The evaluation of range of motion, muscle strength and Constant Score was performed bilaterally. The evaluation always began with the uninjured arm. Only values for the affected side are presented.

A summary of instruments used in the clinical assessment in the four studies is shown in Tables 8 and 9.

The clinical assessment methods used in the four studies are presented below. Under each method description, there is a presentation of reliability and validity according to the literature.

Range of motion

Range of motion (ROM) of the shoulder was measured using a large, transparent handheld universal goniometer. The testing procedure included both active and passive modes.

Active range of motion in flexion, extension and abduction was measured while standing.

Active external ROM in adduction was measured in a sitting position. Passive external and internal rotation in 90º of abduction was measured while lying supine.

In Study III, active external and internal rotation in 90º of abduction was measured while standing.

Reliability: Intra-tester intra-class correlation coefficients (ICC) for passive range of motion while lying supine, in flexion, extension and abduction varied from 0.94 to 0.98.[144]

Gajdosik and Bohannon[49] recommend the active mode while standing when measuring shoulder flexion and abduction. In the passive mode, the pressure exerted by the tester may vary and the pressure should therefore be measured simultaneously to achieve reliability. However, the ICC values for passive internal and external rotation while lying supine, with the shoulder in 90º of abduction, varied from 0.94 to 0.99.[144]

Intratester-reliability measuring range of motion has been found to be higher compared with inter-tester reliability.[11,49]

Validity: Small errors in the construction of the goniometer may exist, but the handheld goniometer is generally accepted as a valid clinical instrument.[49]

Muscle strength measurement

Prior to all muscle strength measurements, patients performed a 5- to 10-minute warm-up with resistance from a rubber band (4 mm), Poly-Ropes®. The following exercises were performed: rowing (Study III), internal and external rotation with the shoulder in the adducted position and elevation in the plane of the scapula with the arm internally rotated.[125,163] There was an interval of at least 5 minutes between warm-up and performance of the muscle strength testing while the patient was placed in the testing position and the apparatus was adjusted. The same test order was used in all patients. No verbal encouragement was given during any of the tests that were performed.

Isometric muscle strength testing

An Isobex® dynamometer (Medical Device Solutions AG, Burgdorf, Switzerland) was used to evaluate the isometric muscle strength in elevation in the plane of the scapula,[59] as well as in internal and external rotation in adduction while sitting on a standard chair.

The test started with an elevation of 90º in the plane of the scapula. The dynamometer was placed on the floor and the band from the dynamometer was placed just proximally to the styloid process of the ulna. The opposite arm hung loosely at the side. Patients kept their legs straight and ankles crossed, with the heel of one foot resting on the floor. Patients were instructed to keep their trunk in an erect and straight position during the test (Figure 13).

Figure 13. Illustration of isometric muscle performance test in elevation in the plane of the scapula.(Photo Jesper Sommansson)

In Study I, isometric muscle strength in elevation was also measured using an isokinetic dynamometer, a KinCom® 550H (Kinetic Communicator, Chattex Corp., Chattanooga, TN, USA).[42] The testing position was 80º of shoulder elevation in the plane of the scapula.[59] The patient was seated on the standard chair, secured with Velcro straps over the opposite shoulder. The resistance pad was placed just distal of the elbow. The elbow was kept straight during the test. The rotational axis of the apparatus was aligned to the axis of the shoulder joint. The test started with the uninjured arm. Gravity correction was used.

While measuring internal and external rotation, the chair was placed close to a door to which the suction pads of the Isobex® dynamometer were attached. The patient was seated in the same body position as described above. The arm was held at the side with a small pillow between the trunk and elbow to ensure 15-20º of abduction and thereby avoiding tension in the supraspinatus tendon. The elbow was held in 90º of flexion and the forearm in a neutral position of rotation and supination/pronation. The band from the dynamometer was placed just proximally to the styloid process of the ulna (Figure 14).

If any compensatory movements were observed, the trial was regarded as false and it was interrupted. The test protocol consisted of three maximum muscle actions held for five seconds in each direction. The trial with the highest force value (kg) for each tested variable was used for the analysis.

Figure 14. Illustration of isometric muscle performance test in internal rotation.(Photo Göran Persson)

Reliability: The intra-rater reliability of the Isobex® dynamometer evaluating elevation, internal and external rotation has been shown to be high. ICC values ranged from 0.90 to 0.97.[105] The reliability test was performed in the sitting position. Isometric elevation in this study was evaluated with the shoulder at 45º in the plane of the scapula. Rotations were evaluated with the shoulder in adduction, neutral shoulder rotation and the elbow flexed at 90º.[105]

Validity: No evaluation of the validity of the Isobex® dynamometer was found in the literature.

Isokinetic muscle strength testing

A KinCom® 550H (Kinetic Communicator, Chattex Corp, Chattanooga, TN, USA)[42,173] isokinetic dynamometer was used in the dynamic strength assessment.

Muscle strength was measured in the concentric mode with a test velocity of 120º s^{-1} in internal and external rotation while sitting. The patient was seated on the standard chair as described above. The legs were kept straight, crossed at the ankles, with the heel of one foot resting on a stool.

The dynamometer head was tilted 60º and the chair was adjusted in order to place the shoulder joint in 30º of elevation in the plane of the scapula.[59] The axis of rotation was aligned through the elbow and humerus to accommodate the axis of the dynamometer. The "V-pad" supported the elbow and the shin pad, with the load cell, was placed on the distal part of the forearm.

The position of the forearm in the horizontal position, verified with a water-level instrument, was defined as 0º of rotation. The end point of 50º in external rotation was set first, followed by the end point of 50º of internal rotation. The test always started with the evaluation of external rotation. From the end position of external rotation, the test of internal rotation followed after 10 seconds of rest. This sequence was repeated three times.

Muscle strength of elevation in the plane of the scapula was measured in the concentric mode with the angular velocity set at 120º s^{-1}. The chair was positioned in relation to the dynamometer in order to place the shoulder joint in the scapular plane.[59] The resistance pad was placed just distal to the elbow, which was kept straight during the test. The range of motion during the test ranged from 0 to 90º.The arm was lowered by the research therapist who also ensured that the arm was placed in 0º of abduction prior to the next test.

All adjustments of the dynamometer head, lever arm and chair were recorded individually to ensure the same test position on each test occasion.[42,173]

Prior to the isokinetic testing, patients familiarised themselves with the test procedure by performing three tests at sub-maximum level.

The evaluation consisted of three maximum concentric muscle actions in each direction. An interval of at least 10 seconds between each trial was used. Total work was represented by one (1) torque curve obtained in the testing procedure. The trial with the highest total work (J) was selected for analysis to reflect the patients' maximum capacity.

Reliability: The intra-rater reliability of isometric shoulder muscle testing has been found to be high, using the Biodex® Isokinetic Dynamometer. Abduction, internal and external rotation were evaluated in a group of healthy volunteers. ICC values ranged from 0.97 to 0.99.[105]

In Studies I and II, isokinetic testing of internal and external rotation was performed in 30º of elevation in the plane of the scapula. However, intra-rater reliability of isokinetic shoulder muscle testing in internal and external rotation was checked in 45º of elevation in the plane of the scapula. The testing was performed in a group of patients with chronic rotator cuff pathology. The test was performed using the KinCom® dynamometer and the peak torque values were reported. The test speed was a fixed rate of 60º s^{-1}.The ICC values ranged from 0.90 to 0.96 for the affected shoulder and 0.75 to 0.86 for the unaffected shoulder.[4]

Validity: A validity test on the KinCom® was performed using simultaneous measurement with an external device. Force measurements averaged a difference of 3.2% and lever arm speed was within 1.5% of the target speed.[46]

Shoulder function

Constant Score

The original Constant Score was used (Figure 15).[31,52] The patient was interviewed in order to complete the first subjective part, accounting for 35 points. This first part consists of an assessment of pain (15 p), the patient's subjective opinion of his/her ability to work (4 p), ability to perform recreational activities (4 p), ability to sleep (2 p), and level of use of hand for tasks (10 p). The second, objective, part accounts for 65 points. It consists of measurements of active range of motion in forward flexion (10 p) and lateral elevation (10 p), measured by a handheld goniometer in the standing position. Further, internal and external range of motion are assessed by composite rotational manoeuvres, which are graded according to defined scale steps (10 p respectively).

The muscle strength measurement accounts for 25 points and is based on the number of pounds the patient is able to generate in 90º of elevation in the plane of the scapula. The Isobex® is the most frequently used dynamometer in the evaluation of the Constant Score. The values from the Isobex® dynamometer are given in kilograms. The selected value was multiplied by a factor of 2.2 to be transformed into pounds (Lb) to fill in the Constant Score.

TABLE 1. Functional Constant's Scoring

		Right Shoulder	Left Shoulder
Subjective 35 points/100	Pain: 15 points/100 None 15 Mild 10 Moderate 5 Severe 0		
	Activities of daily living: 20 points/100 Professional handicap (0 to 4 points) 0: severe handicap, 4 points: full work		
	Recreational handicap (0 to 4 points)		
	Sleep (0 to 2 points) Affected sleep: 0 point, unaffected sleep: 2 points		
	Level of use of hands (10 points) Waist 2 points / Xiphoid 4 points / Neck 6 points / Top of head 8 points / About head 10 points		
	Subtotal/35 points		
Objective 65 points/100	Painless active mobility: 40 points/100 Forward elevation 0–30 0 point / 30–60 2 points / 60–90 4 points / 90–120 6 points / 120–150 8 points / 150–180 10 points		
	Lateral elevation 0–30 0 point / 30–60 2 points / 60–90 4 points / 90–120 6 points / 120–150 8 points / 150–180 10 points		
	External rotation Hand behind head with elbow held forward 2 points Hand behind head with elbow held back 2 points Hand on top of head with elbow held forward 2 points Hand on top of head with elbow held back 2 points Full elevation from on top of head 2 points		
	Internal rotation: Dorsum of hand to Thigh 0 point / Buttock 2 points / Sacrum 4 points / L3 6 points / Th 12 8 points / Th 7 10 points		
	Power 25 points/100 Measured in 90° abduction in scapula plane using a dynamometer		
	Subtotal/65 points		
	Total/100 points		

Figure 15. The original Constant Score.

Reliability: The total score has been tested for intra-tester reliability with two parallel testers and it was r=0.94 and r=0.96, respectively, using Spearman's rank correlation. Inter-tester reliability was r=0.9, indicating a high correlation.[146] However, there was low agreement between the examiners; the total score varied by up to 25 points.[146]

Validity: A primary source for validating the Constant Score has not been not found. Nevertheless, the Constant Score has been used in validation research for other instruments evaluating shoulder function and structures and limitations in activities.[148]

Hand In Neck, Hand In back and Pout Of a Pot

Three standardised composite active movements described by Solem-Bertoft were used (Figure 16).[156,170] To evaluate *Hand In Neck (HIN)*, the patient was instructed to put both hands behind his/her neck with the elbows positioned as far to the side as possible. This bilateral performance was not described by Solem-Bertoft but was adopted to avoid compensatory movements.

To assess *Hand In Back (HIB),* the patient was instructed to put both hands against his/her back and lift them as far as possible in the midline.

To assess *Pour out of a Pot (POP),* the patient was instructed to lift a coffee pot containing one litre of water and pour the water into a sink in front of him/her.

The patient was asked, in all three tests, to freeze the final position for 3-5 seconds to facilitate the evaluation. The movement pattern and compensatory movements were registered according to the scale steps defined by Solem-Bertoft.[170] Pain was not assessed in combination with the HIN, HIB or POP performance, as suggested by Solem-Bertoft.[156,170]

The inter-rater reliability of HIB has been evaluated in patients after proximal humeral fracture. The result is not given using numbers but by two regression lines describing the healing course. The two examiners made almost identical judgements in terms of changes in performance over time.[170]

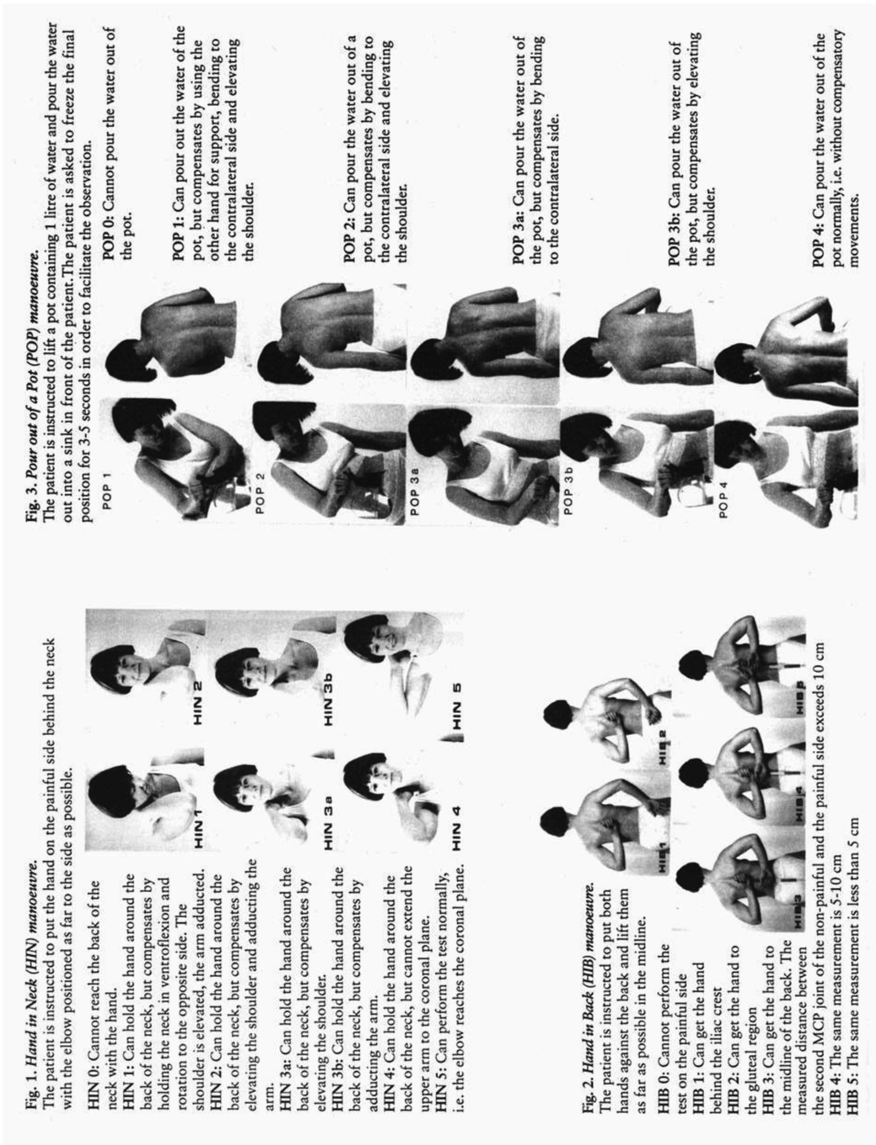

Figure 16. Illustration and description of the scale steps in HIN, HIB and POP. (with courtesy of Eva Solem-Bertoft)

3.4.2 Self-reported assessment

Perception of pain

Patients rated the intensity of pain during activity and pain at rest using a visual analogue scale (VAS).[153] Activities were not specified. It was explained that this referred to patients' daily activities at work, if applicable, at home and during leisure time. The scale represented an ungraded 100 mm long line with vertical bars at each end. The anchor points were labelled "No pain" and "Worst imaginable pain".

