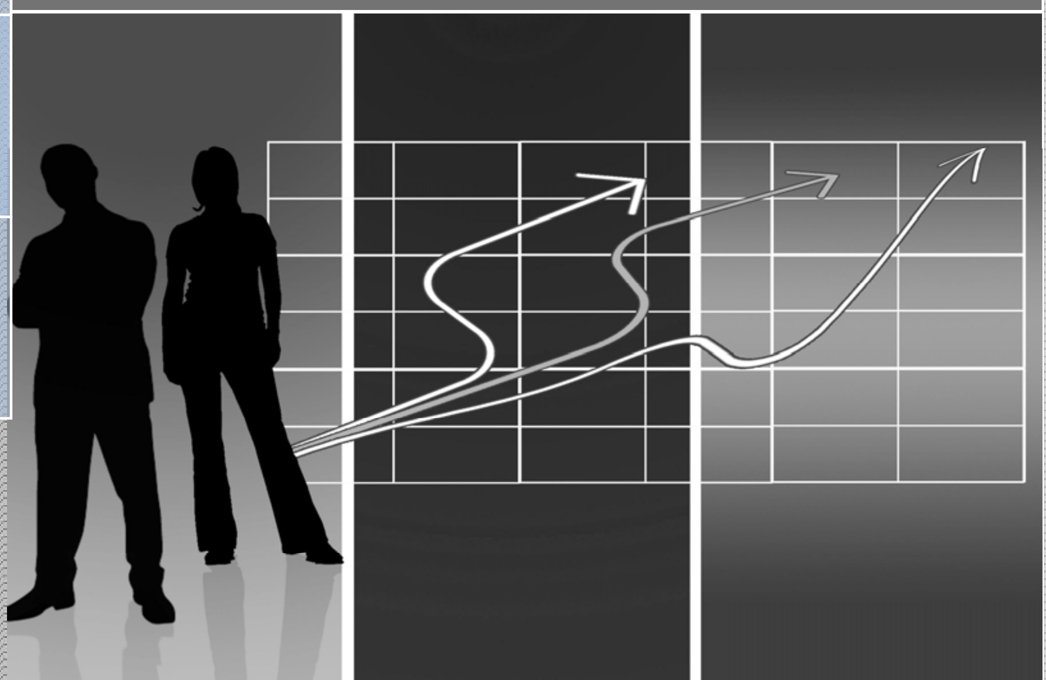
2012

Effect of different training regimes on musculoskeletal pain in neck and shoulder

[PhD Thesis]



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Preface

This thesis was accomplished at the National Research Centre for the Working Environment, Copenhagen, Denmark and the Institute of Sports Science and Clinical Biomechanics, Faculty of Health, University of Southern Denmark, Odense.

Supervision was provided by main supervisor professor, DrMedSci, Gisela Sjøgaard, from the Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark and co-supervisor senior researcher, PhD, Lars L Andersen, the National Research Centre for the Working Environment, Copenhagen, Denmark.

The studies presented in this thesis have been approved by the Local Ethical Committee (H-C-2008-103), and conforms to The Declaration of Helsinki. The intervention studies qualified for registration in the ClinicalTrials.gov database, number NCT01205542 (Study B) and NCT01027390 (Study C). All subjects were informed about the purpose and content of the project and gave written informed consent to participate.

The PhD project was financed by the National Research Centre for the Working Environment, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark and by a grant from the Danish Ministry of Culture Committee for Sports Research (TKIF2007-023). Further, Study C was financially supported by funding from the Danish Working Environment Research Fund case number 20070014666/4.

The PhD project was initiated January 2009, and the thesis submitted January 2012

Contents

Summary (English)

Introduction

Chronic pain in the neck and shoulder area is the most frequent type of musculoskeletal pain among office workers. Different kinds of exercise have been examined for treatment of these problems. The most promising type of exercise seems to be specific training of the painful muscles, e.g. strength training. High intensity strength training for the neck and shoulder area with emphasis on training the painful muscle has led to marked pain reductions, but on the other hand training non-painful muscles within the same muscle synergy ï while avoiding intensive training of the painful muscle - is often recommended in physical therapy. However, it is unknown whether exercise targeting specific muscles surrounding the painful muscle provides similar benefit as exercise targeting the entire neck/shoulder area. Further, it is not known whether many short or fewer longer training sessions provide the greater benefits.

The aim of the PhD project was, 1) in an electromyography (EMG) study to evaluate and select exercises that when performed at high intensity predominantly activate the serratus anterior and lower trapezius muscles over the upper trapezius, 2) in one intervention study (based on the results of the EMG study) to investigate the rehabilitating effect of intensive shoulder function training (SFT) targeting the serratus anterior and lower trapezius muscles more intensively than the upper trapezius on neck/shoulder pain, and 3) in a second intervention study to investigate the influence of frequency and duration of upper dominant training (UDT) ï i.e. training targeting mainly the upper trapezius - for effective management of neck and shoulder pain. The overall goal was to elucidate the effectiveness of different training regimes for reducing neck/ shoulder pain, and based on such knowledge to recommend effective implementation of workplace training programs.

Methods

Two randomised controlled intervention studies were performed in Denmark during the year 2009. The thesis is based on the major findings from these studies.

First we performed EMG validation of exercises specifically targeting the serratus anterior and lower trapezius muscle over the upper trapezius (Study A). Before initiation of the two interventions we published protocol papers with the rationale for these studies, methods, hypotheses and specification of primary as well as secondary outcomes (Paper II and IV).

On the basis of the EMG validation study (Study A) we selected two primary exercises for a 10 week workplace intervention with shoulder function training under full supervision 3 x 20 minutes a week (Study B). Isometric shoulder strength and pain pressure threshold was determined before and after the intervention. During the intervention period neck/shoulder pain and training adherence was reported weekly via an email questionnaire.

In the second intervention study (Study C) three time-wise combinations with equal total volume of UDT were investigated: The 1 weekly session (1WS) group trained for 1 hour once a week, the 3WS group trained 20 minutes 3 times a week, and the 9WS group trained 7 minutes 9 times a week. The training sessions were performed at the workplace for 20 weeks and every other session was supervised by experienced instructors. Exercises were chosen from the general strength training literature to target especially the upper trapezius. Email based questionnaires were used to evaluate effect on neck and shoulder pain, training adherence and training weights.

Main findings and conclusions

In Study A, we found predominant activation of the serratus anterior and lower trapezius muscle over the upper trapezius in the shoulder function training: push-up plus and press-up exercise.

In Study B, SFT led to clinically relevant reductions in pain intensity, increased pressure pain threshold and increased shoulder strength compared to a reference group. In Study C, the UDT intervention, one hour of specific UDT led to reduced neck and shoulder pain and reduced disability in arms, shoulders and hands in 1WS and 3WS. The pain reductions in Studies B & C were of a similar magnitude, on average 2.0 and 1.9 (0-9 scale), respectively.

In conclusion, both SFT and UDT of different time-wise combinations reduce neck/shoulder pain in office workers. This suggests flexibility regarding both exercise mode and time-wise distribution when implementing intensive training at the workplace.

Resume (Dansk)

Introduktion

Kronisk smerte i nakke- og skulderregionen er den hyppigst forekommende form for muskelskeletbesvær blandt kontoransatte. Forskellige typer træning har været undersøgt til behandling af denne type besvær. Den mest lovende form for træning lader til at være specifik træning af de smertende muskler, f.eks. styrketræning. Højintensiv styrketræning for hele nakke- og skulderregionen og fokus på træning af den smertende muskulatur har ført til markante smertereduktioner. På den anden side er anbefales det dog ofte i fysioterapien at træne ikke-smertende muskler inden for samme muskelsynergi mens intensiv træning af den smertende muskel undgås. Det er dog endnu ikke undersøgt hvorvidt træning målrettet til specifikt at træne de muskler som assisterer den smertende muskels funktion medfører samme udbytte som træningsprogrammer for hele nakke/skulder regionen. Endvidere er der endnu utilstrækkelig viden om hvorvidt flere korte eller færre længerevarende træningspas medfører størst udbytte.

Formålet med ph.d.-projektet var, 1) via elektromyografi (EMG) at vurdere og udvælge øvelser, som ved udførelse under høj intensitet overvejende aktiverer serratus anterior og den nedre trapezius muskel over den øverste del af trapezius, 2) i et interventionsstudie (baseret på resultaterne af EMG undersøgelsen), at undersøge effekten på nakke/skuldersmerter af intensiv skulderfunktionstræning (SFT), hvor serratus anterior og nedre trapezius trænes mere intensivt end øvre trapezius, og 3) i et andet interventionsstudie at undersøge betydningen af den tidsmæssige fordelingen af øvre-dominant træning (UDT) ï dvs. øvelser primært målrettet mod øvre trapezius - for effektiv behandling af nakke- og skuldersmerter. Det overordnede mål var at belyse effektiviteten af forskellige træningsformer og baseret på denne viden komme med anbefalinger om effektiv implementering af træning på arbejdspladsen.

