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# EXERCISES FOR SHOULDER GIRDLE REHABILITATION:
# A LITERATURE REVIEW

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Satakunnan ammattikorkeakoulu

# EXERCISES FOR SHOULDER GIRDLE REHABILITATION: A LITERATURE REVIEW

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The purpose of this thesis was to search recent literature about shoulder rehabilitation exercises and identify the exercises used in them. Another purpose was to gather information about activity level of shoulder musculature during these exercises. The thesis is aimed to serve as a tool to help physiotherapists to choose rehabilitation exercises accurately.

A literature search was conducted from Ebsco, PubMed and Science Direct databases. The information was assembled from articles published between years 2004-2008. As a result a review involving 14 studies was written.

The theoretical part of the thesis contains a brief introduction to the anatomy of the shoulder girdle musculature. The emphasis of the theory is on the shoulder girdle exercises.

Exercise therapy plays an important role in treatment of shoulder girdle dysfunctions. Therefore, it is essential to gather recent information together so that it is easily available for health care professional to apply into the clinical work.

HARTIARENKAAN KUNTOUTUKSESSA KÄYTETTÄVÄT HARJOITTEET: KIRJALLISUUSKATSAUS

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Tämän tutkimuksen tarkoituksena oli etsiä kirjallisuutta koskien hartiarenkaan kuntoutuksessa käytettäviä harjoitteita ja määrittää niissä esiintyneet harjoitteet. Toinen tarkoitus oli kerätä informaatiota hartiarenkaan lihaksiston aktiivisuudesta harjoitteiden aikana. Opinnäytetyö on tarkoitettu auttamaan fysioterapeutteja valitsemaan kuntoutuksessa käytettävät harjoitteet spesifisti.

Kirjallisuutta etsittiin seuraavista tietokannoista: Ebsco, PubMed ja Science Direct. Tieto kerättiin artikkeleista, jotka on julkaistu vuosina 2004–2008. Tuloksena kirjoitettiin kirjallisuuskatsaus 14 artikkelista.

Opinnäytetyön teoreettinen osuus sisältää lyhyen kertauksen hartiarenkaan lihaksiston anatomiasta. Pääpaino on kuitenkin hartiarenkaan kuntoutuksessa käytettävissä harjoitteissa.

Terapeuttisella harjoittelulla on merkittävä rooli hartiarenkaan toimintahäiriöiden kuntoutuksessa. Siksi on tärkeää kerätä kokoon uusi tutkimustieto, jotta se olisi helposti terveydenhuollon ammattilaisten saatavilla.

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# 1 INTRODUCTION

We find that exercise therapy has a significant role in treatment of shoulder problems. To support our opinion, a study of Haahr et al discovered that exercise therapy including strengthening of scapula -and glenohumeral stabilizers is as effective as surgery in treatment of subacromial impingement. (Haahr et al 2004, 761-763.) In addition, another study found out that exercise program increased function and satisfaction and decreased the pain levels in subjects with shoulder impingement. (McClure, Bialker, Neff, Williams & Karduna 2004, 832-847.)

The importance of exercise therapy in treatment of shoulder problems has fascinated us to gather specific information about exercises from Ebsco, PubMed and Science Direct. Based on the literature search, we wrote a review of publications concerning shoulder girdle rehabilitation exercises. This information is meant to guide physiotherapists to choose rehabilitation exercises more accurately based on recent knowledge.

In future more studies of the shoulder rehabilitation exercises are needed involving symptomatic subject groups. Based on our literature search, we found out that majority of the studies used an asymptomatic study population. We find that these results cannot necessarily be directly used in rehabilitation of clients with shoulder injury or pain. In addition, more randomized controlled trials are needed in this field in order to offer more reliable and valid information.

# 2 PURPOSE

The purpose of this thesis was to collect recent literature about shoulder rehabilitation exercises and identify the exercises used in them. Another aim was to gather information about activity level of shoulder musculature during these exercises.

# 3 METHODS

A literature search of Ebsco, PubMed and Science Direct was conducted. The following search terms were used: shoulder and exercise; shoulder and electromyography and exercise; shoulder and exercise therapy; shoulder joint and exercise; shoulder joint and electromyography and exercise; scapula and exercise; scapula and exercise therapy; scapula and electromyography. In addition, MeSH database was used to help in determination of these search words.

Included articles had to meet the following criteria: The articles must be published during the past five years (2004-2008) and be written in English. Case reports were excluded because of their low evidence-based level. Systematic reviews were either not included because they may include information older than five years. In addition, in Science Direct database we used the search category ‘nursing and health professions’ and ‘all journals’.

# 4 EXERCISES FOR THE SHOULDER GIRDLE

Shoulder joint consists of three bony components: scapula, clavicle and humerus. These structures are controlled by four joints: scapulothoracic joint (ST), sternoclavicular joint (SC), acromioclavicular joint (AC) and glenohumeral joint (GH). (Norkin & Lewangie 1992, 208-237.) Muscular structures considered to be parts of the shoulder girdle are: m. deltoideus, m. supraspinatus, m. infraspinatus, m. teres minor, subscapularis, m. teres major, m. trapezius, m. serratus anterior, m. rhomboideus minor, m. rhomboideus major, m. latissimus dorsi, m. pectoralis major, m. pectoralis minor, m. levator scapulae, m. biceps brachii(long head) and m. triceps brachii(long head). (Thompson, D. 2000.)

## 4.1 The rotator cuff

Rotator cuff consists of four muscles: supraspinatus, infraspinatus, teres minor and subscapularis (Agur & Dalley 2005, 497). Rotator cuff muscles are dynamic stabilizers of the glenohumeral joint. They apply stability to the joint in three ways: Firstly, they offer stability through their passive muscle tension. Secondly, their active contraction draws the head of humerus into the glenoid fossa. Thirdly, joint motion caused by these muscles causes tightening of the ligaments which as a consequence increases joint stability. (Carr 1996, 149.)

### 4.1.1 Supraspinatus

To begin with, supraspinatus originates from the supraspinous fossa of scapula. It runs underneath the acromion process to insert to the superior facet of greater tubercle of humerus. It also inserts to superior half of middle facet where it is overlapped by infraspinatus tendon. (Minagawa et al 1998, p.302-303.) Supraspinatus functions to initiate abduction and to keep the humeral head in the glenoid cavity in co-operation with other rotator cuff muscles. It is also an external rotator of humerus. (Agur & Dalley 2005, 493-497.)

An cadaveric study of Terrier, Reist & Farron studied supraspinatus. They found out that deficiency of supraspinatus causes increased superior translation of humeral head. This may lead into limitation of active abduction and degenerative changes in the shoulder joint. (Terrier, Reist & Farron 2006, 647-650.)

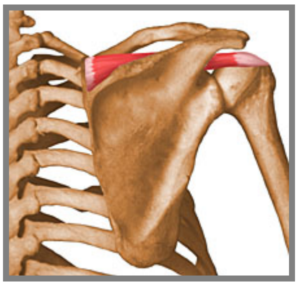

Figure 1. Supraspinatus (Turun ammattikorkeakoulu).