Reliability: Gallagher et al.[50] tested the test-retest reliability of VAS in patients with acute abdominal pain with one minute separating the VAS measurements. High values were found with ICC=0.99 (95% CI 0.989 to 0.992). The use of VAS has been concluded to be reliable to evaluate intensity of pain in the clinical practice.[26,174]

Validity: VAS were validated as measurements for both chronic and experimental pain by Price et al.[137] Chronic pain patients and healthy volunteers graded changes in six noxious thermal stimuli up to 51ºC, applied for five seconds to the forearm. Internal consistency was shown as VAS scores varied in a predicted ratio proportional to the changes in the noxious stimuli and thereby demonstrating the valid use of VAS for the measurement of pain.[137]

Clinically important difference: Gallagher et al.[50] found that the minimum clinically significant difference in VAS in patients with acute abdominal pain was 16 mm (95% CI 13-18 mm).

Tashjian et al. [159] found that the minimum clinically important difference for VAS measurements in patients treated for rotator cuff disease was 14 mm.

"Patient acceptable symptomatic state" (PASS): Tashjian et al. established that the patient acceptable symptomatic state was 30 mm (CI-2.27-3.73) based on the 75th percentile of the final follow-up VAS score for patients who stated satisfaction (yes/no) with their symptom state.[159]

Patient satisfaction

Patients graded the outcome of surgery and physiotherapy using a 5-graded Likert scale (Figure 17). The scale steps were defined by a panel of experts, consisting of two orthopaedic surgeons and two physiotherapists. The definitions of the scale steps were discussed until consensus was reached.[71,98]

The patients were asked in Studies I and II to answer the following question:
How satisfied are you with the result of the treatment of your shoulder?

In Studies III and IV the question was slightly different:
How satisfied are you at present with the result of the treatment of your shoulder?

☐	☐	☐	☐	☐
Very satisfied	Quite satisfied	Neither satisfied nor dissatisfied	Quite dissatisfied	Very dissatisfied

Figure 17. Patient satisfaction.

In all four studies, the patients' statement on "the result of the treatment" was interpreted as stating satisfaction with the overall symptomatic state of their shoulder.

Function and health-related quality of life

Functional Index of the Shoulder (FIS)

The Functional Index of the Shoulder (FIS) was developed by the authors to evaluate shoulder function prior to the start of Studies I and II (Figure 18). When Studies I and II were set up, there were no established self-assessment or functional questionnaires for use in patients with subacromial pain. Using the FIS, patients rate their ability to perform 10 specific tasks using visual analogue scales. The scales are represented by an ungraded 100 mm line. The anchor points are labelled "Can perform without difficulty" (0 mm) and "Cannot perform" (100 mm). A low value thus represents high, unrestricted shoulder function. The FIS form was patient administered.

The development of the FIS was based on a questionnaire used in back pain, the Disability Rating Index.[152] A panel of experts, consisting of two orthopedic surgeons and two physiotherapists, listed different activities often described in the clinical setting to be of concern for patients with subacromial pain. The activities were intended to represent various effort levels of the shoulder, from low to high demands. Discussions continued until consensus was reached. The physiotherapists' clinical experience had a major impact on the decision-making when it came to selecting activities or constructs to be used in the FIS.

Reliability: The reliability of the FIS was evaluated with a test-retest procedure, with a two-week interval between the tests. In a patient group (n=20) with different shoulder diagnoses, listed for surgery, Spearman's rank correlation, $r_{s,}$ for the ten questions varied between 0.64-0.89. In a group of healthy individuals (n=20), the correlation, $r_{s,}$ varied between 0.7-1.0. For the total sum of the FIS, the r_s was 0.91 in the patient group and 0.92 in healthy individuals. All correlations were statistically significant.

Validity: The FIS has not been evaluated for validity. However, it can be argued that *face validity* was established, as the physiotherapists and the orthopaedic surgeons were experienced in treating patients affected by subacromial pain.

Funktions Index för Axel (FIA)

Utan svårighet — Exempel — Inte alls

Med viss svårighet - Med svårighet - Med stor svårighet

Hur klarar Du följande aktivitet?

Sätt ETT sträck tvärs över linjen efter varje fråga

Var god besvara alla frågorna

	Utan svårighet → Inte alls
1. Bära en väska eller kasse i handen	________
2. Deltaga i idrottsaktivitet	________
3. Hälla upp ur mjölkpaket	________
4. Utföra Ditt ordinarie arbete	________
5. Kasta en boll över huvudhöjd	________
6. Sova på den onda axeln	________
7. Stoppa handen i bakfickan	________
8. Tvätta den motsatta armhålan	________
9. Kamma håret	________
10. Göra armhävningar	________

Figure 18. The Functional Index of the Shoulder (FIS) questionnaire.

Western Ontario Osteoarthritis of the Shoulder (WOOS)

The WOOS is a disease-specific tool for measuring shoulder-related quality of life.[111] The questionnaire contains 19 items, each with a visual analogue response option. The items cover 4 domains:

A. *Pain and physical symptoms*
B. *Lifestyle function*
C. *Sport recreation and work*
D. *Emotional function*

The scores range from 0-1900. The developers recommend that the raw score from the total score and each domain should be converted into percentages. The value may therefore represent the percentage of normal, unrestricted shoulder function. A score of 0 signifies that the patient has an extreme decrease and 100 no decrease in shoulder-related quality of life.

The questionnaire has been translated and culturally adapted into Swedish by an expert group, according to the methodology presented by Guillemin et al.[62] The questionnaire is published on the website of the Swedish Shoulder and Elbow Surgeons Society (www.ssas.se).

Reliability: The reliability of the total WOOS score has been shown to have an ICC value of 0.96 and, in the four domains, the ICC varied from 0.87 to 0.95.[111]

Validity: In the test of validity, as an evaluative instrument, the WOOS showed the highest correlation with the Constant Score (r=0.73) of the methods mentioned below.[111]

Responsiveness: In the test of responsiveness, the WOOS was compared with other shoulder assessment methods, i.e. McGill VAS, UCLA shoulder rating scale, ASES, McGill Pain, Constant Score, SF12 (physical score), range of motion and SF 12 (mental score). The WOOS obtained the highest value for the standardised response mean, 1.91.[111]

European Quality of Life in 5 Dimensions Questionnaire (EQ-5D)

The EuroQol Group[61], established in 1987, consists of a network of international, multidisciplinary researchers who met to develop a standardised, non-disease-specific instrument for describing and evaluating health-related quality of life. The EQ-5D is a generic health-related quality of life questionnaire, where health status is described by five dimensions within three severity levels. The first part of EQ-5D consists of questions covering five domains;

1) *Mobility (walking)*
2) *Self-care*
3) *Usual activities (work, leisure)*
4) *Pain/discomfort*
5) *Anxiety/depression*

The three levels are "*no problem*", "*moderate problem*" or "*severe problem*". The most appropriate statement in each dimension is marked.

The second part consists of a vertical calibrated visual analogue scale, also called the EQ rating scale.[24] The anchor points were labelled "Worst imaginable health state" and "Best imaginable health state" adopted from the study by Burström et al.[24] In the Study III, the version of the EQ-5D designed for self-completion by the respondent was used.[24]

To facilitate the interpretation and comparison of the EQ-5D, the $EQ\text{-}5D_{index}$ has been developed and the answers transformed into health states. In this way, there are a total of 243 possible health states. Each state is referred to using a 5-digit code, where state 11111 indicates no problems in any of the five domains. A state of 11223 indicates no problems with mobility and self-care, moderate problems performing usual activities and moderate pain or discomfort and extreme anxiety or depression.[39] The $EQ\text{-}5D_{index}$ includes negative values, indicating a health state worse than death. In Study III, negative values were translated to 0, as suggested by Burström.[24]

The English version has been evaluated in terms of reliability, validity and responsiveness in a patient group with rheumatoid arthritis.[73]

Reliability: ICC values for the $EQ\text{-}5D_{index}$ has been reported to be 0.7, while those for the EQ rating scale were also 0.7.[73]

Validity and responsiveness were established using the Stanford Health Assessment questionnaire, self-reported clinical change and patient rated pain (VAS), among others. It has been concluded that the EQ-5D has construct validity in rheumatoid arthritis and is as responsive and reliable as many condition-specific scores used in rheumatoid arthritis.[73]

Summary of instruments used in the thesis

The instruments being used in this thesis are summarized in Table 8 and 9 to give an overall view of the assessment methods.

Table 8. *Instruments used in the clinical assessment in the four studies.*

	Study I	Study II	Study III	Study IV
Range of motion	x	x	x	
Isometric strength, Isobex®	x[1]	x[1]	x[3]	
Isometric strength, Kin Com®	x[1]			
Isokinetic strength, Kin Com®	x[2]	x[3]		
Constant Score	x	x	x	x
HIN	x	x		
HIB	x			
POP	x	x		

1. Elevation in the plane of the scapula; 2. Internal and external rotation;
3. Elevation in the plane of the scapula as well as internal and external rotation.

Table 9. *Instruments used in the self-reported assessment in the four studies*

	Study I	Study II	Study III	Study IV
Pain during activity	x	x	x	x
Pain at rest	x	x	x	x
Patient satisfaction	x	x	x	x
FIS	x	x		
WOOS				x
EQ-5D				x

FIS= Functional Index of the Shoulder; WOOS= Western Ontario Osteoarthritis Shoulder index; EQ-5D= European quality of life in 5 Dimensions questionnaire.

An illustration of the instruments used at the different levels according to the ICF model, is shown in Figure 19.

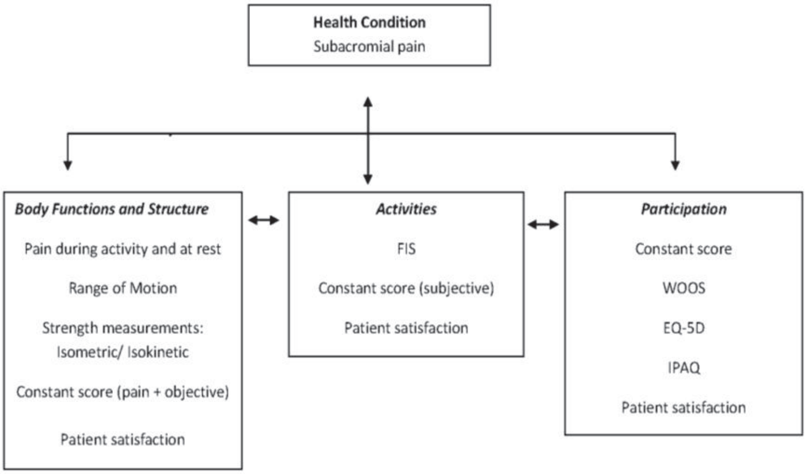

Figure 19. Instruments used in the thesis according to the International Classification of Functioning, Disability and Health (ICF) model.

3.5 Statistics

Studies I and II

For statistical analysis, StatView 5.0 was used. Non-parametric tests were used due to data level and small sample sizes. For changes over time between follow-ups, Friedman's two-way analysis of variance was used. All values denote the median of paired observations. Only patients attending all follow-ups were included in the analysis of change over time.

An unpaired comparison of differences between pre-operative values and each follow-up assessment (*change score*) was made between the two groups on all available data using the Mann-Whitney *U*-test.

In study II, differences between groups at each follow-up were calculated on raw data and on all available data using the Mann-Whitney *U*-test.

In Study II, Spearman's rank correlation coefficient was used to test the intra-rater reliability of the FIS.

Study III

For statistical analysis, the SPSS®, version 15 for Windows, was used. Descriptive statistics for all items were presented as the mean or median for the VAS pain during activity and at rest with a 95% confidence interval.

Maximum and minimum values are also presented for age and pain during activity and at rest.

To calculate the association between ROM, muscle strength, pain during activity and pain at rest, Pearson's correlation coefficient was used. Multiple, forward stepwise regression analyses were performed to find the strongest explanatory variables for patient satisfaction and for pain-free shoulder activity. Which variables were used in the regression models were based on a combination of clinical experience and the result of the correlations between variables.

To analyse differences between genders, as well as painful and pain free shoulders, the Mann-Whitney *U*-test was used for non-parametric data, while Student's *t*-test was used for parametric data.