Metoder

To randomiserede, kontrollerede interventionsstudier blev gennemført i Danmark i år 2009. Afhandlingen er baseret på hovedfund fra disse studier.

Først blev der udført EMG-validering af øvelser specifikt rettet mod aktivering af serratus anterior og den nedre trapezius muskel over øvre trapezius (Studie A). Før opstart af de to interventioner offentliggjorde vi protokolartikler med rationale for disse undersøgelser, metoder, hypoteser og specifikation af primære såvel som sekundære effektmål (artikel II og IV).

På baggrund af EMG validering (Studie A) udvalgte vi to primærøvelser til en 10 ugers arbejdspladsintervention med intensiv skulderfunktionstræning under fuld supervision 3 gange 20 minutter ugentligt (Studie B). Der blev målt isometrisk skulderstyrke og pressure pain threshold før og efter interventionen. Løbende under interventionen blev nakke/skuldersmerter og træningsdeltagelse rapporteret via et ugentligt e-mailbaseret spørgeskema.

I den anden intervention (Studie C) undersøgte vi effekten af tre tidsmæssige kombinationer af UDT: 1 ugentlig træningssession (1WS) gruppen trænede i 1 time én gang om ugen, 3WS gruppen trænede 3 gange 20 minutter om ugen, og 9WS gruppen trænede 9 gange 7 minutter om ugen. Træningen blev udført på arbejdspladsen i 20 uger og hver anden session blev superviseret af erfarne instruktører (Studie C). Øvelserne blev valgt fra den almindelige styrketræningslitteratur og var målrettet mod den øverste del af trapezius. Der blev benyttet e-mail-baserede spørgeskemaer til at evaluere effekten på nakke- og skuldersmerter, træningsdeltagelse og træningsvægte.

Hovedresultater og konklusioner

I Studie A fandt vi den højeste aktivering af serratus anterior og nedre trapezius over øvre trapezius ved øvelserne push-up plus og press-up.

I Studie B førte SFT - til klinisk relevante reduktioner i smerteintensitet, øget pressure pain threshold og øget skulderstyrke sammenlignet med en referencegruppe.

I Studie C fandt vi at UDT-interventionen med en time ugentlig træning førte til reduceret smerte i nakke og skulder samt reduceret ôDisabilities of the Arm, Shoulder and Handô ved 1WS og 3WS. Smertereduktionerne i Studie B & C var af samme størrelse, i gennemsnit henholdsvis 2.0 og 1.9 (0-9 skala).

Det kan konkluderes at både SFT og UDT af forskellige tidsmæssigt kombinationer reducerer nakke / skulderbesvær hos kontoransatte. Dette tyder på fleksibilitet med hensyn til både træningsmodalitet og den tidsmæssige fordeling, når man implementerer intensiv træning på arbejdspladsen.

List of papers

This thesis is based on five papers from three studies. The three studies will be referred to as Study A, B, and C in the text:

Study A

I. Scapular muscle activation balance at low and high intensity during selected rehabilitation exercises. *Andersen CH, Zebis MK, Saervoll C, Sundstrup E, Jakobsen MD, Sjøgaard G, Andersen LL.* Journal of Strength and Conditioning Research (E-Pub ahead of print)

Study B

II. Protocol for Shoulder function training reducing musculoskeletal pain in shoulder and neck: a randomized controlled trial. *Andersen CH, Andersen LL, Mortensen OS, Zebis MK, Sjøgaard G.* BMC Musculoskelet Disord. 2011 Jan 14;12:14.

III. Shoulder function training reducing musculoskeletal pain in shoulder and neck: a randomized controlled trial. *Andersen CH, Andersen LL, Zebis MK, Sjøgaard G.* In Review

Study C

IV. Protocol for work place adjusted intelligent physical exercise reducing musculoskeletal pain in shoulder and neck (VIMS): a cluster randomized controlled trial. *Andersen LL, Zebis MK, Pedersen MT, Roessler KK, Andersen CH, Pedersen MM, Feveile H, Mortensen OS, Sjøgaard G.* BMC Musculoskelet Disord. 2010 Aug 5;11:173

V. Influence of frequency and duration of strength training for effective management of neck pain. *Andersen CH, Andersen LL, Pedersen MT, Gram B, Mortensen OS, Zebis MK, Sjøgaard G.* Br J Sports Med (E-Pub ahead of print)

List of abbreviations

DASH : Disabilities of the Arm, Shoulder and Hand

DWECS : Danish Work Environment Cohort Study

EMG : Electromyography

ITT : Intention-to-treat

MVC : Maximal Voluntary Contraction

PPT : Pressure Pain Threshold

RCT : Randomized Controlled Trial

REF : Reference group

RM : Repetition Maximum

SFT : Shoulder Function Training (Lower Dominant exercises, e.g. exercises preferentially activating the lower trapezius and serratus anterior over the upper trapezius)

UDT : Upper Dominant Training (Exercises preferentially targeting the upper scapular muscles, e.g. the upper trapezius)

VAS : Visual Analogue Scale

WS : Weekly Sessions

WHO : World Health Organisation

Introduction

The International Association for the Study of Pain defines pain as ñ*an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*ò(Merskey and Bogduk, 1994). In the current understanding of pain, the experience itself is multidimensional and produced by patterns of nerve impulses generated by an extensive network of brain regions (Iannetti and Mouraux, 2010). Pain can be triggered by sensory stimuli, but may also be generated independently of them. Acute pain evoked by brief noxious inputs have been thoroughly investigated by neuroscientists, and the sensory transmission mechanisms are generally well understood (Iannetti and Mouraux, 2010,Melzack, 2005). In contrast, our understanding of chronic pain syndromes, often characterized by high pain intensity frequently associated with heightened pain sensitivity and little or no noticeable injury, is still limited (Moseley, 2003,Melzack, 2005).

Chronic pain syndromes within the musculoskeletal system due to working life conditions are an important socio-economic problem in the industrialized world. Musculoskeletal diseases constitute a third or more of all registered occupational diseases (Punnett and Wegman, 2004,Baldwin, 2004), are a huge burden to society, and are affecting more than half of the adult Danish population within any given two-week period (www.sundhedsprofil2010.dk). This massive impact includes a lowered workforce and income as well as increased costs for medical treatment, sick leave and early retirement. The financial cost in the Nordic countries and Holland has been estimated to be between 0.5 and 2% of the Gross National Product (Johansson et al., 2003,Hansson and Jensen, 2004,Kilbom et al., 1996). Work-related musculoskeletal disorders are particularly frequent in the neck and shoulder muscles, primarily in occupational groups employed with highly repetitive work tasks.

The problem is widely recognized, but the mechanisms behind the development of work-related neck pain are not well understood. Both peripheral as well as central mechanisms have been proposed (Edwards, 1988,Henriksson, 1988,Hägg, 1991,Sjøgaard and Søgaard, 1998,Barr and Barbe, 2004).

Prevalence and work relatedness of neck/shoulder disorders

Work-related musculoskeletal disorder is by the World Health Organisation (WHO) defined as a multi-factorial concept and it includes work both exposure and individual capacity as contributors to the development (Armstrong et al., 1993). Epidemiological studies have shown that self-reported shoulder-neck pain for more than 30 days in the last year, is prevalent in many occupations that involve repetitive job tasks (Jensen et al., 1998,Fredriksson et al., 2000,Jensen, 2003). Furthermore, in one systematic review it was concluded that highly repetitive work and forceful arm or hand movements cause neck and shoulder disorders. In addition it was further concluded that there were even *strong evidence* that work activities involving prolonged static loads on the neck and shoulder muscles increase neck and shoulder disorders (National Research Council and the Institute of medicine, 2001). The estimated 1 year incidence of neck pain from available studies ranges between 10.4% and 21.3% with a higher incidence noted in office and computer workers (Hoy et al., 2010,Andersen et al., 2011c,Fejer et al., 2006). While some studies report that between 33% and 65% of people have recovered from an episode of neck pain after 1 year, most cases experience returning symptoms over a person's lifetime and, thus, relapses are common (Hoy et al., 2010). Most studies indicate a higher incidence of neck pain among women than among men (Andersen et al., 2011c,Fejer et al., 2006,Hogg-Johnson et al., 2009) and an increased risk of developing neck pain until the 35-49-year age group, after which the risk begins to decline (Hoy et al., 2010,Fejer et al., 2006). Epidemiological research supports that both physical and psychosocial factors related to work could play a role in the development of these disorders. However, studies have shown the etiologic role to be stronger for the former than for the latter (Johansson et al., 2003,Larsson et al., 2007).