To begin with, ipsilateral kinetic chain exercises may be safe after a supraspinatus repair according to an electromyographic (EMG) study of Smith et al. The aim of these ipsilateral kinetic chain exercises is to activate efficiently stabilizing muscles of scapula with minimal rotator cuff activity. This would enable the training of scapular muscles already in the immobilization phase after a supraspinatus repair. (Smith et al 2007, 1377-1381.)

The current study compared ten different ipsilateral kinetic chain exercises: cross-body rotation at low level without and with stepping (figure 2), cross-body rotation at mid level without and with stepping, cross-body rotation at high level without and with stepping, attempted overhead reaching without and with stepping and attempted ipsilateral floor touch without and with stepping (figure 2). All of these exercises were implemented with the shoulder immobilizer on. (Smith et al 2007, 1378.)

They discovered that supraspinatus activity was low during all the exercises except the attempted overhead reach with stepping. Therefore all the exercises may be safe after a supraspinatus repair except the attempted overhead reach with stepping. Furthermore, the most effective exercise may be the cross-body rotation at low level with and without stepping because it activates serratus anterior most efficiently. (Smith et al 2007, 1379-1381.)

Figure 2. A) Cross-body rotation at low level. B) Attempted ipsilateral floor touch(Smith et al 2007, 1378-1381.)

A previous study of Smith et al measured EMG activity of shoulder girdle muscles during scapulothoracic exercises implemented with a shoulder immobilizer on. The exercises consisted of scapular depression, scapular elevation, scapular protraction, scapular retraction, scapular clock clockwise and scapular clock counterclockwise. Scapular clock counterclockwise means rounding the shoulder first anteriorly and then superiorly, posteriorly, inferiorly and again anteriorly. Scapular clock clockwise is implemented in the opposite order. (Smith et al 2006, 923-924.)

The highest supraspinatus activity was noticed during the two scapular clock exercises. Also scapular elevation and retraction exercises caused increased supraspinatus activity. Thus, these exercises should be avoided, while other exercises may be safe after a supraspinatus injury - already during the immobilization phase. (Smith et al 2006, 924-925.)

To continue with, an electromyographic research of Wise, Uhl, Mattacola, Nitz and Kibler studied shoulder muscle activity during different active range of motion (ROM) exercises. They compared supported and unsupported exercises in 20 asymptomatic subjects. Supported exercises included vertical wall slide (figure 3) and diagonal wall slide (figure 3). In both of them the palm of the patient is in contact with the wall. Unsupported exercises included diagonal (figure 3) and vertical shoulder motions without any support. (Wise, Uhl, Mattacola, Nitz & Kibler 2004, 614-616.)

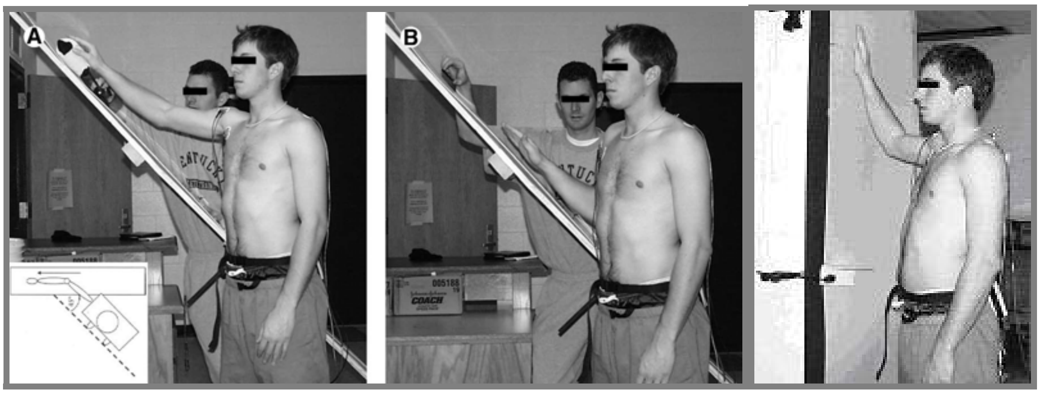


Figure 3.A) Diagonal wall slide B) Unsupported vertical shoulder motion C)Vertical wall slide. (Wise et al 2004, 616).

The study revealed that diagonal shoulder motion was more strenuous for the supraspinatus than vertical motion. In addition, unsupported exercises caused increased supraspinatus activity compared to supported exercises. Therefore the writers suggest starting a rehabilitation program with supported exercises and then progressing to more demanding unsupported exercises. (Wise, Uhl, Mattacola, Nitz & Kibler 2004, 616-617.)

Next, Reinold et al studied electromyographic activity of supraspinatus and deltoid muscles during three shoulder rehabilitation exercises in 22 asymptomatic subjects. According to their study supraspinatus is effectively activated during all three exercises: full can exercise in standing (elevation in the scapular plane with external rotation of shoulder), empty can exercise in standing (elevation in the scapular plane with internal rotation of shoulder) and prone full can exercise (prone horizontal abduction at 100˚ with external rotation of shoulder). See figure 4. (Reinold et al 2007, 464-467.)

Figure 4. A) Full can exercise B) Empty can exercise (Reinold et al 2007, 466).

Although all three exercises are efficient for the supraspinatus, the full can exercise in standing may be most effective to isolate supraspinatus activity. This is due to the lower activity level of deltoid muscle during full can exercise compared to other exercises. (Reinold et al 2007, 465-467.)

To continue with, another article of Reinold et al studied electromyographic activity of rotator cuff muscles during seven external rotation exercises in 10 asymptomatic volunteers with no history of shoulder pain or injury. The exercises consisted of prone horizontal abduction at 100˚ with full external rotation, prone external rotation at 90˚ of abduction, standing external rotation at 90˚ of abduction, standing external rotation in scapular plane, standing external rotation at 0˚ abduction, standing external rotation at 0˚ abduction with a towel roll between trunk and elbow and side lying external rotation at 0˚ abduction. All exercises were implemented with dumbbells. They found out that supraspinatus is most active during prone horizontal abduction at 100° of abduction and full external rotation (figure 5). However, it must be considered that also deltoid muscle had the highest activity level during this particular exercise. (Reinold et al 2004, 385-390.)

Figure 5. Prone horizontal abduction at 100˚ with full external rotation (Reinold et al 2004, 387).

### 4.1.2 Infraspinatus

Infraspinatus originates from infraspinous fossa of scapula (Agur & Dalley 2005, 497). It inserts to middle facet of greater tubercle where it covers the supraspinatus tendon (Minagawa et al 1998, p.302-303). Infraspinatus rotates shoulder externally and stabilizes the humeral head into glenoid fossa with other rotator cuff muscles (Agur & Dalley 2005, 497).

Figure 6. Infraspinatus (Turun ammattikorkeakoulu).