Study IV

For statistical analysis, the SPSS®, version 17 for Windows, was used. Descriptive statistics for all items were presented as the mean or median for the VAS pain during activity and at rest with a 95% confidence interval. Maximum and minimum values are also presented for pain during activity and at rest. Maximum and minimum values and standard deviation (SD) are presented for age.

To analyse differences between genders, the Mann-Whitney *U*-test was used for non-parametric data, while Student's t-test was used for parametric data.

Pearson's correlation coefficient was calculated to measure the association between the WOOS, $EQ\text{-}5D_{index}$, EQ rating scale, patient satisfaction, pain during activity and the Constant Score. To analyse the dichotomised association between pain (low: ≤30; high: >30) and patient satisfaction (dissatisfied: 1-3; satisfied: 4-5), Fisher's exact test was used.

Binomial logistic regression analysis was calculated with patient satisfaction (dichotomised variable) as the dependent variable and the WOOS, pain during activity and the Constant Score as independent variables.

Intention to treat

An additional intention to treat analysis was performed in Studies I and II. The last observation carried forward (LOCF) method was used. Both parametric and non-parametric statistical methods were used.

The level of $p \leq 0.05$ was regarded as significant in all four studies.

4 RESULTS

4.1 Study I

In the present study, comprising patients who underwent full-thickness rotator cuff repair, the primary outcome was the evaluation of pain during activity and pain at rest.

The analyses, *change over time,* were based on the patients who attended all four follow-ups. The Progressive Group showed a significant reduction over time in pain during activity and at rest ($p<0.01$). The Traditional Group showed a significant reduction over time, in pain during activity ($p=0.01$).

The Progressive group obtained a significantly ($p\leq0.05$) higher *change score* after surgery compared with the Traditional Group at:

- **12 months** in pain at rest
- **24 months** in pain during activity and pain at rest

No significant differences in *change score* were found between groups in the other variables based on all the available data.

Pain during activity based on raw data and all the available data is shown in Figure 20.

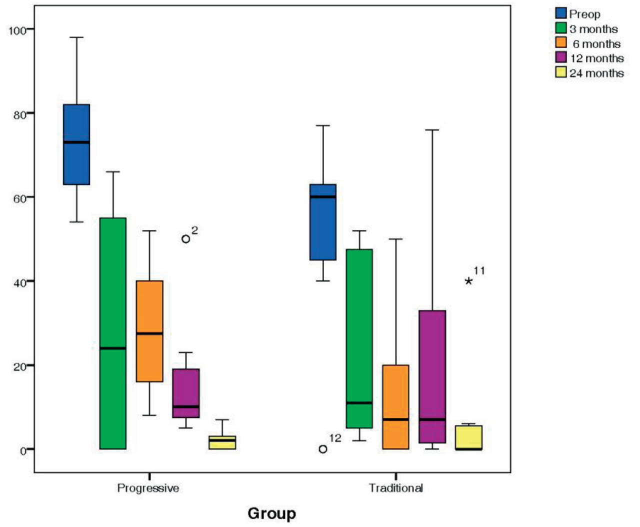

Figure 20. Full-thickness rotator cuff repair: pain during activity (VAS, mm) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

The Constant Score based on raw data and all the available data is shown in Figure 21.

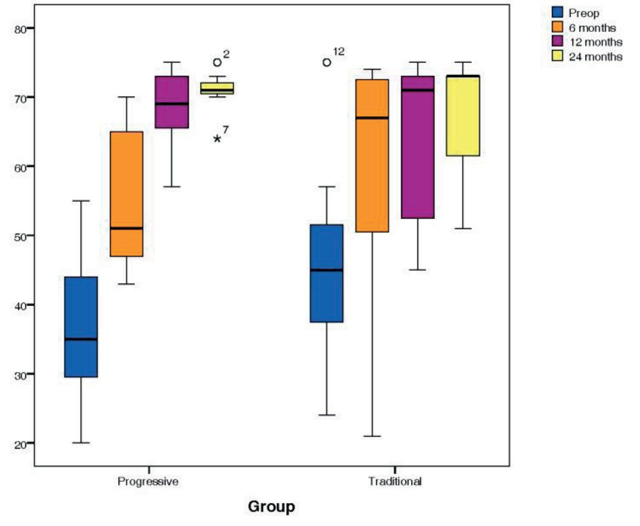

Figure 21. Full-thickness rotator cuff repair: modified Constant Score (75 points) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

Isometric muscular strength (Isobex®) in 90º of elevation in the plane of scapula at two years was 11.5 (7.5-21.8) kg in the Progressive Group and 14.9 (0-22.2) kg in the Traditional Group. The median strength in both groups was 13.2 (0-22.2) kg.

Patient satisfaction based on all the available data is shown in Table 10.

Table 10. *Patient satisfaction at follow-ups in the Progressive Group (PG) and the Traditional Group (TG) after full-thickness rotator cuff repair.*

	3 m		**6 m**		**12 m**		**24 m**	
	PG	TG	PG	TG	PG	TG	PG	TG
5: very satisfied	3	3	2	4	4	4	7	4
4: quite satisfied	3	4	4	3	3	3		2
3: neither satisfied nor dissatisfied								
2: quite dissatisfied								1
1: very dissatisfied								

4.2 Study II

In this study, comprising patients who underwent ASD, the primary outcome was also the evaluation of pain during activity and pain at rest.

The analyses, *change over time,* were based on the patients who attended all five follow-ups. Both groups showed a significant reduction over time in pain during activity and at rest ($p<0.01$).

The analyses based on all the available data showed that both groups reported median pain at rest <10 mm at six weeks after surgery. The majority of patients maintained a low pain level at rest until two years after surgery.

No significant differences in *change score* were found between groups in any of the variables based on all the available data.

The Progressive Group showed significantly ($p<0.05$) higher values based on raw data and all the available data after surgery compared with the Traditional Group at:

- 6 weeks in range of motion in flexion, in abduction, in external rotation in 90º of abduction as well as in terms of the Constant Score and in Hand In Neck

- 3 months in range of motion in extension and in abduction, as well as in terms of Functional Index of the Shoulder (FIS)

- 6 months in range of motion in adduction

- 12 months in range of motion in abduction and in Hand In Neck, as well as in terms of Functional Index of the Shoulder (FIS)

Pain during activity based on raw data and all the available data is shown in Figure 22.

Range of motion in external rotation based on raw data and all the available data is shown in Figure 23.

Muscle strength in external rotation based on raw data and all the available data is shown in Figure 24.

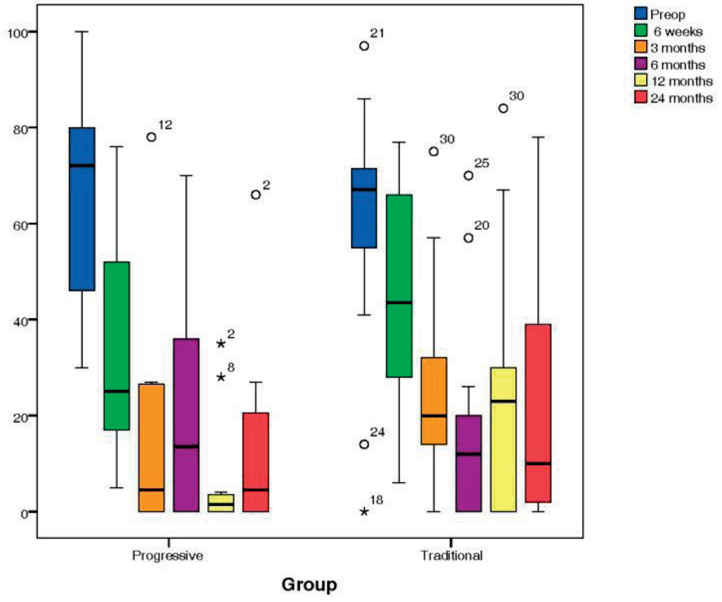

Figure 22. ASD: pain during activity (VAS, mm) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

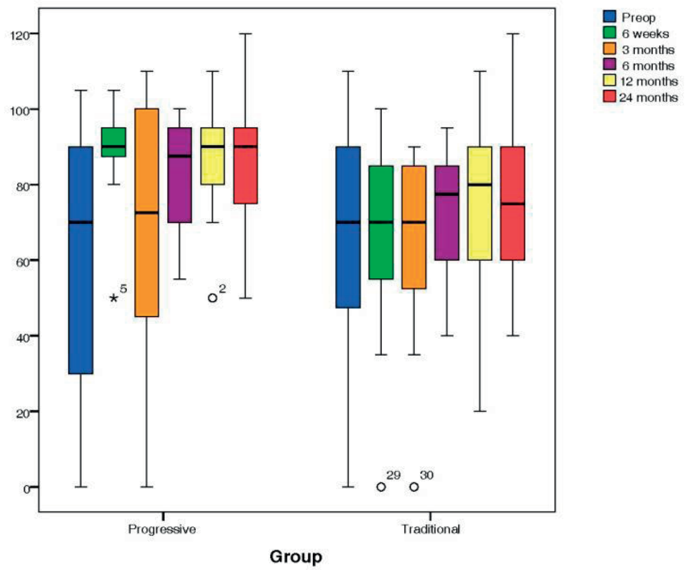

Figure 23. ASD: range of motion in external rotation (degree) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

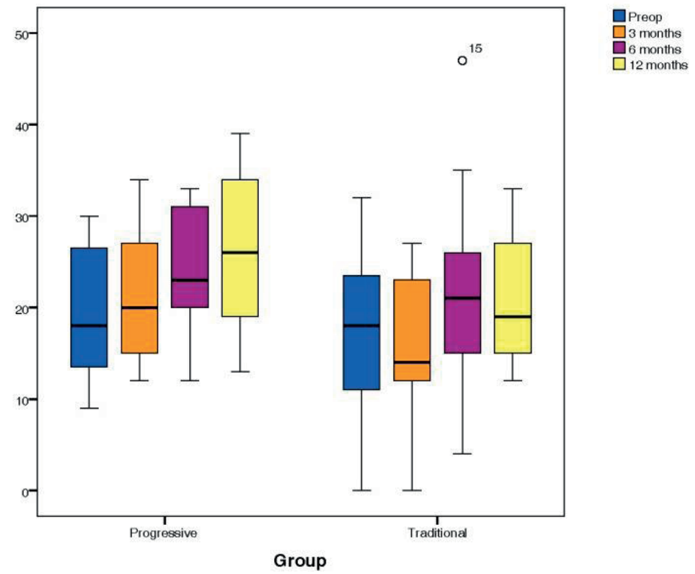

Figure 24. ASD: muscle strength in external rotation (Joule) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

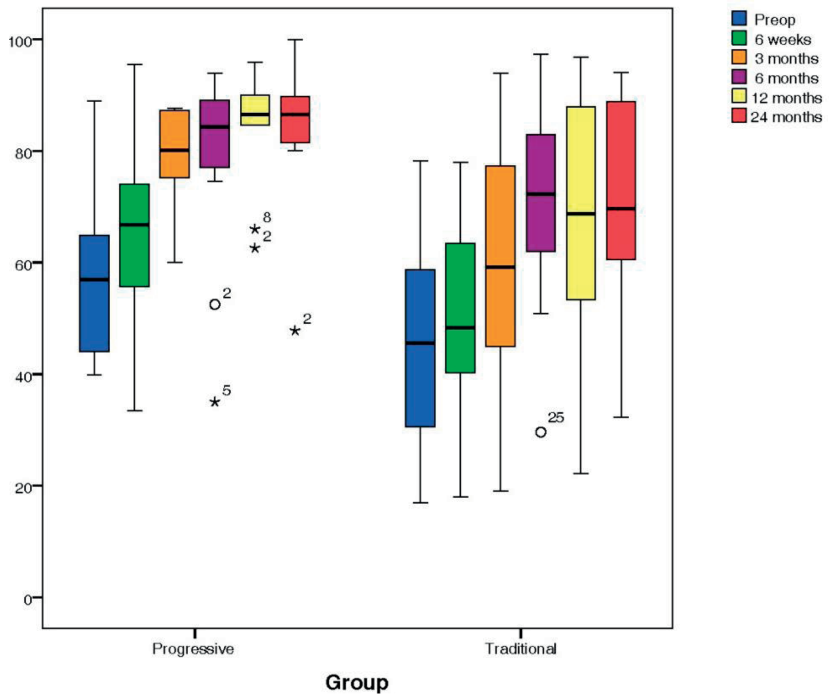

Figure 25. ASD: Constant Score (100 points) at pre-operative and follow-up assessments in the Progressive Group and the Traditional Group.

The result for the Constant Score based on raw data and all the available data is shown in Figure 25.

Patient satisfaction based on all the available data is shown in Table 11.

Table 11. *Patient satisfaction at follow-ups in the Progressive Group (PG) and the Traditional Group (TG) after ASD.*

	6 we		**3 m**		**6 m**		**12 m**		**24 m**	
	PG	TG	PG	TG	PG	TG	PG	TG	PG	TG
5: very satisfied	5	4	6	6	7	9	8	7	6	9
4: quite satisfied	4	5	1	5	2	4	2	6	1	4
3: neither satisfied nor dissatisfied		4	1	1	1			2	1	2
2: quite dissatisfied	3	1		1	1	1	1	1		1
1: very dissatisfied					1			2		1

4.3 Study III

Studies III and IV comprised the same group of patients. In the presentation of the results in Studies III and IV, the patients were divided into three groups.

Group 1: Pain-free patients (n=53)

Group 2: Patients with shoulder pain, no arthropathy (n=41)

Group 3: Patients with shoulder pain and arthropathy (n=11)

Patients' ratings of shoulder pain during activity of <10 mm were regarded as "painfree".[36]

Arthropathy was defined as a progressive pathology such as rheumatoid arthritis including Sjögren's Syndrome, Bechterew's Syndrome (ankylosing spondylitis), psoriatic arthritis and polyarthropathy.