Pathomechanisms of neck and shoulder pain among office workers

One characteristic feature of the repetitive work tasks in office work is that it implies low force requirements. Inhomogeneous activation of a muscle exerting low forces is a characteristic that may be considered a risk factor for the development of work-related muscle pain (Zajac and Faden, 1985). The functional unit in muscles is a motor unit, consisting of one motor neuron and the muscle fibres it innervates. It is well-known that muscle fibres are recruited in a hierarchical manner according to the Henneman size principle, starting with the smallest motor units with the lowest threshold (Henneman et al., 1965). This has led Hägg to develop *the Cinderella hypothesis* (Hägg, 1991); stating that as a result of prolonged contraction even at low force levels, some motor units will become fatigued or exhausted and thereby be relatively overloaded even though the muscle as a whole is working at a low energy demand (Søgaard, 1995,Sjøgaard and Søgaard, 1998,Rosendal et al., 2004). Cinderella fibres have been identified ï a stereotype recruitment pattern is found during static as well as dynamic contractions (Kadi et al., 1998). The continuous activity of a subgroup of muscle fibres will involve a high local energy turnover and may result in a localized increase in the intramuscular pressure around the fibres, thus reducing blood flow to the muscle fibres that need the most oxygen. This has been shown in females with trapezius myalgia where insufficient muscle blood flow and oxygenation was found in the trapezius muscle during repetitive pegboard and stress tasks (Sjøgaard et al., 2010). In support of the Cinderella hypothesis, biopsy studies on subjects with work-related muscle pain have indicated various structural changes and mitochondrial disturbances indicating disturbed metabolism (Visser and van Dieen, 2006). In subjects with trapezius myalgia, an increased frequency of type-I fibres as well as grossly hypertrophied type-I fibres has been demonstrated (Larsson et al., 1988,Andersen et al., 2008e), indicating a load-induced hypertrophy (Gross et al., 2004,Karjalainen et al., 2000).

Compensatory patterns

Healthy function of the shoulder girdle is dependent of several muscle synergies (e.g. the deltoids, all segments of the trapezius, serratus anterior, and supraspinatus)(Veeger and van der Helm, 2007). Because coordinated activation of these muscle synergies play a vital role for performing controlled shoulder movement during work, dysfunctions in these muscles can alter the movement of the scapulae (dyskinesis) and eventually lead to neck and shoulder pain. When the arm is raised the scapula rotates upwards, tilts posterior and is abducted (Ludewig et al., 1996,McClure et al., 2001). Research have suggested that shoulder abnormalities and abnormal scapular motions (dyskinesis) may be linked to global weakness of the scapulothoracic muscles; others attribute scapular dyskinesis to scapular muscular imbalance rather than absolute strength deficits (Cools et al., 2007). However, the causal chain of action has not been established.

From both the scientific literature and physiotherapeutic experience it is proposed that excess activation of the upper trapezius, combined with decreased control of the lower trapezius and the serratus anterior contributes to neck/shoulder pain (Cools et al., 2007,Sahrmann, 2005). It may apply both ways as Schulte et al found that experimentally induced pain in the biceps muscle increases trapezius EMG activity during sustained isometric contractions of arm muscles (Schulte et al., 2004). A recent study by Lin and co-workers on persons with general shoulder dysfunctions found reduced posterior tilt in the scapula during four sub maximal functional work tasks compared with pain free controls, and attributed this to lower serratus anterior muscle activity. The study also showed increased activation in the upper trapezius during two out of the four work tasks (Lin et al., 2005). A recent study found lower EMG activity in all muscles but the trapezius in response to repeated cognitive stress (Willmann and Bolmont, 2011). Where other muscles showed lower EMG activity as the stressful task was repeated this did not happen in the trapezius. A study by

Samani and coworkers showed increased activity in the upper parts of trapezius due to experimental pain during computer work. Thus, pain during computer work may led to altered muscle activation patterns worsening the pain symptoms and entering a vicious cycle (Samani et al., 2009). Other research has also indicated that dysfunction develops after the onset of pain and pathology (Comerford and Mottram, 2001b). Although pain and dysfunction are related, the pain often diminish while the dysfunction remains (Hides et al., 1996,Hodges and Richardson, 1996,Comerford and Mottram, 2001a). This is a key concept in the thought process that led to Study A and B.

One aspect of the changes that occur when pain persists is that the proprioceptive representation of the painful body part in primary sensory cortex changes (Flor et al., 1997,Flor et al., 2006,Maihofner et al., 2003). This may have implications for motor control because these representations are the maps that the brain uses to plan and execute movement (Buonomano and Merzenich, 1998). If the map of a body part becomes inaccurate, then motor control may be compromised ï it is known that experimental disruption of cortical proprioceptive maps disrupts motor planning (McCormick et al., 2007). The notion of distorted proprioceptive representation has been discussed with regard to its impact on motor control (Byl et al., 2000,Byl et al., 1997) and, more recently, in a theoretical way with regard to pain (Harris, 1999). Although exceptions exist, there is mounting evidence that changes in cortical representation occur in association with chronic pain, and it is feasible that these changes may become part of the problem (Flor et al., 2006). Further, pain has an inhibitory effect on the motor neurons of the painful muscles that is counteracted by a complex reorganization of the motor strategy at the level of the muscle group involved so the required force output can be maintained (Madeleine et al., 2003,Madeleine et al., 2006b,Falla et al., 2007,Sjøgaard et al., 2000,Andersen et al., 2008d,Graven-Nielsen et al., 1997,Hodges et al., 2003,Madeleine et al., 1999). There is some experimental evidence that the transition from acute to chronic pain is accompanied by changes in motor patterns (Cagnie et al., 2011,O'Leary et al., 2011). Restoration of muscle control and balanced co-activation in particular is thus a challenge for the clinician. In order to counteract compensation patterns and specifically target neck/shoulder dysfunctions through training rehabilitation detailed knowledge of exercise-specific activation balance of the scapular muscles is required. For patients with a compensatory pattern in the scapular muscles, selective activation of the weaker muscle parts with minimal activity in the hyperactive muscles is an important component in the reduction of the compensation. Because a lack of activity in the lower trapezius, middle trapezius, and serratus anterior frequently is seen combined with excessive use of the upper trapezius, the balance ratios upper trapezius/lower trapezius, upper trapezius/middle trapezius, and upper trapezius/serratus anterior are of particular importance. A study by Wegner and co-workers found that scapular postural correction exercise may be effective in altering the distribution of activity in the trapezius during office work in people with neck pain to better reflect that displayed by healthy individuals (Wegner et al., 2010). In view of the new insights and research findings on the role of scapular control in pathologic shoulder abnormality, current exercise protocols emphasize the importance of scapular muscle training as an essential component of shoulder rehabilitation. However, randomized controlled trials are needed.

Therapies to reduce neck and shoulder pain

Among clinicians a wide range of therapies are used even though there is little or no backing evidence, in terms of randomized controlled trials, for the individual forms of therapy. Most systematic meta-analyses have shown lack of evidence for the effectiveness of physical therapy and even multidisciplinary rehabilitation in cases of chronic neck pain (Verhagen et al., 2007,Sihawong et al., 2011,Andersen et al., 2011c,Hurwitz et al., 2009). There is a discrepancy between conclusions from recent review studies. One review found there was limited evidence for general exercise (Andersen et al., 2011c). Another review was more specific and concluded that there is strong evidence of supervised resistance exercise and a duration of at least ten weeks for the beneficial effects of exercise to control shoulder and neck pain in sedentary work environments (Coury et al., 2009). Although the Andersen review study is recent, they performed a general evaluation of the effects of exercise, without considering that this therapeutic modality has very diverse intervention protocols that vary in relation to the type of exercise, adherence, duration of the exercise protocol, frequency and duration of sessions. The training protocols also varied in form and body region of application.

Several training strategies have been examined, ranging from cardiovascular training only involving non-painful muscles (Andersen et al., 2008c), all-round physical exercise (Blangsted et al., 2008), kettlebell training (Jay et al., 2011), proprioceptive/ muscle coordination training (Waling et al., 2000,Taimela et al., 2000) and qigong (Skoglund et al., 2011) to intensive strength training for the neck and shoulder muscles (Andersen et al., 2008c,Waling et al., 2000,Andersen et al., 2011e,Ylinen et al., 2003,Zebis et al., 2011,Hagberg et al., 2000). As little as 2 minutes daily of UDT have also provided modest benefits in adult office workers with frequent neck/shoulder pain(Andersen et al., 2011e). Thus, several training strategies can have a positive effect.