To begin with, infraspinatus muscle is effectively activated during external rotation exercise implemented with a dumbbell and in side lying (figure 7). Also teres minor activity is high during the same exercise. This was discovered by a study of Reinold et al which compared seven different shoulder external rotation exercises which included prone horizontal abduction at 100˚ with full external rotation, prone external rotation at 90˚ of abduction, standing external rotation at 90˚ of abduction, standing external rotation in scapular plane, standing external rotation at 0˚ abduction, standing external rotation at 0˚ abduction with a towel roll between trunk and elbow and side lying external rotation at 0˚ abduction. (Reinold et al 2004, 387-390.)

Figure 7. External rotation exercise in side lying

Next, infraspinatus activity was low during all ten ipsilateral kinetic chain exercises which were studied by Smith et al. The aim of these ipsilateral kinetic chain exercises is to activate efficiently stabilizing muscles of scapula with minimal rotator cuff activity. The exercises that were studied consisted of cross-body rotation at low level (without and with stepping), cross-body rotation at mid level (without and with stepping), cross-body rotation at high level (without and with stepping), attempted overhead reaching (without and with stepping) and attempted ipsilateral floor touch (without and with stepping). According to results all these exercises may be safe after an infraspinatus repair - already during the immobilization phase. (Smith et al 2007, 1377-1381.)

### 4.1.3 Subscapularis

Then, subcapularis is an internal rotator and adductor of the shoulder. It functions with other rotator cuff muscles to compress the humeral head into glenoid fossa of scapula. Subscapularis originates from subscapular fossa of scapula and inserts to lesser tubercle of humerus. (Agur & Dalley 2005, 497.)

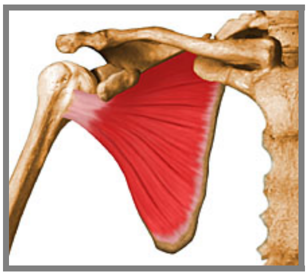

Figure 8. Subscapularis (Turun ammattikorkeakoulu).

Scapulothoracic exercises may not be safe after subscapularis injury or repair. This was discovered by Smith et al who studied muscle activity during scapulothoracic exercises implemented with the shoulder immobilizer. These exercises consisted of scapular clock counterclockwise, scapular clock clockwise, scapular depression, scapular elevation, scapular protraction and scapular retraction. All exercises caused high emg-activity of subscapularis and therefore should not be implemented in the early phase after subscapularis repair. (Smith et al 2006, 923-926.)

Another research studied muscle activity during ipsilateral kinetick chain exercises implemented with the shoulder immobilizer. Exercises consisted of cross-body rotation at low level (without and with stepping), cross-body rotation at mid level (without and with stepping), cross-body rotation at high level (without and with stepping), attempted overhead reaching (without and with stepping) and attempted ipsilateral floor touch (without and with stepping). Emg-activity of subscapularis was high during all these exercises. Therefore it is recommended to avoid these exercises in the early phase after subscapularis repair. (Smith et al 2007, 1378-1381.)

### 4.1.4 Teres minor

Another external rotator of the shoulder is teres minor which co-operates with other rotator cuff muscles to hold the head of humerus in the glenoid cavity of scapula. The proximal attachment of teres minor is superior part of lateral border of scapula. It inserts to inferior facet of tuberculum major of humerus. (Agur & Dalley 2005, 497.)

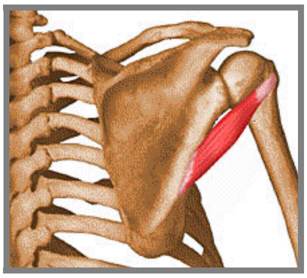

Figure 9. Teres Minor (Turun ammattikorkeakoulu).

## 4.2 Trapezius and serratus anterior

Upper part of trapezius muscle origins from the external occipital protuberance, medial third of superior nuchal line, ligamentum nuchae and spinous process of the seventh vertebrae. The muscle attaches to the lateral third of the clavicle and to the acromion process. The main action of upper trapezius is to rotate scapula laterally. In addition, when acting with other sections of trapezius, it retracts the scapula. Middle trapezius origins from the spinous processes of the first until fifth thoracic vertebras. The muscle inserts to the superior border of the spine of scapula. Lower part of the trapezius originates from the spinous processes of the sixth to 12$^{th}$ thoracic vertebrae and inserts to the medial third of the spine of scapula. (Agur & Dalley 2005, 496.)

The middle part of the trapezius muscle is active in the elevation of the arm, especially in abduction. Moreover, middle trapezius functions as a stabilizing synergist with the muscles that rotate the scapula together with the rhomboid muscles. They eccentrically control the position of scapula when lower trapezius and serratus rotate the scapula. Dysfunction of the middle part of the trapezius or the rhomboideus muscles may cause impairments in the normal scapulohumeral rhythm. (Norkin & Lewangie 1992, 236.)

The serratus anterior muscle origins from the surface of upper eight (sometimes nine) ribs at the side of the chest and inserts to the whole medial border of the scapula. Serratus anterior is responsible for the protraction of the scapula. In addition, the muscle has a great role in stabilizing the scapula. (Agur & Dalley 2005, 479.)

Trapezius and serratus anterior are the main movers of the scapulothoracic upward rotation. Furthermore, these muscles play an important role acting as stabilizing synergists for the deltoid muscle in the glenohumeral joint. trapezius and serratus anterior produce a desired scapular upward rotation and therefore prevent the undesirable movement of deltoid during elevation of the glenohumeral joint. In addition, these two muscles support the shoulder girdle against the downward pull of the gravity with the help of levator scapulae muscle. (Norkin & Lewangie 1992, 234-235).

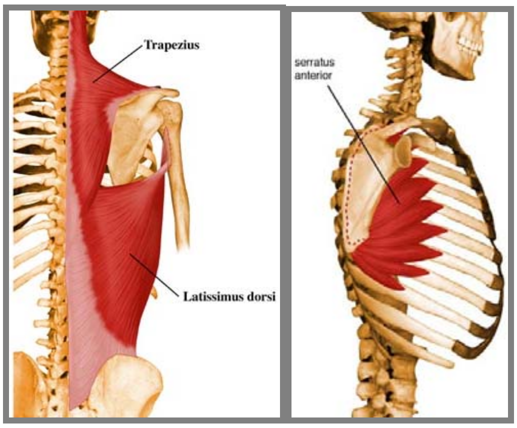


Figure 10. Trapezius and Serratus Anterior (Turun ammattikorkeakoulu).

An electromyographic study of Kibler, Sciascia, Uhl, Tambay and Cunningham studied muscle activation during four early phase shoulder rehabilitation exercises among 18 symptomatic and 21 asymptomatic subjects. The exercises included inferior glide (figure11), low row (figure 12), lawnmower (figure 12) and robbery (figure 11) during which EMG activity of serratus anterior, upper trapezius, lower trapezius, anterior deltoid and posterior deltoid was measured. (Kibler, Sciascia, Uhl, Tambay & Cunningham 2008, 1790-1791.)

Figure 11. A) Robbery starting position B) Robbery end position C) Inferior glide

Lawnmover and robbery exercises succeeded in activating lower and upper trapezius moderately whereas serratus anterior was moderately activated during all four exercises. There was no difference in muscle activation between the symptomatic and asymptomatic groups – except during the robbery exercise in which they noticed a difference in the muscle activation timing. Thus, the inferior glide, lawnmover and low row may be effective for both, asymptomatic and symptomatic clients. (Kibler et al 2008, 1794-1797.)