Eighty-eight patients, 84%, stated that they were satisfied with their present shoulder function, as shown in Table 12.

Table 12. *Patient satisfaction with shoulder function 8-11 years after ASD.*

	All patients	**Pain free**	**Pain, no arthropathy**	**Pain, and arthropathy**
	n=105	n=53	n=41	n=11
5: very satisfied	61	47	11	3
4: quite satisfied	27	3	19	5
3: neither satisfied nor dissatisfied	10	3	7	0
2: quite dissatisfied	6	0	3	3
1: very dissatisfied	1	0	1	0

ASD= arthroscopic subacromial decompression.

Intensity of pain during activity and at rest is shown in Table 13.

Active range of motion in flexion, in external and internal rotation and strength in external rotation, as well as Constant Score are shown in Table 14.

Table 13. *Pain intensity, measured with VAS, 8-11 years after ASD.*

	All patients	**Pain free**	**Pain, no arthropathy**	**Pain and arthropathy**
	n=105	n=53	n=41	n=11
Pain during activity **95% CI** **Min-max**	8 3 - 17 (0-90)	0 0 - 0 (0-8)	40 28 - 50 (10-87)	28 * (10-90)
Pain at rest **95% CI** **Min-max**	0 0 - 3 (0-80)	0 0 - 0 (0-10)	14 3 - 37 (0-80)	28 * (5-62)

ASD = arthroscopic subacromial decompression.

All the values (mm) are presented as mean and 95% confidence intervals, (CI), except when n ≤ 11.

Table 14. *Active range of motion, shoulder strength and Constant Score, 8-11 years after ASD.*

	All patients	**Pain free**	**Pain, no arthropathy**	**Pain and arthropathy**
	Men n=53 Women n=46 Total n=99	Men n=25 Women n=26 Total n=51	Men n=24 Women n=15 Total n=39	Men n=4 Women n=5 Total n=9
Flexion (degree)	150 (144 - 156) 153 (146 - 159) 151 (147 - 155)	155 (150 - 159) 164 (160 - 168) 159 (156 - 163)	147 (136 -159) 138 (123 - 153) 144 (135 - 153)	134 138 136 (123 - 149)
External rotation in abduction (degree)	87 (82 - 92) 88 (81 - 95) 87 (83 - 91)	94 (91 - 97) 99 (96 - 103) 97 (94 - 99)	82 (72 - 93) 74 (61 - 88) 79 (71 - 87)	70 67 68 (46 - 91)
Internal rotation in abduction (degree)	30 (26 - 34) 39 (34 - 43) 34 (31 - 37)	34 (29 - 38) 42 (37 - 47) 38 (34 - 41)	28 (22 - 35) 36 (28 - 45) 31 (26 - 36)	23 28 26 (12 - 39)
Strength, external rotation (kg)	9.4 (8.7 - 10.1) 6.2 (5.6 - 6.8) 7.9 (7.4 - 8.5)	9.8 (9.1 - 10.5) 6.9 (6.4 - 7.5) 8.4 (7.8 - 8.9)	9.5 (8.4 - 10.6) 5.3 (4.1 - 6.6) 7.9 (6.9 - 8.9)	5.7 5.0 5.3 (2.9 - 7.7)
Constant Score (100 p)	89 (75 - 84) 74 (69 - 79) 77 (74 - 80)	89 (87 - 92) 84 (82 - 87) 87 (85 - 89)	72 (65 - 79) 63 (54 - 72) 69 (63 - 74)	62 56 59 (45 - 72)

ASD= arthroscopic subacromial decompression.

All the values are presented as the mean and 95% confidence intervals (CI), except when n≤11.

The multiple regression analysis in all patients showed that a low level of pain during activity was the strongest single predictor of patient satisfaction (β= -0.50, $p<0.0001$). For all patients, range of motion in external rotation was the strongest explanatory variable for pain-free shoulder activity (β= -0.47, $p<0.0001$).

4.4 Study IV

When shoulder-related quality of life was evaluated with the WOOS, 8 to 11 years after ASD, all patients reported a mean of 83% of optimal shoulder-related quality of life.

When divided into the three groups, the mean of optimal shoulder-related quality of life showed that:

Group 1: *Pain free patients* reported a mean of 95%

Group 2: *Pain, no arthropathy* reported a mean of 71%

Group 3: *Pain and arthropathy* reported a mean of 73%

There were no significant differences in shoulder-related quality of life between men and women within any of the three groups in the total WOOS or in any of the four domains.

In all patients, the mean EQ-5D$_{index}$ was 0.77 (CI 0.72-0.82).

Using the EQ rating scale, 56% of all the patients scored >80 of "best imaginable health state". The mean value for all patients was 74.7 (CI 70.6-78.8).

There were no significant differences in perceived health-related quality of life between men and women in all patients or within the three groups.

The IPAQ (n=105) showed that 41 patients were physically active at a high level, 34 at a moderate level, 24 at a low level, while six performed no physical activity/lived a sedentary life (less than 30 minutes' walking per week).

Post-operatively, 49 patients had physiotherapy for more than two months, 27 patients for less than two months, 26 had followed individualised, home-based training and three patients had not been recommended or had chosen not to follow physiotherapy-guided rehabilitation.

High, negative correlations were found between pain during activity and the WOOS (r= -0.78) and between pain during activity and the Constant Score (r= -0.72). High correlations were also found between the Constant Score and the WOOS (r= 0.76). A moderate correlation was found between patient satisfaction and the WOOS (r= 0.62).

Low correlations were found between the $EQ\text{-}5D_{index}$ and EQ rating scale compared with the other instruments (0.39-0.53). A low correlation was found between the $EQ\text{-}5D_{index}$ or EQ rating scale and patient satisfaction (0.41 and 0.33).

A significant association was found between patient satisfaction and pain during activity (dichotomised variables) and, accordingly, patients with a low degree of pain (VAS<30 mm) are more likely to state satisfaction with present shoulder function and vice versa. In the multivariate logistic model, only the WOOS showed a significant association with patient satisfaction, odds ratio (OR=1.095 (CI 1.036-1.157). Including the Constant Score and pain during activity did not improve the model further.

When controlled for age, gender and activity level, age almost reached a significant level (p=0.053).

4.5 Additional results

The intention to treat analysis in study I and II did not alter the content of the results of the original statistical analysis.

In the original analysis as well as when using the intention to treat method, where significant differences in *change scores* were shown, it was always in favour of the Progressive Groups. Not at any time or in any item did the Traditional Groups reach significantly higher *change score* compared with the Progressive Groups in studies I or II.

5 DISCUSSION

Although it is not life threatening, subacromial pain in fact often results in major disability. Subacromial pain forces patients into sick leave, results in an inability to perform leisure activities and often causes substantial utilisation of health care resources. Effective postoperative treatment that shortens the duration of disability and produces longstanding positive results will reduce morbidity and costs for both society and the individual.

The incidence of subacromial pain will probably increase as the population ages and becomes more physically active. The number of surgeries performed in patients with subacromial pain is increasing. One reason may be that people today are less willing to accept functional limitations.

A comparison of results after rotator-cuff tear and ASD has been summarised in the Cochrane systematic review – Surgery for rotator cuff disease.[28] The review confirms the feeling of confusion and frustration we experienced while searching for evidence on how to treat and manage patients after surgery for subacromial pain before the initiation of Studies I and II.

Surgical outcome depends on all the individuals involved; the patient is in the centre, while the physiotherapist and the orthopaedic surgeon are parts of the rehabilitation team. The communication between team members is important. The expectations of the patient, the patient's family and perhaps also the patient's workplace or sports team members may play an important role.

The patient should be an informed and active participant throughout the process. It is the patient's goal that should guide the goal-setting for the rest of the team. The collaboration and communication between patient, physiotherapist and surgeon should be established during the preoperative management. The patient's goals should be discussed and described in detail before surgery takes place. The demands imposed on the patients after surgery should also be clearly specified. After rotator-cuff repair in particular, patients are often overwhelmed when they realise how much time they must spend performing the exercises. They may also be astonished by how much time it takes before they are able to lift their arm to reach a shelf in the cupboard without experiencing pain or without compensatory motions.

The role of the physiotherapist is to guide the patient safely and smoothly in order to realise his/her goals for shoulder function. By selecting specific, strategic exercises, the physiotherapist thereby contributes to the remodelling process of the injured tissue to achieve optimal strength. The role of the physiotherapist is also to guide the patient to adjust the level of strain and loading in all his/her activities in order to prevent a relapse and also to ensure longstanding results.

The two new progressive protocols in Studies I and II were based on the literature available at that time but also on clinical and biomechanical reasoning between the first two authors (IHK and ACG).

5.1 General discussion of the results

There is a lack of standardisation in outcome measures for evaluating results after surgery in patients with subacromial pain. Consequently, specific comparisons between studies are difficult. However, rotator-cuff repair and ASD are reported to produce good overall results. To our knowledge, no study has made comparisons between comprehensive physiotherapy treatment protocols with specified progression of work-load after surgery in subacromial pain in order to establish evidence on how to optimise the postoperative regimen.

Study I

The principal finding in Study I was that pain during activity and at rest decreased by approximately 50% within three months postoperatively in both groups. Both groups showed a median decrease of 49 mm in pain during activity from the preoperative examination to the three-month follow-up. Both groups had a median of ≤30 mm in pain during activity at the three-month follow-up and it remained low until two years postoperatively. Tashjian et al.[159] suggested that the “Patient acceptable symptomatic state” (PASS) is VAS ≤30 mm in subacromial pain, and that a pain level of ≤30 mm is associated with a high level of patient satisfaction. In the present study, this may provide evidence that rotator-cuff repair followed by physiotherapy produced satisfactory results in patients from both the short- and long-term perspective.

Two studies have evaluated different physiotherapy interventions after full-thickness rotator-cuff repair.[67,104] The physiotherapy treatment protocols in the studies by Hayes et al.[67] and Lastayo et al.[104] were different compared with the present study in that there was less specificity in the exercises that were used and the number of visits to the physiotherapy department and the loads varied. Concerns may be raised about the methodology that was used when it comes to evaluating the overall results. The instruments used in the present study and in the studies by Hayes et al.[67] and Lastayo et al.[104] are not the same and comparisons are therefore not possible.

In Study I, patients attained approximately 150º in flexion and 170º in abduction in both groups, at one year. This can be compared with normative data of 138º and 151º respectively.[118] Isometric strength in elevation in the plane of the scapula was 13.2 kg, which is slightly higher than reference values from our research group (unpublished data). Therefore comparison between the present study and normative values indicates excellent results when it comes to both range of motion and isometric muscle strength.

Using the Constant Score, the Progressive Group and the Traditional Group obtained 82 and 77 points respectively at two years. Normative data for the Constant Score based on age and gender have been presented by Constant et al.[30] In the 51- to 60-year age group, the mean value in men was 90 and in women 73 points. The corresponding values in the 61- to 70-year age group were 83 and 70 points. Katolik et al.[87] have also established normative data for the Constant Score. They found slightly higher values than Constant et al. reported.[30] Katolik et al.[87] found that the total score was approximately 93 and 91 points in men and 83 and 82 points in women in the age groups corresponding to those reported by Constant et al.[30] Ambiguity when it comes to comparing the results for the Constant Score between shoulder centres is discussed later in this section, see *Methodological considerations.* However, the results in the present study showed that patients obtained values that were slightly lower compared with the normative values. This can be regarded as a satisfactory result.

Zingg et al.[179] re-evaluated 17 patients with massive full-thickness rotator-cuff tears after 48 months (30-65). They were managed non-surgically because of low demands, few symptoms or refusal to undergo surgery. The evaluation showed that the tear size increased by 3.3 cm^2. Osteoarthritis progressed significantly and the acromial-humeral distance decreased from 8.2 mm to 5.6 mm. The fatty infiltration increased significantly within the ruptured tendons. Of an initial eight reparable tears, four were irreparable. The pain score was 11.5 (VAS 0-15, 15=pain free). Active flexion and abduction were 136º. Strength in abduction was 3.1 kg. Zingg et al.[179] conclude that the degenerative structural changes deteriorate over time. Although satisfactory shoulder function may be maintained for an average of four years,[177,179] there is a risk that a reparable tear will become irreparable. When it comes to the range of motion and Constant Score[31], a comparison with the results in Study I may indicate that surgery followed by physiotherapy is favorable compared with non-surgical management alone.

Study II

The principal findings in Study II were the considerable reductions in pain perceived during activity and at rest in both groups. The greatest improvement in perceived pain occurred within the first six weeks.

The Progressive Group reported ≤30 mm in pain during activity at six weeks after surgery and were pain free at rest from six weeks after surgery. These results were maintained until two years after surgery.

The Traditional Group reported ≤30 mm in pain during activity at three months after surgery and rated pain free activity first at the two-year follow-up. They were pain free at rest six weeks after surgery and remained pain free until one year.

This shows that patients after ASD attained the ”Patient acceptable symptomatic state” (PASS) that, according to Tashjian et al.[159], is associated with a high level of patient satisfaction. The favourable longstanding result for the perception of pain during activity and rest 8-11 years after ASD, as shown in Study III, is also noteworthy.

When it comes to the Constant Score, the Progressive Group obtained 87 points at both the 12- and 24-month follow-ups. The Traditional Group obtained 69 and 67 points, respectively, at the corresponding follow-ups. This indicates that the Progressive Group had values similar to the normative values, while the Traditional Group had somewhat lower values. Even though the *change score* did not differ significantly between the Progressive and Traditional Groups, the difference in raw score was 20 points. This difference of 20 points between groups is at the level recommended by Conboy et al.[29] as relevant in order to argue in favour of a “true” difference in results between groups.