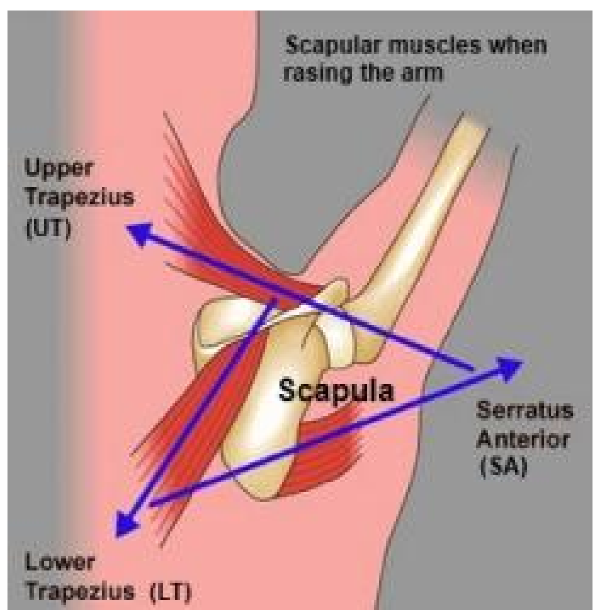

Figure 1: Basic muscle synergy between upper trapezius, lower trapezius and serratus anterior in scapular upward rotation.

Although high-intensive UDT involving

the painful muscles can be effective, it is also shown to acutely increase neck pain (Andersen et al., 2008c) and may therefore be a psychological barrier for individuals with existing neck and shoulder pain. For patients with a scapular compensatory pattern, many physical therapists recommend neuromuscular SFT with selective activation of the weaker muscle parts with minimal activity in the hyperactive upper trapezius muscle (Cools et al., 2007,Donatelli, 2004,Sahrmann, 2005). This latter approach has not previously been tested in a randomized controlled trial. A recent review concluded that targeted exercise training is likely to improve muscle onset timing, and isolated muscle training appears to be the most efficient exercise mode to achieve these effects (Crow et al., 2011). Electromyographic and mechanomyographic biofeedback during computer work can also lead to a significant decrease in the trapezius activity and lower rating of perceived exertion (Madeleine et al., 2006a,Ma et al., 2011), but this kind of equipment can be both expensive and fragile and thus not always practical to implement during regular work. For physical exercise to be feasible in a workplace setting, the exercise should be easy to implement in the daily routines (Finch, 2011,Donaldson and Finch, 2011). Although different strength training protocols appear feasible, the optimal frequency and duration of strength training for effective management of neck pain remain unknown. This is an important question as how ñexercises fit daily routineò has been reported as a key predictor of training adherence with an odds ratio of 7.4 (Medina-Mirapeix et al., 2009). At some companies a few long training sessions each week may be most suitable, whereas at other companies several short bouts of exercise may be more feasible.

This leads up to Study B & C in this thesis where we investigate different rehabilitation strategies for reducing neck and shoulder pain (Figure 2). In one track we try to relieve the upper trapezius by strengthening its synergists in scapular upward rotation (Figure 1) through SFT and thus reducing the exposure on the upper trapezius (Study A and B). In the other track - involving UDT exercises (Andersen et al., 2008b) - we investigate the effect of three different time-wise distributions on pain and strength. (Study C).

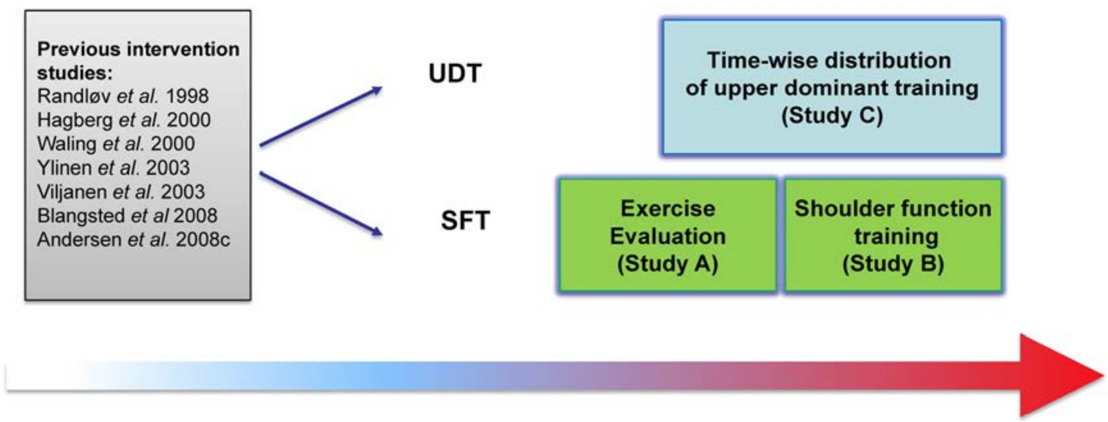

Figure 2: The two tracks in rehabilitation of neck pain investigated in this thesis.

Study population

We have chosen office workers for our study population as these constitute a large part of the Danish work force and they are characterized by a high frequency of musculoskeletal disorders in the neck and shoulder region.

Office work in Denmark is characterized by working averagely 35 hours per week and close to 78% of the employees report being sedentary at least ¾ of that time (Danish Work Environment Cohort Study (DWECS) 2010). Further, approximately 48% are performing repetitive movements of the arms and fingers ñalmost all the timeò (DWECS 2010). These types of movement require stabilization from the shoulder and neck muscles (Blangsted et al., 2004) and 43% -which is significantly above national average of 38% - of all office workers report being fatigued in the neck and shoulders after work (DWECS 2010). This also transfers to 78% having experienced pain in the neck and shoulder area within the last 12 months and an average pain intensity of 2.9 (0-9 scale) the last 3 months. This is significantly higher than the 2.4 reported by the general working population in Denmark (DWECS 2010).

In Denmark 44% of the office workers are employed in companies which have exercise facilities for the employees at the workplace and 26% are offered different kinds of exercise sessions on a weekly basis. However, only 32% from each group respectively have taken advantage of these offers (DWECS 2010).

Aim

General aim

The aim of this PhD project was, in an exercise evaluation study and two intervention studies, to investigate effects of contrasting types of intensive muscle training on pain, disability and strength in office workers with nonspecific neck and shoulder pain.

The specific aims were

- in the exercise evaluation study, to determine the level of muscle activation in different compartments of the trapezius and in the serratus anterior during training exercises for the neck/shoulder muscles (Study A)
- to determine changes in neck/shoulder pain and muscle strength in response to shoulder function training[a] (Study B) and upper dominant training[b] (Study C) in office workers with nonspecific neck pain

[a] Exercises preferentially activating the lower trapezius and serratus anterior over the upper trapezius

[b] Exercises preferentially targeting the upper scapular muscles, e.g. the upper trapezius

Hypotheses

In the baseline exercise evaluation study (Study A) we tested whether some exercises would provide preferential activation of the serratus anterior and/or lower trapezius over the upper trapezius. We expected that several of the training exercises would show relevant activation differences ï i.e. high activity of the serratus anterior and or/ high activity of the lower trapezius along with low activity of the upper trapezius - for them to be used in SFT (Study B). Therefore we statistically tested whether we could reject the following null-hypothesis:

A. *For the investigated exercises there is no significant difference in normalized EMG between 1) serratus anterior minus upper trapezius and 2) lower trapezius minus upper trapezius.*

We expected that shoulder function training (Study B) would reduce pain more than being in a reference group. Since the training would be performed with high intensity we also expected that the training would lead to an increase in strength specifically of the muscles trained, i.e. an increase shoulder protraction strength but not elevation strength. We statistically tested the following null-hypotheses:

B. *There is no difference between a shoulder function training group and a reference group for the change in neck/shoulder pain from baseline to follow-up at week 10*

C. *There is no difference between a shoulder function training group and a reference group for 1) the change in protraction strength and 2) for the change in elevation strength from baseline to follow-up at week 10*

In the second intervention study (Study C) several outcomes would be plausible in relation to pain. On one hand the group with short frequent sessions would be less fatigued during each session and thus be able to train with slightly heavier weights. A strategy used by many elite Eastern European weightlifters (Bompa and Haff, 2009,Kraemer and Fleck, 2007). On the other hand one long training session might be able to induce a large protein turnover in the muscles involved although the participants would fatigue during the session and training intensity would go down. This resembles an approach often used in the sport of bodybuilding(Bompa and Haff, 2009,Kraemer and Fleck, 2007). Strength-wise we expected that the former approach would lead to greater strength gains. We statistically tested the following null-hypothesises:

D. *There is no difference between the three training groups 1WS, 3WS,and 9WS for the change in neck and shoulder pain from baseline to follow-up at week 20 compared with a reference group, REF*

E. *There is no difference between the three different training groups 1WS, 3WS, 9WS for the progression rate in training loads during the intervention*

Methods

Study Overview

An overview of the methods used in the studies is summarized in Table 1 and described in more detail below. Baseline anthropometrical measures, age, pain intensity (scale 0-9, from questionnaire where 0 means no complaints and 9 means pain as bad as it can be) and weekly working hours are given in Table 2 and Table 3.