Figure 12. A) lawn mover starting position  B) lawn mover end position C) low row

Mottram, Woledge & Morrisey proved that all parts of the trapezius muscle (upper, medial and lower) were active in maintaining a scapular orientation position. The purpose of the study was to identify the motions occurring during a commonly used scapular orientation exercise. Another aim was to describe the ability of subjects to learn this position after a brief period of instruction. A group of 13 subjects with no history of shoulder pain were analyzed with a motion analysis system and surface electromyography. (Mottram, Woledge & Morrissey 2008, 1-6.)

The subjects were sitting on a chair with the feet supported on the ground and spine in a neutral position. To evaluate the activity of trapezius (all parts) and latissimus dorsi, EMG activity was measured as the subjects raised their arm through 150º in the scapular plane. The arm was raised over a three second period and lowered over a three second period. As a result all parts of the trapezius muscle were active in maintaining the scapular orientation during the exercise while the latissimus dorsi activity was low. (Mottram, Woledge & Morrissey 2008, 4-5.)

Andersen et al studied muscle activation during five selected strength exercises in women with chronic neck muscle pain. Exercises included upright rows, one-arm rows, shrugs (figure 13), reverse flys and lateral raises (figure 13). The electromyographic activity was recorded from the upper trapezius muscle and the anterior, medial, and posterior parts of the deltoid muscle with a biopolar sufrace EMG. The level of trapezius muscle activation was higher during shrugs and lateral raises compared with reverse flys and one-arm rows. In addition, the level of trapezius muscle activation during upright rows was higher compared with one-arm rows. (Andersen et al 2008, 703-706.)

Figure 13. A) Shrug B) Lateral raise

Subjects included twelve female workers with a clinical diagnosis of trapezius myalgia. Therefore, the results may be different in subjects with shoulder problems. However, we believe that this research supports the clinical importance of these specific strength exercises in the rehabilitation process of the upper part of trapezius muscle. (Andersen et al 2008, 703-706.)

An electromyographic study compared muscle activity during three exercises on a stable base of support and on a medicine ball in 12 asymptomatic male participants with no history of shoulder pain or injury. The exercises included wall-press, push-up and bench press (figure 14). The results revealed that trapezius activity was considerably higher during the wall-press exercise when implemented on a medicine ball compared to a stable base of support. Also the push-up implemented on a medicine ball showed increased trapezius activity compared to stable base version. Furthermore, serratus anterior activity was increased during wall-press and bench press when exercised with a medicine ball compared to stable base of support (Oliveira, Carvalho & Brum 2006, 472-477.)

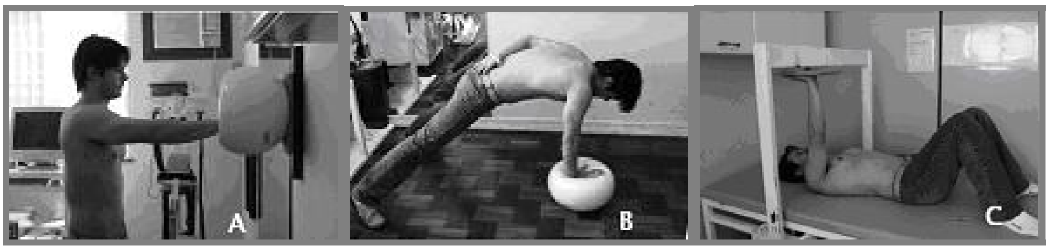


Figure 14. A)Wall press with medicine ball B)Push up with medicine ball C)Pench press with medicine ball

Ludewig, Hoff, Osowski, Meschke and Rundquist compared the push-up exercises for their ability to maximally activate the serratus anterior (SA) while minimally activating the upper trapezius (UA). Four exercises, standard push-up plus (figure 15), knee push-up plus (figure 15), elbow push-up plus (figure 15) and wall push-up plus (figure 16), were examined with EMG attached to the trapezius and serratus anterior. A total of thirty subjects were examined. The first group (n = 19) was a control group with no history of shoulder pain, trauma, dislocation or surgical procedure. The second group (n = 11) consisted of subjects with shoulder pain or dysfunction of the shoulder). (Ludewig et al 2004, 484-486.)

Figure 15. A) Standard push-up B) Knee push-up C) Elbow push-up

Both groups responded similarly to the exercises with no statistical difference in the EMG activity. Serratus anterior activity was highest in the standard push-up plus exercise (highest in the plus phase). In addition, the serratus anterior activity level was above 80% in all of the exercises. The ratio between the upper trapezius and serratus anterior was high in the non-plus phases of all exercises and low in the plus phases except in the wall push-up plus exercise where trapezius was active in the plus phase as well. However, trapezius muscle reached the maximum EMG activity level of 25% in the exercises. If low ratio between the serratus anterior and trapezius is desired, the push-up plus exercises are beneficial. Especially, trapezius activity was the lowest in the standard push-up plus exercise in the plus phase. (Ludewig et al 2004, 489-491.)

Figure 16. Wall push-up

To continue with, Cools et al measured emg activity during twelve scapular muscle exercises in 45 asymptomatic subjects. The purpose was to find out which exercises are most effective in activating lower trapezius, middle trapezius and serratus anterior with minimal upper trapezius activation. Studied exercises consisted of prone shoulder abduction with dumbbell, forward flexion with dumbbell, forward flexion in side-lying with dumbbell (figure 17), high row with pulley, horizontal abduction with dumbbells, horizontal abduction with external rotation with dumbbells, low row (flexed elbows) with pulley, low row (extended elbows) with pulley, prone extension with dumbbells (figure 17), rowing in sitting with pulley, scaption with external rotation with dumbbells, side-lying external rotation with dumbbell. (Cools et al 2007, 1744-1747.)

Figure 17. A) Forward flexion in side lying B) Prone extension

As a result the writers picked up three exercises that met the criteria best. These exercises are side lying external rotation, forward flexion in side lying and prone horizontal abduction with external rotation. These exercises had a low upper trapezius/lower trapezius ratio. (Cools et al 2007, 1745-1749.)

## 4.3 Pectoralis major

Pectoralis major origins from the clavicle (anterior surface of medial half of clavicle) and from the sternocostal part (anterior surface of sternum, superior six costal cartilages, and aponeurosis of external oblique muscle). The muscle inserts to the crest of greater tubercle of humerus, also called the lateral lip. Main action of the pectoralis major muscle is to adduct and medially rotate the humerus. In addition, it draws the scapula anteriorly and inferiorly. Acting alone the clavicular part flexes the humerus and sternocostal part extends it from the flexed position. (Agur & Dalley 2005, 479.)