Andersen et al.[3] concluded that no beneficial effect of physiotherapistsupervised rehabilitation after ASD could be demonstrated. In the study by Andersen et al., the content of the physiotherapy intervention was poorly described. However, there appear to have been fairly large differences compared with both the progressive and traditional protocols used in Study II. Their supervised protocol was different in terms of the specificity of the exercises, the number of visits to the physiotherapy department and loading.

The studies by Brox et al.[19] and Haahr et al.[63] compared surgical treatment with physiotherapy treatment. However, these studies do not present raw data, which makes comparisons impossible.

Studies III and IV

Normative data for range of motion were established by McIntosh et al.[118] The pain free patients in Study III had higher values in all directions except internal rotation compared with the corresponding age group in the study by McIntosh et al.[118] However, in the two groups of painful shoulders, patients obtained similar values in flexion but inferior results in abduction and external and internal rotation compared with normative data.

Normative data have been established for the Isobex® (unpublished data). In Study III, in the pain free group, similar values were obtained in men and even higher values in women. The result in the other two groups was lower compared with normative data. However, the patients in Study III were older than the patients comprising the normative data. It has been shown that isometric strength decreases with age.[120] Further studies of normative data relating to isometric muscle strength measured with the Isobex® would be of great importance, as this measurement is included in the Constant Score.

When it comes to the Constant Score, 8-11 years after ASD, the mean value in the group of pain-free patients, men and women, was 89 and 84 points, respectively. This indicates results that are similar to normative data. However, the painful groups obtained inferior results, as they scored 70 points or less.

In Study IV, the WOOS showed that the pain-free group had almost unrestricted shoulder function, resulting in virtually optimal shoulder-related quality of life. Patients with painful shoulder activity reported an approximate deficit of 30% in optimal shoulder-related quality of life. No normative data from a population with no defined shoulder pathology are available for comparison with the WOOS.

Patients with pain-free shoulder activity reported higher values, when it comes to the EQ-5D, than the Swedish reference values. The other two groups reported lower values compared with the reference values. However, the dimension of *pain/discomfort* was affected in approximately 70% of patients 8-11 years after ASD.

Interestingly, in Study IV, (8-11 years after ASD) no significant differences between genders were shown in the level of pain during activity and at rest, or in shoulder-related or general health-related quality of life. This is not in line with the general idea of differences between genders, as shown, for instance, by Razmjou et al.[140] in patients with rotator-cuff pathology or by the Swedish reference values reported by Burström et al.[23]

Study IV showed that, approximately 10 years after ASD, patients displayed the same pattern of physical activity as Swedish people in general.[23]

Perhaps the patients with shoulder pain during activity and progressive arthropathy (Group 3 in Studies III and IV) experience the greatest benefit from ASD. During the clinical evaluations 8–11 years after surgery, these patients often expressed gratitude for the years with lower levels of shoulder pain and higher shoulder function, although, at the time of follow-up, their pain and functional restrictions had recurred. This is a patient group that is most frequently excluded from prospective, randomised trials when outcome after orthopaedic surgery is evaluated. When conducting similar studies in the future, patients with progressive arthropathy, diabetes and/or neurological diseases, for example, should be included, but their results should be analysed in subgroups and the fluctuations in the disease should be well documented.

5.2 Methodological considerations

5.2.1 The active components of the progressive protocols

The treatment protocol in the Progressive Groups after rotator-cuff repair and after ASD impose heavy demands on the patients. After ASD, patients performed the home-training programme every two hours, i.e. up to 7 sessions a day, until six weeks after surgery. They then performed the home-training programme 3 times a day until 4 months postoperatively. Treatment sessions at the physiotherapy department were held 2-3 times a week in both groups. Patients who had undergone rotator-cuff repair had additional aquatic training twice a week.

All patients filled in a compliance log. On the log form, patients could make comments about experiences during home-training sessions. This was used by the physiotherapist in charge when deciding to adjust loads in the exercises at the physiotherapy department. The log was also discussed with the independent research physiotherapist at follow-ups. It is our impression that patients were honest in reporting how often they had performed the home training. The log may also be a helpful tool to motivate the patient to perform the home-training exercises.

Strategies to promote rotator cuff function

The findings by Longo et al.[112] support the theory that the restoration of scapular and rotator-cuff muscular function may reduce the mechanical stress on the subacromial tissue. A relapse of symptoms after surgery in patients with subacromial pain, rotator cuff repair or ASD may therefore be prevented. The results of the analyses of the function of the muscles within the rotator cuff in several studies by Kronberg et al.[100], Sharkey et al.[154] and Liu et al.[110] may explain why patients with an isolated supraspinatus tear may be asymptomatic.[177] The rest of the rotator cuff and the long head of the biceps may compensate for the loss of supraspinatus function and are capable of centring the humeral head within the glenoid fossa during shoulder activities.[100,110,154] This ability may be a part of the explanation of why patients with small full-thickness supraspinatus tears both in the study by Norlin and Adolfsson[130] and in Studies III and IV report a high level of function and shoulder-related quality of life. It may also support the idea that, when repair is not possible, it is important to maximise the function within the remaining parts of the rotator cuff to obtain the greatest possible pain free function.

In the Progressive Groups, the prolonged eccentric course of the exercises for the rotator cuff was introduced as early as possible and was adjusted to be pain free, if possible. The purpose of the prolonged eccentric course in the exercises was twofold, to enhance the steering capacity of the rotator cuff and to enhance tendon healing. The term *eccentric training* is most usually interpreted as painful and extremely strenuous muscle activations. However, in Studies I and II, it was more the prolonged eccentric phase of the exercise that was promoted. To achieve optimal co-ordination, i.e. optimising the neuromuscular capacity within the rotator cuff, a slow speed was thought to be beneficial. The patients were instructed to perform the exercises in front of a mirror, both at home and at the physiotherapy department. Patients were also recommended to have bare shoulders to be able to identify when correct motions of the humeral head were achieved and to reduce the speed or range of the exercise if the humeral head showed a tendency to glide superiorily.

The exercise selected for the supraspinatus was elevation in the plane of the scapula, with the humerus internally rotated, i.e. "empty can position".[163] The biomechanical studies to date do not prove that this position is the most effective when it comes to strengthening the supraspinatus while assuring minimal humeral head migration and low activity within the deltoid muscle.[10] However, these studies did not evaluate the performance of the exercise or the way we instructed the patients. In addition, these studies have had the scope to establish evidence of the most suitable exercise to strengthen the supraspinatus. In our studies, the quality of the muscle performance was more important than strength development alone. It may also be argued that the supraspinatus primarily acts as a stabiliser and the selection of exercises and performance may differ from exercises in muscles better known as motors and strength-developing muscles.

Escamilla et al.[45] conclude that having the humerus rotated externally, i.e. in the "*full can position*", while performing elevation in the plane of the scapula, is a more cautious approach. According to Escamilla et al.,[45] this position reduces the risk of compressing the supraspinatus. In Studies I and II, the course of the arm was limited to a low range of motion and the patient changed the direction of the motion as soon as shoulder elevation could be identified or pain was elicited. The risk of subacromial compression was thereby reduced to a minimum.

It was also hypothesised that the exercises for the supraspinatus would reduce the oedema within the tendon, thereby reducing the risk of impingement. However, this was not evaluated in Studies I or II.

The exercise selected for the infraspinatus was external rotation while lying on the side. This exercise has been advocated as one of the most effective when it comes to restoring the strength and function of the infraspinatus muscle.[33,143]

The humeral head is positioned higher in the glenohumeral joint when the rotator cuff is in a state of fatigue.[149,160] In patients with subacromial pain, the humeral head position was even higher compared with healthy persons.[149,160] The large number of training sessions that was used in Studies I and II is therefore justified in order to obtain endurance in the rotator cuff. This may also be recommended when treating patients with subacromial pain.

Strategies to promote the function of the scapular muscles

The purpose of optimising the upward rotation of the scapula was to elevate the acromion and the acromio-clavicular joint to clear the passage for the subacromial tissues. The purpose of optimising co-ordination of the scapular and humeral movements, was to contribute to a reduction of the demand on the rotator cuff. To adjust the scapula and the glenoid fossa in relation to the arm and hand activities, the stabilising requires the rotator cuff to be unburdened. This phenomenon may prevent the rotator cuff from overload during heavy or long-lasting activities.[22,112]

The exercise selected for the serratus anterior in the early period of the rehabilitation was unilateral protraction with a straight arm pointing towards the ceiling while lying prone. This exercise has been shown to be effective in creating high activity levels in the serratus anterior muscle.[44]

To restore activity in the lower trapezius, flexion from 90º to maximum range in flexion while lying prone was used. This exercise was introduced at a later stage in the rehabilitation period, when it was possible, according to individual assessments when it came to pain-free, correct performance. This exercise has been shown to be effective in creating high activity levels in the lower trapezius muscle.[44]

Strategies to restore flexibility in the posterior gleno-humeral capsule

Tyler et al.[165] evaluated stretching procedures for the posterior capsule, but in patients with internal impingement, secondary to instability. One of the manual techniques described by Tyler et al.[165] was identical to one of the techniques used in Studies I and II. In the study by Tyler et al.,[165] the range of motion in internal rotation, cross-body adduction and external rotation was significantly increased after stretching to the posterior capsule. Furthermore, improvement in cross-body adduction and/or posterior shoulder tightness was greater in patients who experienced a complete resolution of symptoms compared with patients with residual symptoms.[165]

The subacromial space is a narrow space and even minor changes in dimension during active shoulder motions can result in impingement.[121] The findings by Flatow et al.[47] indicate that a mechanical disturbance in subacromial gliding, such as increased soft tissue volume in the subacromial space, superior humeral gliding because of rotator-cuff dysfunction or superior humeral head translation due to a tight posterior capsule or glenohumeral instability, might be expected to damage the supraspinatus insertion.[47] Factors that compromise the glenohumeral range of motion, such as the posterior capsule, may therefore increase the compression of the rotator cuff between the humeral head and the acromion.[47] If there is stiffness preventing full range of external rotation, this may increase the impingement of the rotator cuff, as the greater tubercle cannot be moved posteriorly and away from the acromion.[47]

In Studies I and II, patients following the progressive protocol after rotator cuff repair or ASD reached slightly higher levels of internal rotation. However, they did not obtain a significantly higher *change score* in internal rotation on any follow-up occasion. The slightly higher range of motion in internal rotation may be one factor explaining why the Progressive Group reached significantly higher range of motion in abduction.

Nevertheless, according to clinical experience, when internal rotation is gradually increased, shoulder pain gradually subsides. Based on clinical experience and the findings by Flatow et al.,[47] stretching procedures to restore internal rotation can therefore be strongly recommended in the physiotherapy treatment of patients with subacromial pain.

5.2.2 Aquatic training after rotator-cuff repair

The aquatic training started six weeks after surgery in the Progressive Group and eight weeks after surgery in the Traditional Group. The earlier loading in water in the Progressive Group was well supported, as patients in this group experienced a gradual decrease in pain both during activity and at rest. Patients often said that the aquatic training was pleasant. They found it encouraging being able to perform motions throughout a range of motion that were not possible on land. Brady et al.[12] also concluded that, after rotator-cuff repair, patients easily tolerate a protocol consisting of 12 weeks of aquatic training starting just 10 days postoperatively. Their findings support the use of aquatic training in these patients and may also indicate that it can be initiated at an even earlier stage than was indicated in the protocol for the Progressive Group.

5.2.3 Pain monitoring model in postoperative subacromial pain

One of the keystones in the progressive protocols was patient education on the functional anatomy of the shoulder, together with information about the negative effects of painful shoulder activities. The objective was to provide the patient with useful information on the activities and motions that should be avoided and those that were safe to execute. Patient education also included ways of differentiating between muscle soreness from pain due to overload or new events of impingement of the subacromial soft tissue. From the results of Studies I and II, it is not possible to determine whether early activation by specific exercises, soft tissue treatment or patient education had the most important impact on outcome. The philosophy behind the pain-monitoring model that was used may be strengthened by Brewster and Schwab,[15] who stated “No pain, no gain is not part of this scheme”. This means that activities or exercises that trigger shoulder pain are to be avoided. Furthermore, Gazielly[51] suggests that pain relief is accomplished more by strengthening the muscles acting as humeral depressors than by using external adjuvant therapy.

One mechanism explaining why eccentric exercises may be effective in reducing pain in Achilles tendon pathology was identified by Öhberg and Alfredsson.[180] During the eccentric exercise cycle, there was a temporary interruption in blood flow that may damage both the neovessels and accompanying nerves, leading to a reduction in pain.[180] However, the loads in their protocols were higher than the level we used. We did not want our exercises to induce or aggravate existing shoulder pain. We conclude that pain may have negative effects on the sensitive and meticulous muscular co-ordination around the shoulder. Experience of pain was accepted during the exercise sessions both at home and at the physiotherapy department, providing that there was correct movement pattern and scapular control. Loads and complexity in the exercises that were performed were modified so that the pain level should have subsided when the next training session was to be performed.

5.2.4 Instrumentation

Visual Analogue Scale

Pain intensity is not only influenced by pathology. There is a low correlation between pathology and pain.[164] The absence of identifiable pathology does not mean the absence of pain.[164] Pain is influenced by the meaning of pain, if the cause of the pain is curable and also its expected duration.[26,164] Attitudes, beliefs, fear and anxiety, as well as the patients' social environment, have an influence on the experience of pain.[164]

In the present work, the assessment of pain was limited to the *intensity of pain*.

Visual analogue scales were developed within psychological research early in the 20th century. The use of Visual Analogue Scales as it is presented in this thesis was popularised by Aitken.[1] He proposed that VAS were suited to experimental designs employing repeated measures and within-subject comparisons. In Studies I and II, the statistical analysis was calculated using the *change score,* the difference between pre-treatment and each follow-up measuring VAS within subjects. This method was adopted, as it could perhaps overcome some of the difficulties in interpreting the reported values of VAS. The perception or experience of pain may vary considerably among individuals and comparing absolute VAS values between individuals is not meaningful.