Study	**A**	**B**	**C**
Workers with neck pain		X	X
Workers without neck pain	X		(X)
Intervention study		X	X
Exercise evaluation study	X		
Questionnaire	X	X	X
Clinical examination	X	X	
Pain intensity	X	X	X
Logbook		X	X
Rating of Percieved Exertion	X		
Elektromyagraphy	X		
Maximum voluntary contraction		X	
Pressure Pain Treshold		X	

Table 1: Overview of the methods used in Studies A, B and C.

Flow of participants (Studies A, B & C)

Exclusion criteria

Exclusion criteria in all studies were a) hypertension (Systolic BP > 160, diastolic BP > 100) or cardiovascular diseases (e.g. chest pain during physical exercise, heart failure, myocardial infarction and stroke), b) symptomatic herniated disc or severe disorders of the cervical spine, c) postoperative conditions in the neck and shoulder region, d) history of severe trauma, and e) pregnancy, f) other serious disease.

Exercise evaluation (Study A)

In the exercise evaluation study (Study A) we tested female office workers without serious musculoskeletal pain. This was assessed by a short screening performed by a physical therapist. We recruited 17 healthy women from the University of Copenhagen. Their mean (Standard deviation, SD) age, height, and weight was 29 ± 7.2 yrs, 168 ± 6.3 cm, 62.7 ± 11.1 kg, respectively.

Shoulder function training (Study B)

An announcement with a short introduction and invitation text, together with a link to an internet-based questionnaire was sent to office workers from the administrative section of a university in the Copenhagen area. When 100 had replied positive regarding participation to the questionnaire we closed for further recruitment based on a priori power calculations and drop out estimates, and estimates of neck/shoulder pain frequency. Out of the 100 responders 8 subsequently declined to participate in the study. Inclusion criteria were pain intensity in the neck or shoulder of at least 3 on a 0-9 scale (where 0 means no complaints and 9 means pain as bad as it can be). Further, the participants went through a clinical neck and shoulder investigation by a physical therapist (Andersen et al., 2011d) to exclude individuals with serious musculoskeletal disease. This lead to exclusion of one participant (generalized myalgia and radiating pain). The remaining 47 participants were randomly allocated to Shoulder Function Training (SFT) (n = 24) or Reference (REF) (n=23). After the baseline testing seven of the individuals did not respond to the emails sent to them, and the four in the SFT group did not start up training. The flow of participants in Study B is shown in Figure 3.

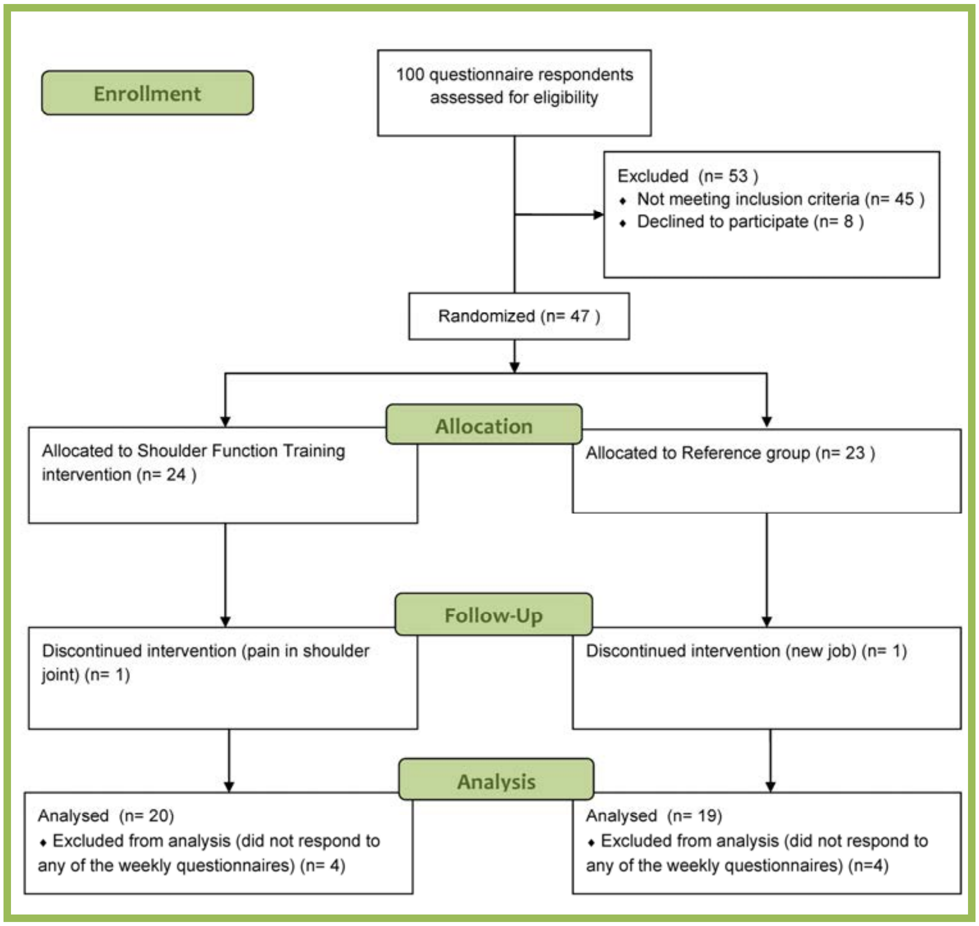

Figure 3: Flow of participants in Study B

	All	REF	SFT	P
N	47	23	24	
Women	37	18	19	
Men	10	5	5	
Age	44 (12)	45 (11)	44 (13)	NS
Height	171 (7)	171 (8)	171 (7)	NS
Weight	72 (12)	72 (12)	72 (13)	NS
Body Mass Index (BMI)	25 (4)	25 (4)	24 (3)	NS
Blood Pressure (systolic/diastolic)	131/85	130/86	133/85	NS
Weekly working hours	35.5 (8.9)	35.4 (9.0)	35.6 (8.8)	NS
Neck or shoulder Pain last month (0-9)	5,6 (1,7)	5,4 (1,5)	5,7 (1,9)	NS

Table 2: Characteristics of employees randomized into the two intervention groups in Study B.

Upper dominant training (Study C)

The participants were office workers recruited from 12 geographically different units located in all major cities throughout Denmark balanced according to the population density with around half in the Copenhagen area and half in other parts of Denmark.

We invited 2114 employees to participate in this study via an internet-based questionnaire and an invitation text went out to the prospective participants by email. Out of the invited employees, 990 replied to the questionnaire. The total number of employees included in Study C was 449 and of these, a total of 256 participants were neck pain cases (a baseline pain intensity of at least 3 on a 0-9 scale). In total 280 participants (62%) replied to both the baseline and follow-up questionnaires and are termed ócompletersô. The flow of the participants is shown in Figure 4. There was no statistical difference in any of the baseline parameters between completers and non-completers.