Myers, Ju, Hwang, McMahon, Rodosky, and Lephart studied the reflexive muscle activation alterations in shoulders with anterior glenohumeral instability. The study revealed that measured with surface electromyography device, there is a pectoralis major mean activation decrease in patients with anterior glenohumeral instability compared to the control group. Pectoralis major provides partly anterior stability to the glenohumeral joint and therefore should be considered to take part of the rehabilitation process in patients with anterior glenohumeral instability. (Myers et al 2004, 1013-1018.)

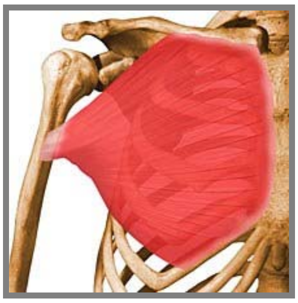

Figure 18. Pectoralis Major (University of Washington Department of Radiology).

Dark, Ginn and Halaki studied the shoulder movement patterns during commonly used rotator cuff exercises with an electromyography device. The aim of this study was to compare the movement pattern of the rotator cuff muscles and other shoulder muscles which rotate the humerus during rotation exercises implemented with the arm by the side. The study discovered that, in people who are healthy, the motor strategy used to deal with increasing rotation resistance with the arm by the side, is to gradually increase activity in all shoulder muscles which participate in rotation of humerus. (Dark et al 2007, 1039-1040.)

Pectoralis major is one of these muscles that participates to the internal rotation of the humerus. The results indicated that pectoralis major activity level increased significantly in both concentric and eccentric contractions along with the subscapularis and latissimus dorsi. Moreover, the pectoralis major muscle activity was significantly greater than latissimus dorsi muscle. In addition, there was no significant difference between the pectoralis major and subscapularis. (Dark et al 2007, 1043). Therefore, we believe that in the fields of strengthening the shoulder internal rotation, pectoralis major muscle plays an important role along with the other muscles that internally rotate the humerus.

## 4.4 Pectoralis minor

Pectoralis minor origins from the ribs three to five (near the costal cartilage) and attaches to the medial border and the superior surface of the scapula. The main function of this muscle is to stabilize the scapula by drawing it inferiorly and anteriorly against the thoracic wall. (Agur & Dalley, 479.) The pectoralis minor muscle assists the other muscles such as latissimus dorsi and pectoralis major in the depression of the shoulder girdle. Pectoralis minor acts directly on the scapula to depress and rotate it downwards. (Norkin & Lewangie1992, 236).

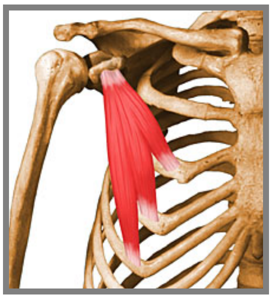

Figure 19. Pectoralis Minor (Turun ammattikorkeakoulu).

Three different pectoralis minor stretches, unilateral corner stretch (figure 20), manual stretch in sitting and manual stretch in supine, were compared in a study of Borstad & Ludewig. The study revealed that the most effective stretch to lengthen pectoralis minor is unilateral corner stretch. (Borstad & Ludewig 2006, 324-330.)

Figure 20. Unilateral corner stretch (Borstad & Ludewig 2006, 326).

## 4.5 Biceps Brachii

Biceps brachii consists of two heads: short head and long head. The short head originates from coracoid process of scapula. (Agur & Dalley 2005, 500.) The long head has usually a dual attachment to supraglenoid tuberosity and labrum (Tuoheti et al 2005, 1244). Both of the heads insert to tuberosity of radius (Agur & Dalley 2005, 500).

Furthermore, the long head of biceps travels along the bicipital groove of humerus. Gleason et al found out that the transverse humeral ligament which stabilizes biceps tendon to bicipital groove is actually formed by fibers of subscapularis tendon. (Gleason et al 2006, 72-77.) This is supported by Clark & Harryman who found out that tendons of subscapularis and supraspinatus form a sheath around biceps tendon. (Clark & Harryman 1992, 713-725.) This may explain why inflammation of rotator cuff often spreads to biceps tendon. (Karistinos & Paulos 2007, 3.)

Biceps brachii supinates forearm and flexes elbow when forearm is in supine position (Agur & Dalley 2005, 500). In addition, some authors believe that biceps brachii has an important role in stabilizing shoulder because of its function as a humeral head depressor. Andrews et al applied electrical stimulation to the biceps brachii during shoulder arthroscopy. They discovered that as a consequence head of humerus was compressed into the glenoid fossa. (Andrews, Carson & McLeod

1985, 337-341.) Furthermore, according to a study of Sakurai et al biceps brachii functions also as a flexor and abductor of shoulder (Sakurai, Ozaki & Tomota 1998, 123-131).

Myers et al studied the reflexive muscle activation alterations in shoulders with anterior glenohumeral instability. One of the main outcomes of the study was that biceps exhibited decreased mean activation measured with surface emg as well as increased reflex latency in patients with anterior glenohumeral instability compared to the control group. Therefore, we agree with the authors that due to the fact that biceps provides stability through its ability to depress the humeral head, increase the shoulder’s resistance to torsional forces and decrease the stress from the inferior glenohumeral ligament, it is an essential muscle to keep in mind when rehabilitating patients with anterior glenohumeral instability. (Myers et al 2004, 1013-1018.)

## 4.6 Other shoulder girdle muscles

Rhomboideus major and minor are medial rotators of the scapula. They also retract scapula. Rhomboideus major origins from spinous processes of Th2-Th5 whereas minor has its proximal attachment in spinous processes of C7 and Th1. They both insert to medial border of scapula. (Agur & Dalley 2005, 496.)
Another scapular medial rotator is levator scapulae. It originates from transverse processes of C1-C4 and inserts to superior part of medial border of scapula. Levator scapulae functions also to elevate scapula. (Agur & Dalley 2005, 496.)

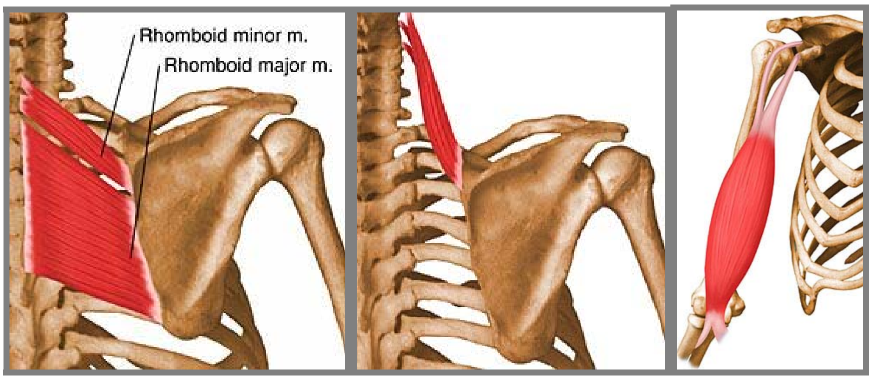


Figure 21. A) Rhomboideus Major and Minor  B) Levator Scapulae (Turun ammattikorkeakoulu). C) Biceps Brachii (University of Washington Department of Radiology).