The work of Scott and Huskisson[153] has influenced the design of the visual analogue scales that are used today. They suggested that the horizontal 10 cm line was more appropriate than a vertical line.[153] However, subjects do not always make use of the potential of the visual analogue scale as a continuum. Responses tend to cluster at the mid- and end-points of the scale.[153]

The difficulty in establishing the reliability of pain measurement is the inherent nature of pain variability. Pain may vary from a short period of time to another.[77] Jensen et al. [77] conducted a study to evaluate the stability of measures of VAS and a composite of pain measures after treatment in patients with chronic pain (not specified). They assumed that only small changes in pain intensity would occur from two weeks to one month after treatment. The correlation coefficient of VAS “Current pain” was r=0.67 from two weeks to one month after treatment.[77]

Jensen et al.[76] stated that the available research indicates that there will be variability in the conclusion of validity analyses of VAS. The variations will depend on the differences in the natural courses of the pathology and/or the type of pain treatment being used. The problem when it comes to determining validity is also the lack of a “gold standard” with which to compare the pain measures.[77]

Ohnhaus and Adler[133] used the Verbal Rating Scale (VRS) as the criterion scale with which to compare VAS. They found high, statistically significant correlations ($r=0.81$, $p<0.001$). They admitted at the same time the limits of the VRS in terms of validity.

VAS was validated as a measurement for both chronic and experimental pain by Price et al.[137] Chronic pain patients and healthy volunteers graded changes in six noxious thermal stimuli up to 51ºC, applied for five seconds to the forearm. Internal consistency was shown, as VAS scores varied in a predicted ratio proportional to the changes in the noxious stimuli, thereby demonstrating the valid use of VAS for the measurement of pain.[137]

Ohnhaus and Adler[133] argue against Verbal Rating Scales (VRS) as they force the patient to translate a feeling into words. They propose that VAS appear to assess more closely what a patient actually experiences with respect to changes in pain intensity.[133] The expression or word selected by the patient may not exactly express what a person really experiences.[133] Words may have different meanings for different individuals. Moreover, the intervals between words do not represent identical steps in pain intensity.[133] They conclude that VAS have greater sensitivity compared with VRS. They also found a tendency for patients to overestimate the change in pain intensity when using VRS compared with the VAS ratings. In contrast to Ohnhaus and Adler, Williamson and Hoggart[174] recommended the Numerical Rating Scale (NRS) and stated that it is more responsive than both VAS and VRS. Although patients in their study found VRS easiest to use, they point out the risk of its lack of sensitivity. O'Connor et al.[132] evaluated the responsiveness of VAS pain scores after ASD and showed high correlations between VAS pain scores and patient-valued changes (better, same, worse). Furthermore, VAS pain scores during activity were shown to be more responsive than VAS pain scores at rest, the Constant Score,[31] UCLA score[6] or SF-36.[132] In all four studies in this thesis, VAS pain scores during activity and VAS pain scores at rest have been used.

VAS were found to be most correlated with misunderstandings and to take the longest time to explain when it comes to using the three scales, VAS, VRS and NRS.[174]

The ease of use of VAS was also questioned by Carlsson.[26] VAS require memory, an ability to transform a complex subjective experience into a visuo-spatial display involving accuracy and perceptual judgement of the length of the 100 mm horizontal line.[26] In agreement with Carlsson,[26] patients do say from time to time that it is odd to express their perception of the intensity of pain in millimetres.

Nevertheless, McCormack[117] concludes that VAS were no weaker than other comparable measurements and had the advantage of ease of construction, use and versatility. Furthermore, Williamson and Hoggart[174] came to the conclusion that there is evidence, based on current literature, that patients are able to use VAS, VRS or NRS to communicate their pain experience and their response to treatment. NRS may be more suitable for audits and research.[174] VAS appear to be more valid than VRS when using fewer than seven response options. There again, VAS may be less sensitive than VRS with 11 or more response options, possibly because VAS are more difficult to comprehend for some patients.[76] The assessment of pain should be complemented by other measurements to describe the patient's course.[26,174]

Range of motion

Low values for inter-tester reliability have been shown; the ICC varied from 0.26 to 0.55.[144] In studies with repeated evaluations, it is recommended that the same person evaluates all patients. The measurement of internal rotation showed the lowest ICC, possibly because of the lack of control of the stability of the scapula, even in the supine position. In Studies I and II, all patients were evaluated by the same research physiotherapist.

Evaluation of isokinetic muscle strength

Total work was chosen to be reported in Studies I and II. The objective was to better reflect the dynamic capacity of the rotator cuff. Total work may appear to be a more valid measure to correlate with functional abilities. Total work is considered to be a more quantitative measurement of muscle strength, as it is made up of torque production throughout a range of motion.

The ability to develop muscle force in the present studies may have been influenced by motivation and the previous level of physical activity, nutritional status and/or fatigue. The subjects' age, gender, height and weight may also have influenced the results of muscle strength measurements. These confounding factors have not been addressed in this thesis.

In the long-term follow-up (Study III), it was decided not to evaluate isokinetic muscle strength. The decision related to the fact that isokinetic testing is time consuming and the value of these measurements is an open question. MacDermid et al.[115] found no evidence that extensive isokinetic testing was more useful than isometric strength testing when evaluating patients with subacromial pain. The isometric strength showed a significant association with disability outcomes.[115]

Constant Score

The use of the Constant Score[31] is widespread and it is also recommended for use by the European Society of Shoulder and Elbow Surgery. In 1991, its Research and Development Committee unanimously agreed that the score should be mandatory for presentations and publications within the society and in the *Journal of Shoulder and Elbow Surgery*.[87]

Conboy et al.[29] concluded that the Constant Score[31] was easy to use. Intra- and inter-observer errors were calculated. In the analysis of inter-observer variability, they found that, for a single observer making a single observation, there is a 95% likelihood of being within 17.7 points of the "true" value. For the intra-observer measurement, the corresponding value was 16.0 points of the "true" value. They thererefore concluded that, to have a true clinical change, the difference between follow-up assessments should be >16 points. However, Conboy et al. recommend >20 points.[29] Conboy et al.[29] also expressed doubt about the responsiveness to changes in the score, especially in patients with instability or high demands on shoulder function. However, they consider the Constant Score to be acceptable for use in patients with subacromial pain and osteoarthritis. Rocourt et al.[146] made an evaluation of the reliability of the Constant Score. To perform the reliability study, the original version of the Constant Score[31] was used. The intra-tester correlation coefficients for the two testers were r=0.96 and r=0.94.[146] The inter-tester correlation coefficient was r=0.90. However, in about 50% of the patients, the total score varied between 10 and 25 points between the testers. Based on these results, they claim unacceptable inter-tester reliability.[146]

Rocourt et al.[146] contacted several shoulder centres in Europe using the Constant Score and asked them to provide their manual for the Constant Score.[31] Descriptions and protocols varied widely. Rocourt et al.[146] concluded that the original description of the Constant Score is too short for a complex test procedure, leading to methodological incertitude.[146]

In agreement with Rocourt, Roy et al.[148] came to the conclusion that there is evidence to support the use of the Constant Score for clinical and research applications, but they underlined the need for standardisation in the assessment of the Constant Score.[148]

The clinical message is that the Constant Score is only appropriate when pre-treatment and post-treatment are evaluated by the same tester. Further, it is questionable and probably inadequate when it comes to comparing outcome between different centres.[146,148] Rocourt et al.[146] conclude further that the Constant Score should not be used for validation purposes.

In a commentary on the Constant Score[31], Lillkrona addresses the problem that the muscle strength section has been given a disproportionately large influence on the total score, 25 points out of 100.[108] The fact that the methodology in muscle strength measurement shows great variations further underlines this concern by Lillkrona.[108]

Constant et al.[30] published modifications and guidelines in 2008 to enhance consistency between different centres in calculating the score and thereby improve intra- and inter-reliability. In this case, normal values are also based on age and gender presented in and retrieved from Constant's thesis.[30] In conclusion, the authors agree with the limitations of the score but nevertheless promote its use until an alternative score is produced and shown to have higher qualities in terms of validity, reliability and sensitivity. The authors maintain that the score is easy and quick to calculate and does not require expensive or sophisticated equipment.[30]

Roy et al.[148] stress the issue of floor and ceiling effects with the strength subscale in the Constant Score. The ceiling effect may not have been of any real importance in the actual sets of patients, as only a minority of patients reach 25 points in the evaluation of muscle strength. In patients with low range of motion, the testing position may not be possible to achieve, raising the issue of a possible floor effect. The floor effect was not of any major importance in the present work, as the majority of the patients in the four studies had the range of motion needed to perform the muscle strength evaluation with Isobex®.

Rocourt et al.[146] proposed that results obtained by the Constant Score should be regarded as ordinal data and should therefore be calculated with non-parametric statistics. Only one study by Dom et al. reporting results after ASD and using non-parametric statistics was found.[40] To be able to compare the results in the present thesis with other similar or relevant studies, the decision to use parametric statistics was made, in spite of the obvious ordinal data level of the Constant Score.[146]

Western Ontario Osteoarthritis of the Shoulder Index (WOOS)

A meticulous process was undertaken by the Canadian research group who developed the WOOS.[111] A high correlation between the WOOS and the Constant Score,[31] both as discriminative and evaluative instruments ($r=0.69$, $r=0.73$), has been shown by Kirkley et al.[96] Like Kirkley et al.[96], in Study IV, a high association between the WOOS and the Constant Score was also shown. It could be argued that this gives increased validity to the Constant Score.

EQ-5D

Generic measures rarely have the precision to be useful at individual level, although they are still precise enough for group-level analysis. They permit comparisons of a group of patients with population norms.[7]

In Study IV, a low association was found between the $EQ\text{-}5D_{index}$ and the EQ rating scale compared with the other instruments. No significant association was established between the $EQ\text{-}5D_{index}$ or the EQ rating scale and patient satisfaction. This might be explained by the results in other studies that have shown that generic instruments like the EQ-5D and SF-36 are more sensitive and responsive in patients with high morbidity, as well as in patients with dysfunction of the lower limbs.[14,132,162] The study by O'Connor et al.[132] supports the impression from Study IV that only a few dimensions in a generic quality of life instrument are affected by a localised problem such as shoulder impingement. Further work is needed to establish the value of the available generic quality of life instruments, the SF-36 and EQ-5D, in the description of patients and in the analysis of treatment effects in patients with subacromial pain.

Furthermore, in a patient group with a high level of function, it is more difficult to detect a change, even with other instruments.[72] Hunsaker et al.[72] and Razmajou et al.[140] showed that age influences patient satisfaction in that older patients obtain higher scores with regard to satisfaction than younger patients. In Studies I and II, there were no differences in age between groups and this may have confounded the result. In the long-term study after ASD, Study IV, patients between 51 and 60 years were the age group that scored the highest degree of satisfaction. Younger and older patients obtained lower satisfaction scores for the results, perhaps indicating a difference when it comes to expectations in relation to age. In the older age group, the lower patient satisfaction values may also have been influenced by age-related degenerative changes.

Brophy et al.[16] suggest that activity level may influence the perception of treatment success. Patients with a high level of physical activity have a tendency to report a lower degree of satisfaction with shoulder function or treatment success.[16] However, in Study IV, patients' physical activity level or gender did not show any associations with patient satisfaction. Brophy et al.[16] suggest that the outcome after shoulder treatment should be related to physical activity level. This is often the case when reporting outcome after treatment after knee injury, for example.

5.2.5 Implication of the correlation analyses

A high level of range of motion in external rotation was shown to be a strong predictor of patients being pain free during activity. This might be valuable information for physiotherapists to enable them specifically to select exercises and treatment procedures targeting all the factors that may limit range of motion in external rotation. One of them might be to restore the flexibility of the posterior capsule. Others might be to enhance shoulder retraction and the erect posture of the upper spine.

The regression analysis of instruments used in Study IV revealed the highest association between the WOOS and patient satisfaction. This indicates that the WOOS is an important instrument in the evaluation of patients with subacromial pain.

Supplementary speculations

Dorrestijn et al.[41] concluded that, to date, there is no evidence to suggest that surgery is superior to physiotherapy in patients with subacromial impingement syndrome. Brox et al.[20] concluded that active interventions, either physiotherapy or surgery, are equally beneficial and superior to placebo.

Virta et al.[175] included 100 patients with subacromial pain from a waiting list for surgery. Seventy-two patients completed the comprehensive, supervised physiotherapy programme according to Böhmer et al.[25] If the symptoms persisted, patients were re-evaluated at the orthopaedic clinic. Only one patient of the 72 was selected for surgery. Twenty-five patients did not complete the physiotherapy treatment and nine of them were selected for surgery.

When patients are identified with subacromial pain, a comprehensive, well-structured physiotherapy treatment programme should be started without delay within primary care. Patients should be routinely treated with non-surgical treatment including physiotherapy for up to six months before surgery is considered. Before the surgeon decides on surgery, the content of the physiotherapy treatment, i.e. the type of exercises and manual techniques used, as well as the duration, should be carefully scrutinised.

If systematically performed, physiotherapy may also help to identify the patients who need surgery to restore shoulder function at an earlier stage and those who reach their personal goals with physiotherapy but without surgery.

It is also important to contribute to national guidelines in order to define the cut-off points in terms of surgical indications. The number of surgeries for subacromial pain has risen by more than 300% from 2005 to 2008, according to the Swedish Board of Health and Welfare.