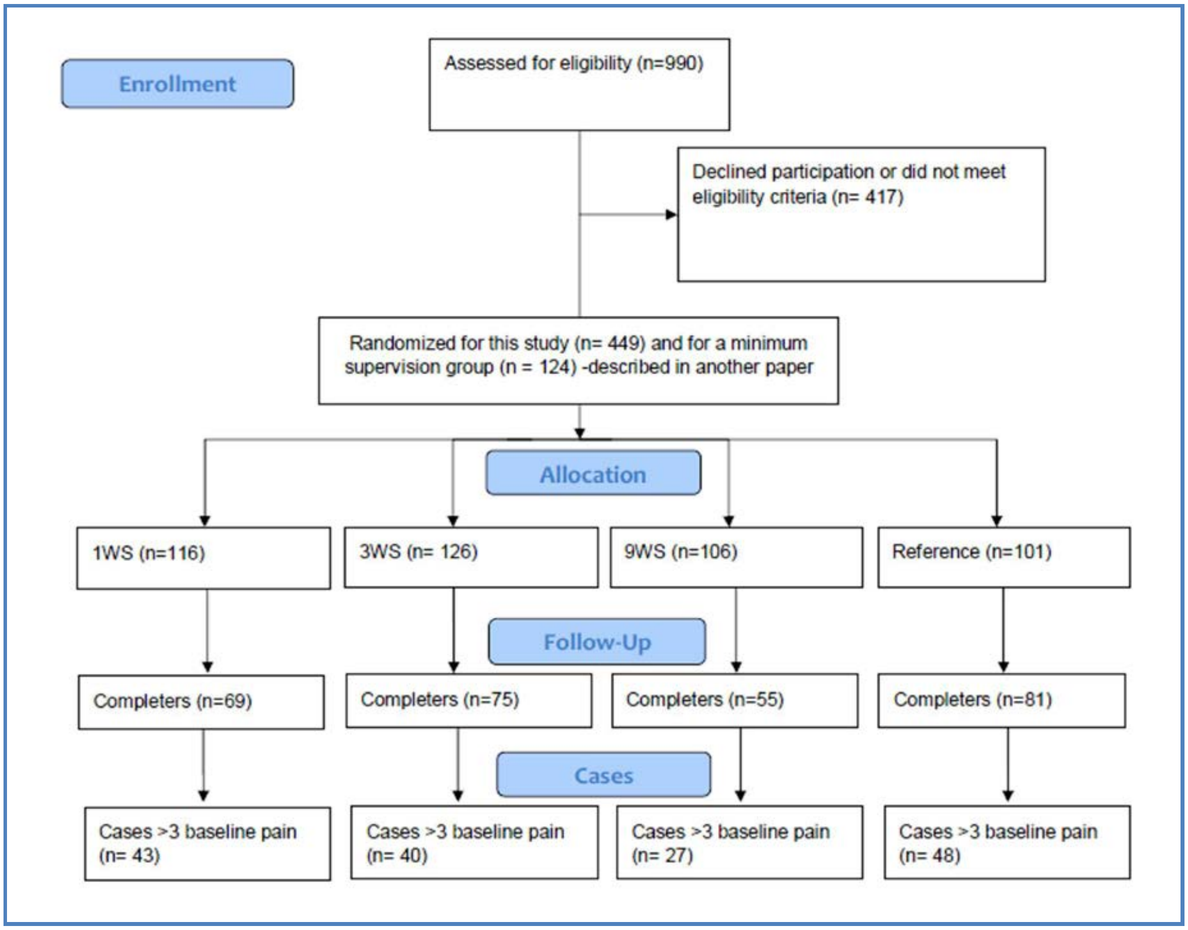

Figure 4: Flow of participants in Study C

	1WS	SD	3WS	SD	9WS	SD	Ref	SD	Total	SD
N randomized	116		126		106		101		449	
Pain cases	70		69		59		58		256	
Males/females	18/52		20/49		19/40		18/40		75/181	
Age (years)	45	(10)	47	(10)	45	(10)	44	(10)	45	(10)
Height (cm)	172	(8)	173	(10)	173	(9)	174	(9)	173	(10)
Weight (kg)	76	(16)	73	(16)	77	(14)	79	(16)	76	(16)
BMI (kg m-2)	25.5	(4.5)	24.3	(3.6)	25.3	(3.3)	26.2	(4.7)	25.3	(4.1)
Weekly working hours	35.9	(7.8)	35.9	(7.1)	36.1	(6.9)	36.7	(6.5)	36.2	(7.1)
Pain intensity in the neck previous 3 months (scale 0-9)	4.8	(1.4)	5.0	(1.6)	4.7	(1.7)	4.8	(1.6)	4.8	(1.6)
Pain intensity in the right shoulder previous 3 months (scale 0-9)	3.0	(2.4)	3.3	(2.4)	2.4	(2.4)	3.2	(2.5)	3.0	(2.4)
Pain intensity in the left shoulder previous 3 months (scale 0-9)	2.1	(2.3)	2.8	(2.5)	2.4	(2.3)	2.2	(2.2)	2.4	(2.4)

Table 3: Characteristics of employees characterized as neck pain cases randomized into the four intervention groups in Study C

Randomization of participants (Studies B & C)

Study B

Using a computer generated random numbers table, the 47 participants were randomly allocated to SFT (n = 24) or REF (n=23). Gender and age (18-39 and 40-69 years) was used as stratification variables. The sample consisted of 37 women and 10 men with a mean age (SD) of 44 (12) years, Body Mass Index (BMI) of 25 (4) kg m^{-1} and a baseline neck/shoulder pain during the last month of 5.6 (1.7).

Study C

For this study we used cluster as the unit of randomization. The clusters were work related groups of employees based on organisation and physical location, thereby also minimizing contamination between clusters. The employees who agreed to volunteer for the studies were randomized at the cluster-level into either a training group or a control group. As the clusters inherently contain different number of individuals, a cluster randomization will most of the time result in unequal group sizes. In Study C the 573 employees who agreed to volunteer for the study were randomized at the cluster-level into either one of four different training groups or a reference group. This thesis, however, will only look at three of the training groups and REF making the total number of participants randomized 449 for Study C (Figure 4). Subsequent adjustments were made in respect to the cluster allocation due to 26 participants being relocated to other work sites between the time of randomization and the start-up of the different interventions (~ 3 weeks) in order to have these participants follow the intervention for the cluster of their new colleagues. The 1WS group trained for 1 hour once a week, the 3WS group trained 20 minutes 3 times a week, and the 9WS group trained 7 minutes 9 times a week. The REF group was not offered any physical training, but replied to the same questionnaires as the intervention-groups. Number of participants in each group: 1WS = 116, 3WS = 126, 9WS = 106, and REF = 101. The combined sample consisted of 279 women and 170 men with a mean age (SD) of 46 (10) years, BMI of 25 (4) kg m^{-1} and a baseline neck pain during the last 3 months of 3.2 (2.3). Out of these participants 256 were neck pain cases with a baseline neck pain of 3 or more. These participants are described in Table 3.

Questionnaire (Studies A, B & C)

First step of recruitment included a reply to an email-based screening questionnaire including e.g. the Standardized Nordic questionnaire for musculoskeletal disorders (Kuorinka et al., 1987) which is is repeatable and sensitive (Palmer et al., 1999,Dawson et al., 2009) ï especially when including numerical rating scales of symptom severity (Descatha et al., 2007). The main questions are described in more detail below.

Musculoskeletal pain symptoms of the neck, shoulder, arm, hand, and back were evaluated using scales concerning both intensity and duration of symptoms. Participants in Study C replied to the question "On average, how intense was your pain in [body part] during the last three months on a 0-9 scale?" (where 0 means no complaints and 9 means pain as bad as it can be) for symptom intensity. The questions were asked with [body part] replaced first by the neck, then by the right shoulder, and then by the left shoulder. Illustrations from the Nordic questionnaire defined the respective body regions (Ohlsson et al., 1994). In Study B the participants replied to ñOn average, how intense was your pain in the neck or shoulders during the last month on a 0-9 scale?" as the intervention period was less than three months.
Each week the participants in Study B received an email asking them "How intense was your worst pain in the neck/shoulder area during the last week on a 0-9 scale? (where 0 means no complaints and 9 means pain as bad as it can be)ò.

Disabilities of the Arm, Shoulder and Hand (DASH).

The DASH Outcome Measure is a self-report questionnaire designed to measure physical function and symptoms in people with any of several musculoskeletal disorders of the upper limb. The tool is designed to give clinicians and researchers the advantage of having a single, reliable instrument that can be used to assess any or all joints in the upper extremity. In Study C participants rated work disability at baseline and follow-up by the work module of the Disability of the Arm, Shoulder and Hand questionnaire (DASH): ñIn the past week did you have any difficulty:ò 1) ñusing your usual technique for your work?ò, 2) ñdoing your usual work because of arm, shoulder or hand pain?ò, 3) ñdoing your work as well as you would like?ò, 4) ñspending your usual amount of time doing your work?ò. Participants replied on a 5-point Likert scale from ñNo difficultyò to ñUnableò. The DASH score was normalized on a scale of 0-100 (by adding the 4 values, dividing by 4, subtracting by 1, and multiplying by 25)(Beaton et al., 2001). The DASH has shown to have good construct validity, excellent test-re-test reliability, responsiveness to change, and have been shown to be acceptable for clinical use (Desai et al., 2010,Roy et al., 2009)

Clinical examination (Studies A & B)

In total 48 neck/shoulder cases participated in a clinical neck and upper limb examination. The examination was performed by a physiotherapist and was originally developed by Ohlsson et al. (Ohlsson et al., 1994) and later modified as described in detail previously (Juul-Kristensen et al., 2006,Andersen et al., 2011d). This included examination of neck and shoulder mobility, soreness during palpation, muscle tightness, and shoulder impingement (Neers test and Hawkins test (Kendall et al., 1983,Calis et al., 2000)).

Pain

In Study B, all participants received a weekly email questionnaire inquired about the intensity of pain in the neck and shoulder in the last week (scale 0-9). The effect of the intervention was determined as the continuous change over time. Further, at baseline and at follow-up *Pressure Pain Threshold (PPT)* was measured using an algometer (Algometer Type 2; Somedic, Hörby, Sweden) at 4 sites by a standardized procedure(Andersen et al., 2010a). Muscle and bone sites to be examined were located by palpation. The following points were outlined: 1) upper trapezius, 2) lower trapezius, 3) sternum and, 4) tibialis anterior.