Extensors of the shoulder include latissimus dorsi and triceps brachii. Latissimus dorsi origins from processes of Th 6-12, thoracolumbar fascia, iliac crest and inferior third and fourth ribs. It inserts to floor of bicipital groove of humerus. In addition to its function as a shoulder extensor, it adducts and internally rotates shoulder. See figure of latissimus dorsi in the page 16. Next, triceps brachii is an extensor of shoulder and elbow. It consists of three heads: long -, medial –and lateral heads. The long head origins from infraglenoid tubercle of scapula whereas the lateral head has its origin superior to radial groove of Humerus. The medial head has its proximal attachment inferior to radial groove of Humerus. They all insert to olecranon process of ulna. (Agur & Dalley 2005, 496.)

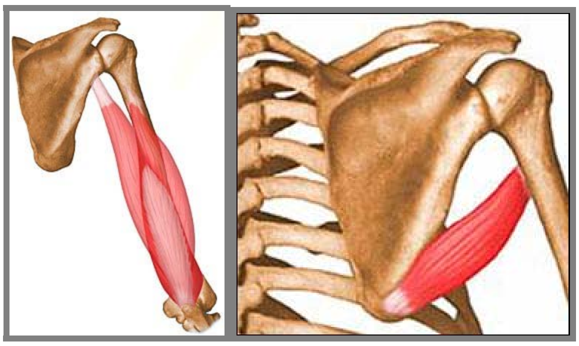

Figure 22. A) Triceps Brachii (University of Washington Department of Radiology). B)Teres Major (Turun ammattikorkeakoulu).

Teres major is one of the shoulder adductors together with pectoralis major, latissimus dorsi and coracobrachialis. Another function of teres major is internal rotation of shoulder. It origins from posterior surface of inferior angle of scapula and inserts to crest of lesser tubercle. (Agur & Dalley 2005, 497.)

Shoulder abductors include supraspinatus and deltoideus. Deltoideus consists of three parts: anterior, middle and posterior. Anterior part flexes and medially rotates humerus. Middle part abducts arm and posterior part extends and laterally rotates arm. The anterior part origins from anterior lateral third of clavicle, the posterior from lateral margin of acromion and the lateral part from spine of scapula. (Agur & Dalley 2005, 496.)

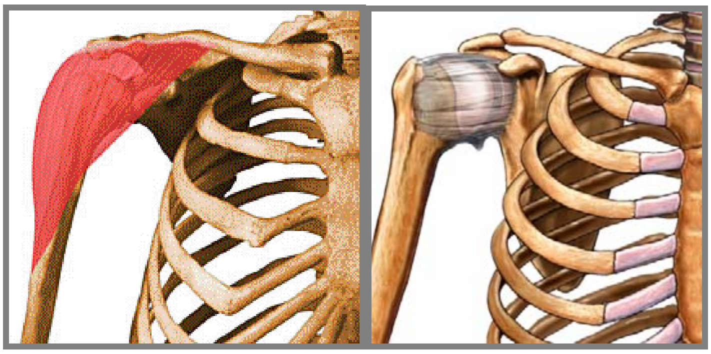

Figure 23. A) Deltoideus (Turun ammattikorkeakoulu). B) Shoulder joint capsule (The Doctors of USC).

## 4.7 Joint capsule

The joint capsule originates from the margin of the glenoid and inserts to anatomical neck of humerus (Agur & Dalley 2005, 510). It is very loose structure allowing vast range of motion of the shoulder. (Della Valle, Rokito, Gallagher Birdzell & Zuckerman 2001, 324).

Izumi, Aoki, Muraki, Hidaka and Miyamoto studied the stretching postions for the posterior capsule of the glenohumeral joint. They found out that the common posterior capsule stretch position (horizontal adduction and 90 degrees of abduction with internal rotation) was not sufficient to stretch the posterior capsule. On the basis of this eight cadaver study, much larger strains on the posterior capsule were obtained at a stretching position of 30 degrees of elevation in the scapular plane with internal rotation (for middle and lower parts of the posterior capsule) and at a stretching position of 30 degrees of extension with internal rotation (upper and lower posterior capsule). See figure 23. The authors suggest that these current stretching procedures might be beneficial in patients with posterior capsule tightness. (Izumi et al 2008, 2014-2022.)

Figure 24. A) Posterior capsule stretch: 30 degrees of elevation in the scapular plane with internal rotation  B) Posterior capsule stretch: 30 degrees of extension with internal rotation

# 5 RESULTS

The total amount of articles that were found as a result of the literature search was 6168. However, majority of the articles were not related to our subject and in the end 14 publications were included to our review. Thus, the results indicate that there are not so many recent articles available concerning the exercises for the shoulder girdle rehabilitation in the databases that we searched.

Table 1. This figure indicates the amount of search results in the databases categorised by search terms.

| | Ebsco | Pubmed | Science Direct |
|---|---|---|---|
| shoulder AND exercise | 1032 | 513 | 1062 |
| shoulder AND electromyography AND exercise | 69 | 62 | 155 |
| shoulder AND exercise | 277 | 293 | 818 |
| shoulder joint AND exercise | 247 | 191 | 651 |
| shoulder joint AND electromyography AND exercise | 16 | 30 | 131 |
| scapula AND exercise | 80 | 48 | 162 |
| scapula AND exercise therapy | 24 | 27 | 141 |
| scapula AND electromyography | 40 | 57 | 42 |
| | | | |
| total results | 1785 | 1221 | 3162 |

To continue with, based on the included publications we were able to identify the exercises that have been studied in the current literature. Majority of the included articles were electromyographic studies. Therefore the publications contained valuable knowledge about the activity of the shoulder girdle musculature during the exercises. Summary of the included articles can be seen in table 2.

Table 2. Summary of the included publications.

| Author, puplication year | Objective | Design/method | Subjects | Exercises | Outcomes |
|---|---|---|---|---|---|
| Dark, A., Ginn, K., Halaki, M. 2007 | To compare the pattern of recruitment of the rotator cuff muscles with that of other shoulder muscles that rotate the shoulder joint during these exercises | Electromyographic analysis | Nondominant shoulders of 15 healthy subjects | Internal rotation | Pectoralis major participates to internal rotation |
| Cools, A., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., Cagnie, B., Witvrouw, E. 2007 | To determine the upper trapezius-lower trapezius ratio, upper trapezius-middle trapezius ratio and upper trapezius-serratus anterior ratio for a number of commonly used shoulder girdle strengthening exercises to determine which exercises are appropriate to optimize scapular muscle balance | Controlled laboratory study, EMG analysis | 45 asymptomatic subjects, mean age 20,7 years (+-1.7 years) | prone abduction, forward flexion, forward flexion in side lying, high row, horizontal abduction, low row with extended elbows, low row with flexed elbows, prone extension, rowing in sitting, scaption with ext. rot., sidelying ext. rot., horizontal abduction with ext. rot. | following exercises had the lowest upper trapezius*lower tapezius ratio:side lying external rotation, forward flexion in sidelying, horizontal abduction with external rotation |
| Andersen, L., Kjaer, M., Anderse, C., Hansen, P., Zebis, M., Hansen, K., Sjogard, G. 2008 | To determine the level of activation ot the neck and shoulder muscles using surface electromyography during selected strengthening exercises in women undergoing rehabilitation for chronic neck muscle pain | Electromyographic analysis | 12 female workers with a clinical diagnosis of trapezius myalgia | 1)Shrug<br>2)Lateral raises<br>3)Reverse flys<br>4)One arm rows<br>5)Upright rows | Trapezius activation was higher during shrugs and lateral raises compared to other exercises |