6 LIMITATIONS

- A small number of patients were included in Studies I and II and these studies were therefore not adequately powered to provide a firm base on which to draw conclusions.
- It is a weakness that information relating to surgical findings in medical records was not standardised when it comes to the precise specification of the patho-anatomical findings in any of the four studies.
- Another limitation in the four studies was that no radiographic evaluation, including magnetic resonance imaging or ultrasound, was performed at the follow-ups.
- The training, sport or leisure activities that the patients in Studies I and II performed outside the protocols, both beneficial or detrimental, were out of our control. We were unable to control for events or factors that might have acted simultaneously with the interventions.
- The fact that the number of visits to the physiotherapy department was not analysed in order to make comparisons between Progressive Groups and Traditional Groups could be regarded as a limitation.
- The fact that the long-term follow-up, Studies III and IV, was not performed prospectively and that there was no control group could also be regarded as a limitation.
- The fact that height, weight and onset of pain were not taken into account when presenting the results in the studies comprising this thesis could be regarded as a limitation.

7 CONCLUSION

- The principal findings in the intervention studies were that pain decreased by approximately 50% within three months post-operatively. From six months until two years, the pain intensity was below VAS 30 mm in the majority of patients. From one year postoperatively the majority of patients who had undergone full-thickness rotator cuff repair were pain free. From two years postoperatively the majority of patients who had undergone ASD were pain free.

- After rotator-cuff repair a comprehensive, well-defined and controlled physiotherapy protocol with early activation and progressive approach produced as good results as did a more protective protocol. After ASD, the protocol with early activation and progressive approach was associated with slightly faster recovery of shoulder function.

- A comprehensive, well-defined and controlled physiotherapy protocol with early activation and progressive approach was well tolerated after rotator-cuff repair as well as after ASD. Patients attained similar values in terms of range of motion and muscle strength as do individuals without shoulder pathology. No adverse effects were noted. The progressive physiotherapy protocols presented in this thesis may therefore be recommended after full-thickness rotator cuff repair and ASD.

- There were no significant differences between men and women in shoulder-related quality of life, health-related quality of life, pain during activity, pain at rest or patient satisfaction 8-11 years after ASD.

- In the long-term follow-up, patients obtained similar results in terms of range of motion, muscle strength and physical activity 8-11 years after ASD to those of individuals without shoulder pathology.

- The majority of patients reported a high level of shoulder-related and general health-related quality of life and satisfaction with their present shoulder function 8-11 years after ASD. ASD may be regarded as a valuable intervention, as sustainable favorable long-term results were shown.

- A low level of pain during activity was the strongest explanatory variable for high patient satisfaction and when it comes to having a pain-free shoulder during activity, range of motion in active external rotation was the strongest explanatory variable.

- The Western Ontario Osteoarthritis Shoulder (WOOS) index was shown to be significantly associated with patient satisfaction, indicating that the WOOS is a valuable instrument for evaluating shoulder-related quality of life in patients with subacromial pain.

8 CLINICAL RELEVANCE

The physiotherapy protocols in Studies I and II may be useful as proposals for physiotherapy treatment for patients with subacromial pain in primary care in order to reduce the need for surgery, as well as postoperative physiotherapy treatment.

Studies I and II present ready-made home-training programmes with specified examples of exercises for use in postoperative treatment. The studies also include further proposals for exercises, manual techniques and patient education.

The time between follow-ups was chosen to provide a comprehensive description of patients' clinical course after rotator cuff repair and ASD. The implication of the evaluations was intended to contribute to consensus on the rehabilitation after surgical treatment for subacromial pain.

Patients should be routinely treated according to a comprehensive physiotherapy protocol up to six months before surgery is considered. The results presented in this thesis may provide physiotherapists with valuable information on attainable goals to give patients realistic expectations of shoulder function in terms of pain, range of motion and muscle strength after rotator cuff repair until two years and until approximately 10 years after ASD. As a result, this thesis also provides important information when it comes to deciding between continuing physiotherapy and proceeding with surgery.

The results presented in this thesis may also be of relevance for physiotherapists when treating patients with other conditions that may result in subacromial pain, i.e. proximal humeral fractures, secondary impingement, osteo-arthritis in the glenohumeral joint and neurological diseases.

9 FUTURE PERSPECTIVES

When we set up Studies I and II, we had some questions that were not possible to assess specifically because of technical difficulties or because they were too invasive and it was therefore not possible to defend their use. New techniques have now been developed.

- Is there any evidence to prove that the strength within the tendon of the rotator cuff is increased as a result of the exercise to the rotator cuff used in Studies I and II?
- Is there any evidence to prove that the effect exerted by the supraspinatus muscle in order to depress the humeral head downwards into the glenoid fossa is enhanced by the exercise to the rotator cuff used in Studies I and II?
- Is upward rotation and scapular stability enhanced by the exercises used for the scapular muscles studied in Studies I and II?
- Can the techniques used for stretching procedures be made more efficient?
- In the short-term perspective, can the oedema in the subacromial soft tissue as a result of the pathology as well as the surgical procedure be diminished by the specified frequency and the specific exercises for the rotator cuff?
- Can the fatty infiltration in the rotator cuff muscle be reduced by the specific exercises frequently performed for the rotator cuff?

The findings in the present study raise some new and interesting questions and important topics for further investigation.

- Evaluate shoulder-related quality of life, patient satisfaction and functional outcome in a long-term follow-up of patients after rotator-cuff repair
- Develop functional shoulder tests to be used both in everyday clinical practice and in research
- Develop a questionnaire in order to discriminate patients with different demanding levels of shoulder-related activities
- Complement normative data for the Isobex® in different age groups

Another interesting question is how physiotherapy should be adjusted in patients who are often excluded from similar studies, e.g. patients with rheumatoid arthritis, diabetes or neurological disorders after surgery for subacromial pain. Can the results from the present study be generalised when it comes to treatment protocols for these patient groups?

Another important field may be to contribute to the development of a chart in order to standardise the specification of the peri-operative patho-anatomic findings. This is a prerequisite in order to draw trustworthy conclusions from future studies evaluating physiotherapy after rotator-cuff repair or ASD.

10 SUMMARY IN SWEDISH

Bakgrund: Det diskuteras fortfarande hur den sjukgymnastiska behandlingen efter operation av patienter med subakromiell smärta skall planeras och genomföras. Det finns endast ett fåtal randomiserade och kontrollerade studier som utvärderar resultatet av olika sjukgymnastiska behandlingsrutiner. Endast ett fåtal studier med noggranna beskrivningar av innehåll och förslag på kontrollerad belastningsökning i träning liksom i vardagliga aktiviteter har presenterats i litteraturen. Det saknas kunskap om hur patienternas axelfunktion förändras över tid samt beskrivning av realistiska mål. Det saknas även kunskap om de långsiktiga resultaten avseende axelfunktion och livskvalitet efter akromioplastik.

Det övergripande målet med avhandlingen var att utveckla nya sjukgymnastiska behandlingsrutiner för patienter som opererats med rotatorkuffsutur och artroskopisk akromioplastik. Det primära syftet var att utvärdera om patienter som behandlades enligt en mångsidig och väl definierad sjukgymnastisk behandlingsrutin med tidig aktivering och progressiv karaktär blev smärtfria och uppnådde högre skulderfunktion tidigare än de patienter som behandlades enligt en mer generell och skyddande rutin. Syftet var också att beskriva realistiska mål på både medellång och lång sikt.

Patienter och metoder: I *Studie I* följdes 14 patienter fram till två år efter rotatorkuffsutur. I *Studie II* följdes 31 patienter (32 axlar) fram till två år efter akromioplastik. I *Studie I* liksom i *Studie II* jämfördes resultaten av två olika sjukgymnastiska behandlingsrutiner. Den ena gruppen följde en rutin med tidig aktivering och med progressiv karaktär medan den andra gruppen följde en rutin med mer skyddande och allmän karaktär. Olika träningsprogram användes i respektive studie. I *Studie III och IV*, utfördes en långtidsuppföljning av 95 patienter (105 axlar) 8-11 år efter akromioplastik. I de fyra studierna utfördes kliniska utvärderingar av patienterna där smärta under aktivitet och värk i vila, rörlighet samt muskelstyrka bedömdes. Dessutom utvärderades skulderfunktion, patientnöjdhet och livskvalitet.

Resultat: I *Studie I* var smärta och värk mindre än VAS 30 mm vid sex månader efter operation och vid ett år var majoriteten av patienterna i båda grupper smärt- och värkfria. Vid ett år hade grupperna uppnått 150° i flexion, ≥170° i abduktion och ≥70° i utåtrotation. Vid två år var Constant Score ≥77

poäng. I den Progressiva Gruppen angav samtliga och i den Traditionella alla utom en att de var nöjda med axelns funktion efter två år. I *Studie II* var smärta och värk mindre än VAS 30 mm vid tre månader och efter två år postoperativt var majoriteten av patienterna smärt- och värkfria. Grupperna uppnådde ≥150° i flexion, ≥170° i abduktion och ≥75° i utåtrotation. Med Constant Score uppnådde den Progressiva Gruppen 87 och den Traditionella Gruppen 67 poäng. Alla utom en i den Progressiva Gruppen och 13/18 i Traditionella Gruppen angav att de var nöjda med axelns funktion efter två år. I *Studie III och IV* uppvisade patienterna jämförbara resultat avseende rörelseomfång, muskelstyrka och fysisk aktivitet som personer utan axelpatologi. Hög livskvalitet i relation till skulderfunktion visades hos en majoritet av patienterna. Åttiofyra procent uppgav att de var nöjda med sin nuvarande axelfunktion 8-11 år efter akromioplastik. Graden av smärta under aktivitet var den starkaste förklarande faktorn avseende patientnöjdhet. Rörelseomfång i aktiv utåtrotation mätt i 90º abduktion var den starkaste förklarande faktorn avseende smärtfri aktivitet. Inga signifikanta skillnader mellan män och kvinnor vad gäller livskvalitet, smärta under aktivitet, värk i vila eller nöjdhet visades 8-11 år efter akromioplastik. Western Ontario Osteoarthritis Shoulder (WOOS) index visade signifikant samband med patientnöjdhet.

Slutsats: Det primära fyndet i interventionsstudierna var att smärta under aktivitet minskade med 50% inom de tre första månaderna efter operation. Patienterna angav att de var smärtfria ett år efter rotatorkuffsutur och två år efter akromioplastik. Efter rotatorkuffsutur gav en sjukgymnastisk behandlingsrutin med progressiv aktivering lika god återhämtning av axelfunktion som en rutin med mer skyddande karaktär. Efter akromioplastik gav en sjukgymnastisk behandlingsrutin med progressiv aktivering något snabbare återhämtning av axelfunktion. Några negativa effekter av den progressiva behandlingsrutinen efter rotatorkuffsutur eller akromioplastik kunde inte noteras.

De sjukgymnastiska behandlingsrutinerna med tidig aktivering som presenteras i denna avhandling, kan därför rekommenderas efter rotatorkuffsutur och akromioplastik. Samband mellan smärtfrihet och aktiv rörlighet i utåtrotation i 90º abduktion påvisades, varför metoder som ökar denna rörlighet, såsom töjning av den bakre kapseln kan rekommenderas. Goda långsiktiga resultat kunde påvisas efter akromioplastik.

Nyckelord: axelsmärta, impingment, rotatorkuffen, sutur, sjukgymnastik, rehabilitering, utvärdering, patientnöjdhet, livskvalitet, bakre ledkapsel, styrketräning, genus

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11 APPENDIX 1

A. Home-training programmes in the Progressive Group after rotatorcuff repair; 1(A), 2(A) and 3(A)

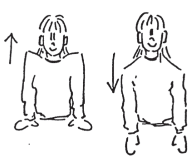
TRÄNINGSPROGRAM 1 ROTATORCUFFSUTUR - TEST

Bandaget skall användas dygnet runt i fyra veckor.

Ta av bandaget tre gånger per dag för träning.

Övn 1
Pumprörelser med handen.
200 gånger per dag

Övn 2
Böj och sträck armbågen maximalt.
10 gånger.



Övn 3
Dra upp axlarna mot öronen - sänk axlarna till samma höjd, slappna av. 20 gånger.

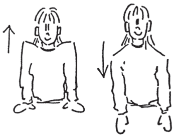
Övn 4
Cirkulationsövning. Stå med bra hållning.
Armbågen böjd till 90°. Handen på magen. Håll en kudde mellan bålen och armbågen. För underarmen utåt (cirka 20 cm) - inåt.
2 x 30.

Övn 5
Lätt sidoböjning mot opererade sidan.
Vrid armen så att tummen pekar mot låret. För armen utåt-inåt med cirka 20 cm rörelseuttag.
2 x 30.

Övn 6
Stå med armarna hängande utmed kroppen.
Böj Dig framåt och låt armarna avslappnat följa med i rörelsen.
Håll knäna lätt böjda.
10 gånger.

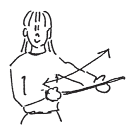
TRÄNINGSPROGRAM 2 ROTATORCUFFSUTUR - TEST

Träna tre gånger per dag.



Övn 1
Dra upp axlarna mot öronen - sänk axlarna till samma höjd, slappna av. 20 gånger.

Övn 2
Stå framför en spegel eller ligg på rygg.
Knäpp händerna. Lyft armarna framåt-uppåt.
Hjälp till med friska armen!!
4 gånger.



Övn 3
Stå med ryggen mot en vägg eller ligg på rygg.
För armen utåt-uppåt. Hjälp till med en käpp.
Tummen skall peka uppåt.
4 gånger.

Övn 4
Sitt vid ett bord. Vila underarmen mot bordet.
Rotera i axelleden genom att föra under-armen ut ut från - in mot magen.
2 x 30.

Övn 5
Stå rakt med armen hängande ut med kroppen.
Vrid armen så att tummen pekar mot låret.
För armen utåt-inåt med cirka 20 cm rörelse-uttag.
Rörelsen skall inte ge smärta.
2 x 30.

UTÖKA TRÄNINGSPROGRAMMET FRÅN SEX VECKOR EFTER OPERATIONEN:

Övn 6
Stå framför spegel med händerna vid axlarna.
Sträck armarna uppåt. För händerna nära ansiktet.
10 gånger.