In Study C the effect of the intervention on pain was determined from the questionnaire as the change from baseline to follow-up (scale 0-9).

Electromyography (EMG) (Study A)

EMG signal sampling and analysis EMG signals were recorded from the upper, middle and lower trapezius, and the serratus anterior. A bipolar surface EMG configuration (Neuroline 720 01-K, Medicotest A/S, Ølstykke, Denmark) and an inter-electrode distance of 2 cm were used. The skin of the respective area was prepared with scrubbing gel (Acqua gel, Meditec, Parma, Italy). Before affixing the electrodes, it was then checked that the impedance was less than 10 kq . The procedure followed the SENIAM recommendations, which are available atwww.seniam.org. The EMG electrodes were connected directly to small pre-amplifiers located near the recording site. The raw EMG signals were lead through shielded wires to instrumentaldifferentiation amplifiers, with a bandwidth of 10-500 Hz and a common mode rejection ratiobetter than 100 dB, sampled at 1000 Hz using a 16-bit A/D-converter (DAQ Card-Al-16XE-50, National Instruments, USA) and recorded on computer via a laboratory interface (CED 1401, Spike2 software, Cambridge Electronic Devices, UK). In the following analysis all raw EMG signals obtained during MVCôs as well as during exercises were digitally filtered, consisting of 1) high-pass filtering at 10 Hz 32, and 2) a moving root-mean-square (RMS) filter of 500 ms. For each individual muscle, peak RMS EMG of the 3 repetitions performed at each level was determined, and the average value of these 3 repetitions was then normalized to the maximum RMS EMG (Jensen et al., 1993,Andersen et al., 2010a).

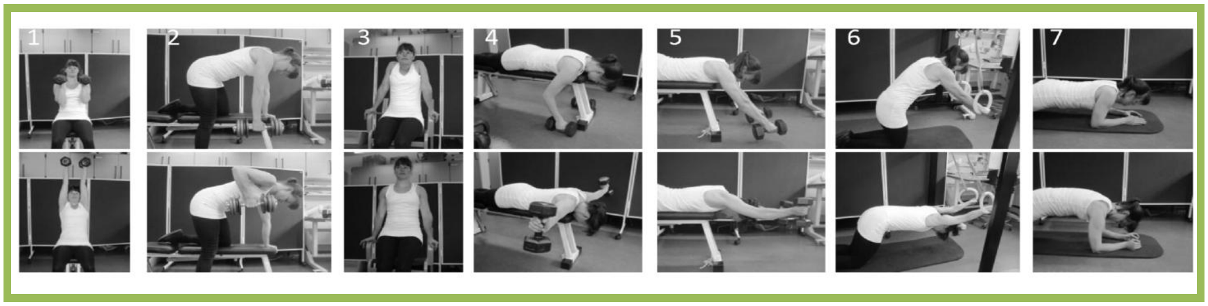

Figure 5: The seven exercises evaluated in Study A 1) shoulder press, 2) one-arm row, 3) press-up, 4) prone abduction, 5) prone flexion, 6) ring fallout, and 7) push-up plus.

Maximal voluntary contractions (MVC) (Study B)

Maximal voluntary contractions (MVC) were performed during shoulder-elevation and shoulder-protraction according to a standardised procedure (Backman et al., 1995). For shoulder elevation strength the participant was sitting upright in a height adjustable chair, and two Bofors dynamometers were placed bilaterally 1 cm medial to the lateral edge of the acromion (Ratamess et al., 2009). For shoulder protraction strength the participant was placed in supine position on a mat on the floor. With straight arms the participant flexed the shoulder to 90°, kept the posterior parts of the shoulder musculature in contact with the ground and two Bofors dynamometers were positioned in the participantôs hands.

The participant was instructed to gradually build up the force over 5 s, then to keep the maximal force for about 2 s and finally to lower the force slowly to zero. The MVCôs were performed at least three times for each exercise. If the third recording was more than 5% higher than the previous two recordings, a fourth test was performed, and a maximum number of five tests were performed. Strong verbal encouragement was given during all trials. During later analyses torque was calculated as force times lever arm length. The individual adjustment of the testing equipment was registered and used during the post-intervention test.

Interventions (Studies B & C)

Training

During both interventions training loads were progressively increased according to the principle of periodization and progressive overload. Relative loadings were progressively increased from approximately 20 repetitions maximum (RM) (~5 out of 10 on the Borg CR10 scale) at the beginning of the training period towards 8 RM (~8 out of 10 on the Borg CR10 scale) during the later phase. In the 10 week intervention in Study B the program followed the principles of undulating periodization from start to finish. Out of a total of 20 weeks in Study C the first 12 weeks of the program followed the principles of linear periodization and the last 8 weeks the principles of undulating periodization. Absolute loads ï i.e. weight of the dumbbells or added resistance from elastic bands - were individually increased to meet the intended intensity level. All exercises were performed using consecutive concentric and eccentric muscle contractions in a controlled manner without pause or breaks, and each set typically lasted 20-30 seconds.

Adjustments in case of acute pain

If a participant in either study experienced joint pain or the like during a specific exercise, we asked them to adjust the exercise as follows: First, slightly alter the path or range of movement during the exercise. Then, the participant reduced the training load of the exercise. If this did not help, the participant reduced the number of sets of the given exercise in the session.

Specific to each intervention

Shoulder function training (Study B)

The training-group was allocated to 3 × 20 minutes training per week during working-hours for 10 weeks, which has previously been shown to be a sufficient intervention period to achieve significant pain reduction (Coury et al., 2009,Andersen et al., 2008b). Experienced instructors assisted in all of the training sessions. REF was not offered any physical training but was encouraged to stay active as usual. The training-group performed scapular function training with exercises (selected from Study A) which have been shown to activate the serratus anterior and lower trapezius muscles to a high extent, but with only a low level of activation - less than 30% - of the upper trapezius (Figure 6). If needed, extra resistance was added by placing elastic bands of varying thickness across the back (push-up plus) or over the shoulders (press-up). Each training session started with a short warm-up by slowly moving the neck, upper back, shoulder blades and shoulder joint through pain-free range of motion.

1) *Press-up.* The subject is sitting erect on a training bench, feet on the floor with straight arms and the palms on the edge of the bench fingers pointing forward. She now lifts herself off the bench and then dips down just in front of the seat just moving the shoulder girdle.
2) *Push-up plus.* The subject starts from a push-up position on the hands and feet or knees, bracing the abdominals to keep the torso rigid. The subject now pushes the body as high as possible off the floor by protracting the scapulas.

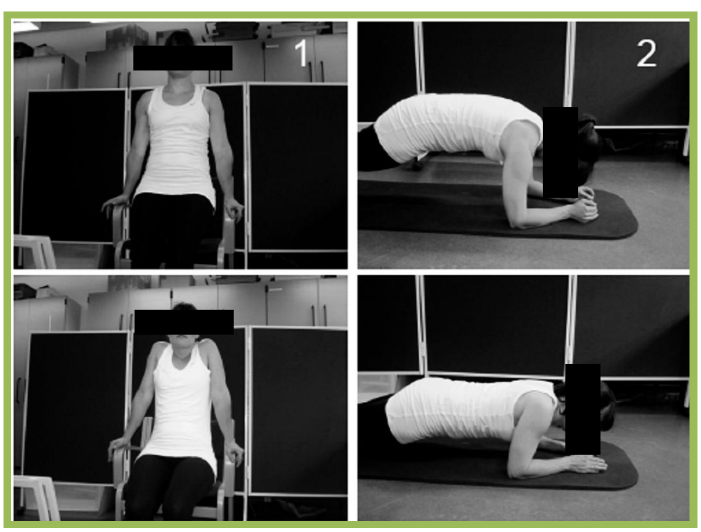

Figure 6: The two exercises used Study B 1) press-up and 2) push-up plus.

Upper dominant training (Study C)

Rhea et al concluded in a meta-analysis on untrained healthy adults that maximum strength gains were obtained using three weekly strength training sessions. This also applies to elderly women, i.e. age seems to be of minor importance for relative strength gains (Rhea et al., 2003). However, as pain relief and strength gain may occur through different physiological mechanisms in different groups and optimal training frequency may therefore be different. We investigated this phenomenon in Study C. The training-groups performed the same total amount of exercises and repetitions per for a total of one hour per week for 20 weeks during working-hours. Experienced instructors supervised every other training session. The participants in the training groups performed supervised high-intensity strength training for the neck, shoulder, and forearm extensor muscles with five different dumbbell exercises, front raise, lateral raise, reverse flies, shrugs, and wrist extensions (Figure 7).

A. Front raise: From a neutral starting position the participant lifts one arm at a time to 90 degrees shoulder flexion, and 90 degrees internal rotation. The elbows are slightly flexed (~5°) during the entire range of motion.