| Author, puplication year | Objective | Design/method | Subjects | Exercises | Outcomes |
|---|---|---|---|---|---|
| Smith, J., Dahm, D., Kotajärvi, B., Boon, A., Laskowski, E., Jacofsky, D., Kaufman, K. 2007 | To measure the EMG activity in the shoulder girdle musculature during ipsilateral kinetic chain exercises performed with a shoulder immobilizer on. | Decriptive EMG analysis | 5 asymptomatic male volunteers, age: 24-32 years | 1)Cross-body rotation (high, middle and low) 2)attempted overhead reach 3)Attempted ipsilateral floor touch - all exercises are implemented with stepping and without stepping | *supraspinatus activity was low during all exercises except attempted overhead reach with stepping *infraspinatus activity was low during all exercises *scapularisactivity was high during all exercises |
| Kibler, B., Sciascia, A., Uhl, T., Tambay, N., Cunningham, T. 2008 | To quantify EMG activity of serratus anterior, upper trapezius, lower trapezius, anterior deltoid and posterior deltoid during specific exercises | Controlled laboratory study. EMG analysis. | 18 symptomatic and 21 asymptomatic subjects | 1)Inferior glide 2)low row 3)lawnmover 4)robbery | *serratus anterior was moderately activated during all four exercises *Lawnmover and robbery activated moderately lower and upper trapezius |
| Wise, M., Uhl, T., Mattacola, C., Nitz, A., Kibler, B. 2004 | To identify the difference in demands on glenohumeral musculature during unsupported and supported active range-ofmotion (AROM) shoulder exercises | EMG analysis | 20 asymptomatic subjects (mean age 21.7 +- 2.8 years) | 1)vertical wall slide 2)diagonal wall slide 3)diagonal shoulder motion (unsupported) 4)vertical shoulder motion (unsupported) | *diagonal shoulder motion is more strenuous for supraspinatus than vertical motion *unsupported exercises caused increased supraspinatus activity compared to supported exercises |
| Mottram, S., Woledge, R., Morrissey, D. 2008 | To quantify the movements occurring during commonly used scapular orientation exercise | motion analys system and surface EMG | 13 asymptomatic (mean age 32) | elevation through 150 degrees in the scapular plane in sitting position | all parts of the trapezius were active, latissimus dorsi activity was low |
| Reynold, M., Maccrina, L., Wilk, K., Fleisig, G., Shoughen, D., Barrentine, S., Ellerbusch, M., Andrews, J. 2007 | To quantify EMG activity of the supraspinatus, middle deltoid and posterior deltoid muscles during exercises commonly used in rehabilitation | One factor, repeated-measures design. EMG analysis | 22 asymptomatic subjects age:26,7 +- 7 years | 1)full can exercise in standing 2)empty can exercise 3)prone full can exercise | *all three exercises activated supraspinatus effectively *lowest deltoid activity during full can exercise in standing |

| Author, puplication year | Objective | Design/method | Subjects | Exercises | Outcomes |
|---|---|---|---|---|---|
| Oliveira, A., Carvalho, M., Brum, D. 2006 | The purpose of this study was to compare Surface EMG activities during axial load exercises on a stable base of support and on a medicine ball | EMG analysis | 12 asymptomatic male volunteers | 1)wall press (with and without medicine ball) 2)push up (with and without medicine ball) 3)pench press (with and without medicine ball) | *trapezius activity was higher during the wall*press and push*up exercises when implemented on a medicine ball compared to a stable base of support *serratus anterior activity was increased during wallpress and bench press when exercised with a medicine ball compared to stable base of support. |
| Borstad, J., Ludewig, P. 2006 | To compare the mean length change for three pectoralis minor stretches | electromagnetic motion-capture system to detect length difference | 50 asymptomatic subjects (mean age 27,5 years) | 1)unilateral corner stretch 2)manual stretch in sitting 3)manual stretch in supine | *most effective stretch to lengthen pectoralis minor is unilateral corner stretch |
| Izumi, T., Mitsuhiro, A., Muraki, T., Hidaga, E., Miyamoto, S. 2008 | To study the effects of 8 shoulder posterior capsule stretches | Controlled laboratory study | 8 fresh-frozen cadaver shoulders (average age, 82.4 years) | 8 stretching positions for the posterior capsule | Large strains on the posterior capsule were obtained at a stretching position of 30° of elevation in the scapular plane with internal rotation, stretching position of 30° of extension with internal rotation |
| Smith, J., Dahm, D., Kaufman, K., Boon, A., Laskowski, E., Kotajärvi, B., Jacofsky, D. 2006 | To measure the EMG activity in the shoulder girdle musculature during scapulothoracic exercises performed in a shoulder immobilizer | Descriptive EMG analysis | 5 asymptomatic male volunteers age: 24-32 years | scapular depression, scapular elevation, scapular protraction, scapular retraction, scapular clock clockwise, scapular clock counterclockwise | *increased supraspinatus activity during the two scapular clock exercises, scapular elevation and scapular retraction *subscapularis activity was high during all exercises |

| Author, puplication year | Objective | Design/method | Subjects | Exercises | Outcomes |
|---|---|---|---|---|---|
| Ludewig, P., Hoff, M., Osowski, E., Mesckhe, S., Rundquist, P. 2004 | To compare push-up exercises for their ability to maximally activate the serratus anterior while minimally activating the upper trapezius | Controlled laboratory study, EMG analysis | 19 asymptomatic subjects and 11 symptomatic subjects | 1)standard push-up plus<br>2)knee push-up plus<br>3)elbow push-up plus<br>4)wall push-up plus | *serratus anterior activity was the highest during the standard push up plus exercise (highest in the plus phase)<br>*serratus activity was high in all the plus phases of the exercises (80%)<br>*ratio between SA and UT was high in all of the non-plus phases and low in all of the plus phases except in the wall push-up exercise |
| Reynold, M., Wilk, K., Fleisig, G., Zheng, N., Barrentine, S., Chmielewski, T., Cody, R., Jameson, G., Andrews, J. 2004 | To quantify EMG activity of the infraspinatus, teres minor, supraspinatus, posterior deltoid, and middle deltoid during exercises commonly used to strengthen the shoulder external rotators. | Prospective single-group repeated-measures design. EMG analysis | 10 asymptomatic subjects | 1)prone horizontal abduction at 100˚ with full ext. rot. 2)prone ext. rot.,90˚ of abduction<br>3)standing external rotation at 90˚ of abduction<br>4)standing ext. rotation in scapular plane<br>5)standing external rotation at 0 abduction<br>6)standing ext. rot. at 0˚ abduction with a towel roll between trunk and elbow<br>7)side lying ext. rot. at 0˚ abduction | *supraspinatus is most active during prone horizontal abduction at 100° of abduction and full external rotation<br>*however, also deltoid was most active during the same exercise<br>*infraspinatus and teres minor are effectively activated during side lying external rotation |

# 6 CONCLUSION

Exercise therapy has an important role in treatment of shoulder dysfunctions. This review identified the rehabilitation exercises that have been studied in the recent literature. Furthermore, the review contains specific information about the activity of shoulder musculature during the exercises. The information was gathered from 14 included publications of which majority were electromyographic studies.