Övn 7
Håll armarna böjda - lyft armbågarna uppåt - utåt.
10 gånger.

TRÄNINGSPROGRAM 3 ROTATORCUFFSUTUR - TEST

Träna 2 gånger per dag.

Övn 1.
Stå framför spegel med händerna vid axlarna. Sträck armarna uppåt. För händerna nära ansiktet.
10 gånger.

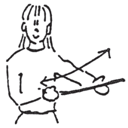
Övn 2.
Håll armarna böjda - lyft armbågarna uppåt-utåt.
10 gånger.

Övn 3.
Träning med gummisnodd fäst i dörrhandtag. Stå med opererade sidan mot dörren. Håll armbågen böjd och ha en liten kudde mellan bål och överarm.
Inåtrotation - dra handen mot magen.
3 x 10.

Övn 4.
Vänd friska sidan mot dörren.
Utåtrotation - för handen ut från magen.
3 x 10.

Övn 5.
Stå rakt med armen hängande ut med kroppen. Vrid armen så att tummen pekar mot låret. För armen utåt-inåt med cirka 20 cm rörelseuttag. Rörelsen skall inte ge smärta.
3 x 10.

Övn 6.
Stå framför en spegel eller ligg på rygg. Knäpp händerna. Lyft armarna framåt-uppåt. Hjälp till med friska armen!!.
4 gånger.



Övn 7.
Stå med ryggen mot en vägg eller ligg på rygg. För armen utåt-uppåt. Hjälp till med en käpp. Tummen skall peka uppåt.
4 gånger.

B. Home-training programmes in the Traditional Group after rotator cuff repair; 1(B), 2(B) and 3(B).

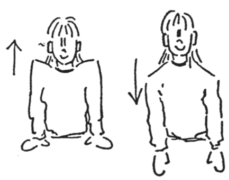
TRÄNINGSPROGRAM 1 ROTATORCUFFSUTUR - KONTROLL

Bandaget skall användas dygnet runt i sex veckor.

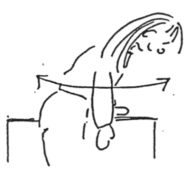
Ta av bandaget tre gånger per dag för träning.

Övn 1
Pumprörelser med handen.
200 gånger per dag

Övn 2
Böj och sträck armbågen maximalt.
10 gånger.



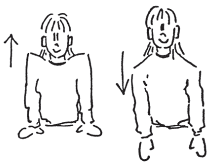
Övn 3
Dra upp axlarna mot öronen - sänk axlarna till samma höjd, slappna av. 20 gånger.



Övn 4
Stå lätt framåtlutad.
Pendla armen framåt-bakåt.
10 gånger

TRÄNINGSPROGRAM 2 ROTATORCUFFSUTUR - KONTROLL

Träna tre gånger per dag.

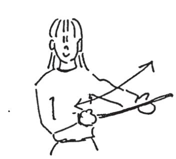


Övn 1
Dra upp axlarna mot öronen - sänk axlarna till samma höjd, slappna av. 20 gånger.

Övn 2
Cirkulationsövning. Stå med bra hållning. Armbågen böjd till 90°. Handen på magen. Håll en kudde mellan bålen och armbågen. För underarmen utåt (cirka 20 cm) - inåt. 2 x 30.

Övn 3
Stå lätt framåtlutad.
Pendla armen framåt-bakåt.
10 gånger.

Övn 4
Stå framför en spegel eller ligg på rygg. Knäpp händerna. Lyft armarna framåt-uppåt. Hjälp till med friska armen!!
4 gånger.



Övn 5
Stå med ryggen mot en vägg eller ligg på rygg. För armen utåt-uppåt. Hjälp till med en käpp. Tummen skall peka uppåt.
4 gånger.

TRÄNINGSPROGRAM 3 ROTATORCUFFSUTUR - KONTROLL

Träna tre gånger per dag.

Övn 1
Stå framför spegel med händerna vid axlarna.
Sträck armarna uppåt. För händerna nära ansiktet.
10 gånger.

Övn 2
Håll armarna böjda - lyft armbågarna uppåt - utåt.
10 gånger.

Övn 3
Träning med gummisnodd fäst i dörrhandtag.
Stå med opererade sidan mot dörren.
Håll armbågen böjd och ha en liten kudde mellan bål och överarm.
Inåtrotation - dra handen mot magen.
3 x 10.

Övn 4
Vänd friska sidan mot dörren.
Utåtrotation - för handen ut från magen.
3 x 10.

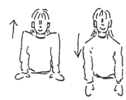
Övn 5
Stå rakt med armen hängande ut med kroppen.
Vrid armen så att tummen pekar mot låret.
För armen utåt-inåt med cirka 20 cm rörelse-uttag.
Rörelsen skall inte ge smärta.
2 x 30.

11.1 APPENDIX 2

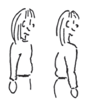
A. Home-training programmes in the Progressive Group after ASD; 1A, 2A and 3A.

TRÄNINGSPROGRAM 1 ACROMIOPLASTIK, TEST
(transartroskopisk, utan sensutur)

Träna övningarna på sida 1 (övning 1-5) varannan timme.
Stå gärna framför en spegel.

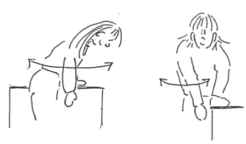


Övn 1.
Dra axlarna upp mot öronen.
Släpp ner dem lika långt. 20 gånger.



Övn 2.
Dra skulderbladen bak och ihop-fram och isär. Håll skuldrorna sänkta.
20 gånger.

Övn 3.
Sitt vid ett bord. Vila underarmen mot bordet. Rotera i axelleden genom att föra underarmen ut från-in emot magen.
2 x 30 gånger.



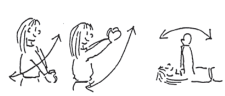
Övn 4.
Pendelövningar:

*Framåt-bakåt 10 gånger.

*Utåt-inåt 10 gånger.

Övn 5.
Stå rakt med armen hängande utmed kroppen. Vrid armen så att tummen pekar mot låret.
För armen utåt-inåt med cirka 20 cm rörelseuttag.
Rörelsen skall inte ge smärta.
2 x 30 gånger.

Träna övningarna på sidan 2 (övning 6-9) tre gånger per dag.



Övn 6
Stå eller ligg på rygg.
Knäpp händerna.
Lyft armarna framåt-uppåt. Håll armbågarna raka.
Ta ut maximalt rörelseomfång.
4 gånger.

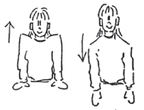
Övn 7
Stå med ryggen mot en vägg. För armen utåt-uppåt med hjälp av en käpp. Tummen skall peka uppåt.
4 gånger.

Övn 8
Stå mot en vägg eller ligg på rygg. Knäpp händerna i nacken. För armbågarna bakåt.
4 gånger.

Övn 9
Stående.
För handen bakåt och upp på ryggen. Ev. hjälp till med friska handen.
4 gånger.

TRÄNINGSPROGRAM 2 ACROMIOPLASTIK, TEST
(transartroskopisk utan sensutur)

Träna övningarna på sidan 1 (övning 1-4) varannan timme.



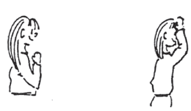
Övn 1
Dra upp axlarna mot öronen-sänk axlarna till samma höjd, slappna av.
20 gånger.

Övn 2
Cirkulationsövning.
Stå med bra hållning. Armbågen böjd till 90°.
Håll en kudde mellan bålen och armbågen.
För underarmen inåt-utåt inom smärtfritt rörelseomfång.
3 x 30 gånger.

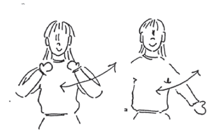
Övn 3
Stå rakt med armen hängande utmed kroppen. Vrid armen så att tummen pekar mot låret.
För armen utåt-inåt med cirka 20 cm rörelse-uttag. Rörelsen skall inte ge smärta.
2 x 30 gånger.

Övn 4
Ligg på icke opererade sidan.
Kudde mellan överarmen och bålen. Rotera i axelleden genom att lyfta underarmen.
3 x 15 gånger.

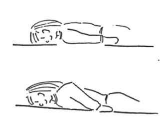
Träna övningarna på sidan 2 (övning 5-9) tre gånger per dag.



Övn 5
Stå framför en spegel. Lyft armarna framåt-uppåt. Håll tummarna uppåt. Tänk på hållning och axelhöjd.
2 x 5 gånger.



Övn 6
Stå framför en spegel.
*Lyft armarna utåt-uppåt med böjda armbågar.
2 x 5 gånger.
När Du klarar detta öka till:
*Lyft armarna utåt-uppåt med raka armbågar.
2 x 5 gånger.



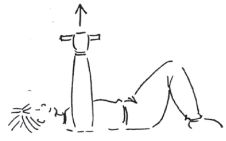
Övn 7
Ligg på mage. Vila huvudet och händerna.
För axlarna bakåt och dra ihop skulder-bladen.
2 x 10 gånger.

STRETCHING

Övn 8
Trapeziusmuskeln:
Lägg vänster öra mot vänster axel. Pressa ner höger axel. Håll 30 sekunder. Byt sida.
Upprepa tre gånger.

Övn 9
Skuldrans framsida:
Stå och knäpp händerna bakom ryggen.
Dra armarna bakåt, lyft armarna uppåt-bakåt.
Håll 30 sekunder. Upprepa tre gånger.

STYRKETRÄNING AXLAR



UPPVÄRMNING:

1 Tryck rak arm upp mot taket. Håll armbågen rak hela tiden.

Belastning:...............

.........x........

2 Stöd hand och knä på pall. "Ro" med andra armen. Dra skuldran bakåt.

Belastning:................

........x........

3 Fäst gummisnodd i dörrhandtag. Stå med god hållning och stabilisera skulderbladen. Kudde mellan bål och överarm. Inåtrotera i axelleden genom att dra handen in mot magen.

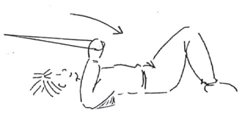
........x........

4 Vänd andra sidan mot dörren. Utåtrotera i axelleden genom att dra handen utåt. Håll armbågen intill kroppen.

........x........

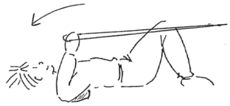
5 Stå på gummisnodden. Ha en god hållning. Stabilisera skulderbladen. För armen utåt-uppåt. Håll tummen nedåt.

........x........



6 Fäst gummisnodden nära golvet. Håll axel och armbåge i rät vinkel. Lägg en kudde under armen. Inåtrotera i axelleden genom att dra handen ner mot golvet.

........x........



7 Byt dragriktning. Utåtrotera i axelleden genom att dra handen mot golvet.

........x........

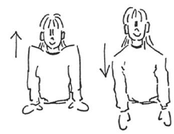
B. Home-training programmes in the Traditional Group, after ASD; 1B and 2B

TRÄNINGSPROGRAM 1 ACROMIOPLASTIK

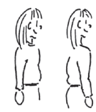
(transartroskopisk, utan sensutur)

Träna tre gånger per dag.

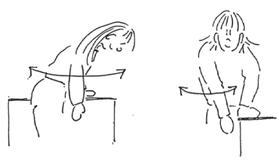
Stå gärna framför en spegel.



Övn 1.
Dra axlarna upp mot öronen.
Släpp ner dem lika långt. 20 gånger.



Övn 2.
Dra skulderbladen bak och ihop - fram och isär. Håll skuldrorna sänkta.
20 gånger.



Övn 3.
Pendelövningar:

*Framåt - bakåt 10 gånger.

*Utåt - inåt 10 gånger.

Övn 4.
Stå eller ligg på rygg.
Knäpp händerna.
Lyft armarna framåt-uppåt. Håll armbågarna raka.

Ta ut maximalt rörelseomgång. 4 gånger.

Övn 5.
Stå med ryggen mot en vägg. För armen utåt-uppåt med hjälp av en käpp. Tummen skall peka uppåt. 4 gånger.

Övn 6.
Stå mot en vägg eller ligg på rygg. Knäpp händerna i nacken. För armbågarna bakåt.
4 gånger.

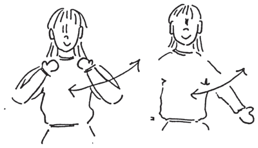
Övn 7.
Stående. För handen bakåt och upp på ryggen. Ev hjälp till med friska handen.
4 gånger.

TRÄNINGSPROGRAM 2 ACROMIOPLASTIK
(transartroskopisk utan sensutur)

Träna tre gånger per dag.

Övn 1.
Cirkulationsövning.
Stå med bra hållning. Armbågen böjd till 90°.
Håll en kudde mellan bålen och armbågen.
För underarmen inåt-utåt inom smärtfritt rörelseomfång. 2 x 30.

Övn 2.
Stå framför en spegel. Lyft armarna framåt-uppåt. Håll tummarna uppåt. Tänk på hållning och axelhöjd. 2 x 5.

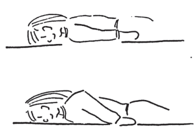


Övn 3.
Stå framför en spegel.

* Lyft armarna utåt-uppåt med böjda armbågar. 2 x 5.

När Du klarar detta öka till:

* Lyft armarna utåt-uppåt med raka armbågar. 2 x 5.



Övn 4.
Ligg på mage. Vila huvudet och händerna.
För axlarna bakåt och dra ihop skulderbladen.
2 x 10.

STRETCHING.

Övn 5.
Trapeziusmuskeln:
Lägg vänster öra mot vänster axel.
Pressa ner höger axel. Håll 30 sek.
Byt sida. Upprepa tre gånger.

Övn 6.
Skuldrans framsida:
Stå och knäpp händerna bakom ryggen.
Dra axlarna bakåt, lyft armarna uppåt-bakåt.
Håll 30 sek. Upprepa tre gånger