# 7 DISCUSSION

To begin with, the idea of our bachelor's thesis topic was formed due to our passion towards exercise therapy. The original idea was to create a computer program of evidence based exercises used in shoulder girdle rehabilitation for an aid for physiotherapists. The computer program would have consisted of video images of the exercises. However, during the literature search process we realized that we lacked recourses for this extensive work. Therefore we altered the topic of our thesis into more slender frames and decided to make a review of the articles concerning shoulder rehabilitation exercises.

We find that the most time consuming phase of the thesis was reading the publications. However, this formed the base for the thesis. The writing process was more rapid and easier. In our opinion, this was due to the fact that the data was extensive and offered a good ground for the writing. Our bachelor's thesis process is described more thoroughly in the appendix 1.

In general we are very satisfied with the final work. However, the outcome may have been better if we were able to determine the final topic already before the beginning of the literature search. Another weak point of our thesis is that we were not able to access to all the full text publications due to the fact that some of them were chargeable. We could not afford all the chargeable articles and therefore we were forced to include only part of them. However, we find that the data of our thesis is extensive enough.

To continue with, another failure may have been the determination of the search terms. It may be that the search terms were not specific enough because of the huge amount of search results that were not at all related to our topic. In addition, it must be considered that there may exist different definitions of the shoulder girdle. We, however, decided to use the definitions of Norkin & Lewangie and the Oklaholma university.

We find that the learning outcome was enormous during the process of our bachelor’s thesis. The amount of the publications we read was considerable. Thus, we were able to learn about the shoulder rehabilitation exercises and to deepen our knowledge of anatomy and function of the shoulder girdle. This will certainly be an advantage in our future work as physiotherapists.

Majority of the included articles, that is 11 out of the 14 articles, studied asymptomatic and relatively young subject-groups. In addition, the study populations were small in most of the included articles. The smallest study populations occurred in the studies of Smith et al 2006 and Smith et al 2007, both consisting of only five asymptomatic subjects. We find that these results cannot be directly transferred to rehabilitation of patients with shoulder problems. Furthermore, only two publications compared symptomatic and asymptomatic subject groups. These were the studies of Ludewig et al 2004 and Kibler et al 2008. Therefore this field needs more research with symptomatic subjects. Moreover, randomized controlled trials are needed in order to make the researches more reliable and valid.

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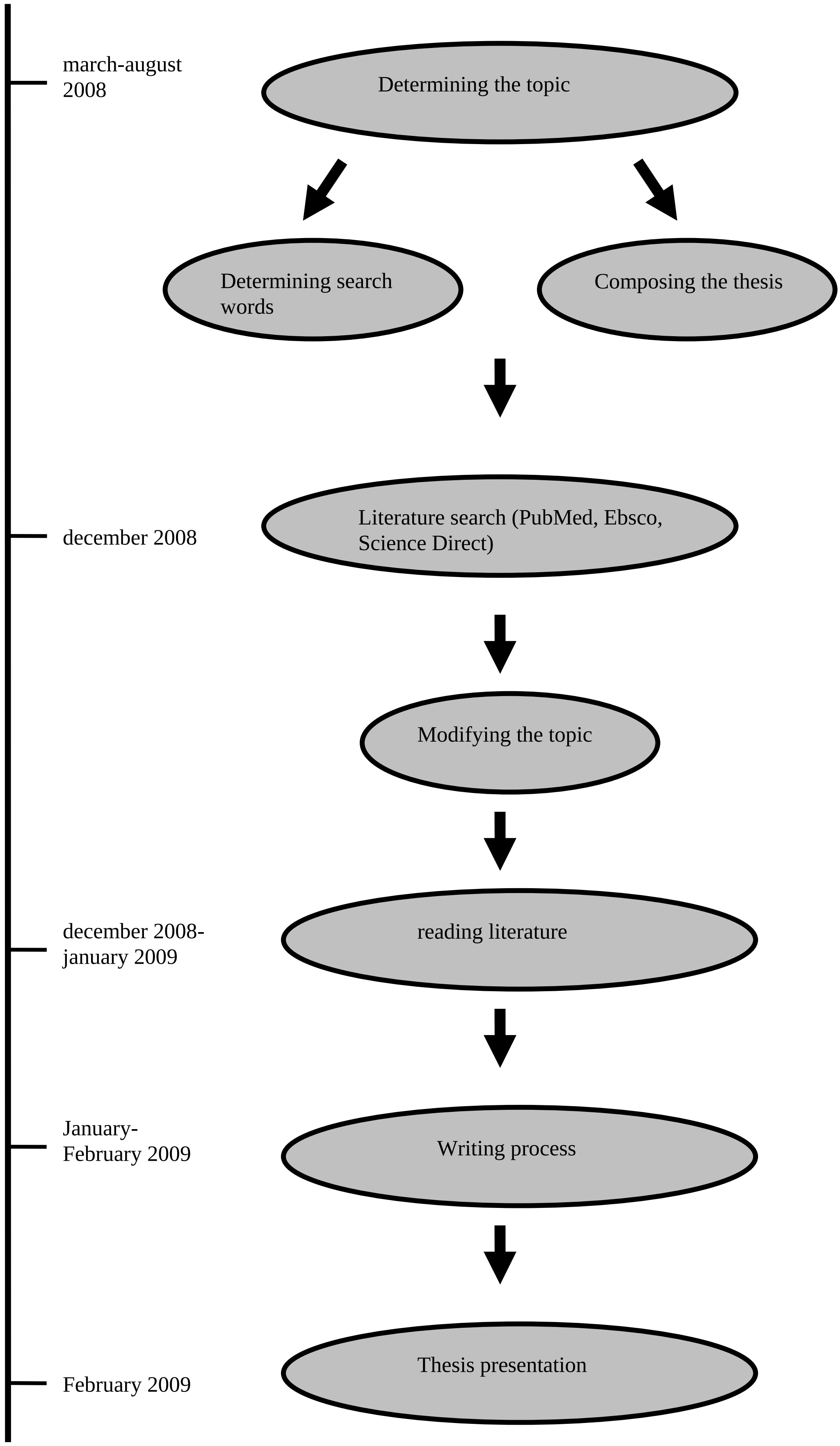
APPENDIX 1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Determining the topic
Determining search words
Composing the thesis
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Literature search (PubMed, Ebsco, Science Direct)
Modifying the topic
december 2008-january 2009
reading literature
January-February 2009
Writing process
February 2009
Thesis presentation