B. Lateral raise: the participant is standing with arms in neutral starting position and the elbows are in a static slightly flexed position (~5°). The participant lifts both arms to 90 degrees shoulder abduction and 30 degrees horizontal flexion.

C. Reverse flies: The participant is sitting bent over forward with the back straight and arms hanging. The arms are raised bilaterally, while keeping the elbows in a static slightly flexed position (~5°), until the upper arms are horizontal.

D. Shrugs: The participant is standing erect with arms to the side and elevates the shoulders as high as possible in a maximal shrug.

E. Wrist extension: sitting with the forearm pronated on a support. From full palmar flexion the participant moves the wrist to full dorsal flexion

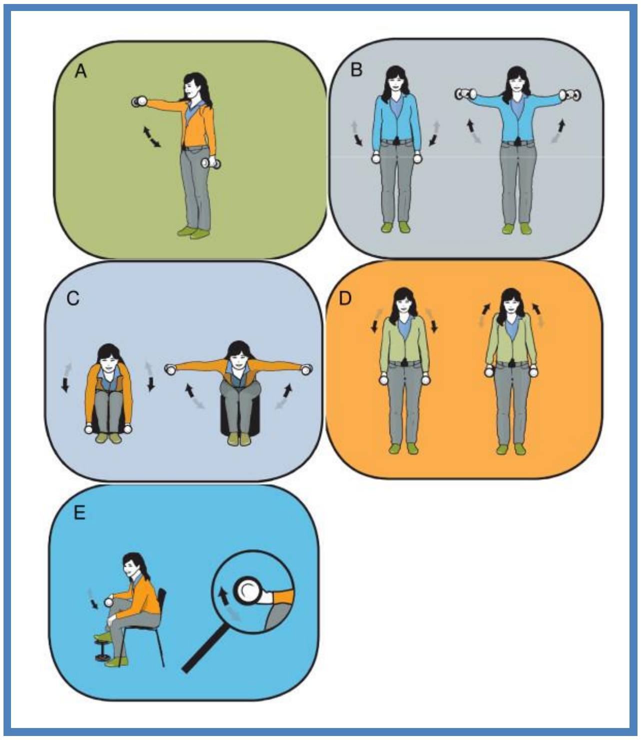

Figure 7: The strength exercises used in Study B A) front raise, B) lateral raise, C) reverse flies, D) shrugs, and E) wrist extension

Sample size calculation

Study A: Power analysis performed prior to the study showed that 16 participants in this paired design were sufficient to obtain a statistical power of 80% at a minimal relevant difference of 10% and a type I error probability of 5%, assuming a standard deviation of 10% based on previous research in our laboratory.

Study B: Power analyses based on pain cases performed prior to Study B showed that - to reject hypothesis B - we should include 20 participants per group (allowing for a 20% loss to follow-up) for 80% power and p=0.05 to detect a clinically significant change in pain of 1.5 (Kovacs et al., 2008,Todd, 1996) on a 0-9 scale between groups based on the pain ratings from the weekly questionnaire.

Study C: Power analyses based on a population both with and without pain performed prior to Study C showed that - to reject hypothesis D - we should include 150 participants per group (allowing for a 20% loss to follow-up) for 80% power and p=0.05 to detect a change in pain of 1,5 on a 0-9 scale between groups from baseline to follow-up.

Statistics

EMG

Analysis of variance with repeated measures determined whether differences during the seven exercises existed in the activation difference between the upper and lower trapezius, between the serratus anterior and the upper trapezius, between the upper and middle trapezius, and between the serratus anterior and the lower trapezius. A difference of 10% or more in normalized EMG between the muscles was considered a relevant difference.

Baseline analyses (Studies B & C)

To determine if differences between the groups had happened by chance in the randomization, descriptive data regarding the variables age, height, weight, body mass index (BMI), and neck and shoulder pain were reported. When comparing the training group(s) and reference group, a Studentõs t-test (Study B) or one way ANOVA (Study C) was conducted for age, BMI, working hours, and pain intensity. Pearsonõs chi^2 was used to test for differences in sex distribution. SPSS version 19 was used for the statistical analyses.

Intervention outcomes (Studies B & C)

When comparing the training group(s) and reference group, a Studentõs t-test (Study B) or two-way ANOVA (group by time) (Study C) was conducted for pain intensity. Post hoc tests with appropriate corrections for multiple comparisons were performed when a significant main effect was found. An alpha level of 5 % was considered statistically significant. Primary outcome in the intervention studies was change in pain while change in strength and DASH were secondary outcomes.

Analyses were performed according to the intention-to-treat (ITT) principle, i.e. including all randomized participants regardless of actual participation and missing reply at follow-up (Hollis and Campbell, 1999,White et al., 2011). In Study B missing values on pain and muscle strength were imputed by last observation carried forward (LOCF) and first observation carried backward. We used linear regression analysis from the first log entry to the last log entry to determine the change in pain over time for each individual. We then performed analysis of variance to model change in pain during the intervention period in the neck/shoulder. This same procedure was used on the weekly responses on 10 RM training weight in the lateral raise exercise before subsequently calculating the slope of the curve for each participant (i.e. average weekly progression in 10 RM training weight).

In Study C imputation of missing values at follow-up on main outcomes were performed by adding the natural seasonal change in pain and DASH score ï defined as the mean change from baseline to follow-up in REF ï to the baseline value (White et al., 2011).

Pearsonøs chi^2 was used to test for differences in self-reported training adherence in Study C.

Correlations

In Study B we performed test-retest reliability for the REF group before and after the intervention using Pearsonøs correlation for the MVCs combined, PPTs combined and each test separately. In Study C correlations between changes in pain in different regions were calculated using Spearman rank correlation.

Results

Exercise evaluation (Study A)

This study demonstrates predominant activation of specific parts of the scapular musculature in selected training exercises performed at high intensities.

Figure 8 and Figure 9 show the muscle activation difference between the serratus anterior and the upper and lower compartments of the trapezius. Several of the exercises ï push-up plus, shoulder press and press-up at - predominantly activated the serratus anterior over the upper trapezius (activation difference (φ) 18-45 %) (Figure 8). Likewise, several of the investigated exercises ï press-up, push-up plus and one-arm row - predominantly activated the lower trapezius over the upper trapezius (φ 13-30 %) (Figure 9). These exercises can thus be classified as SFT exercises. Only the press-up and push-up plus activated both the lower trapezius and the serratus anterior over the upper trapezius while maintaining low activity in the upper trapezius.

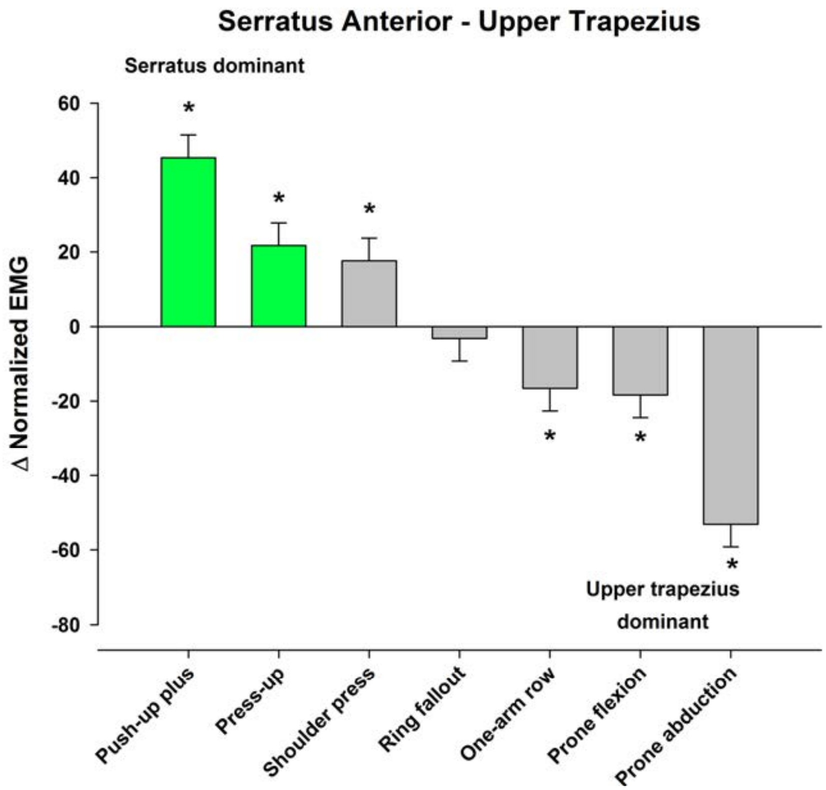

Figure 8: Difference in normalized electromyography (EMG) between serratus anterior and upper trapezius during the different exercises and intensities. Exercises chosen for Study B are marked in green. * indicates 10 % significantly different activation between muscles.

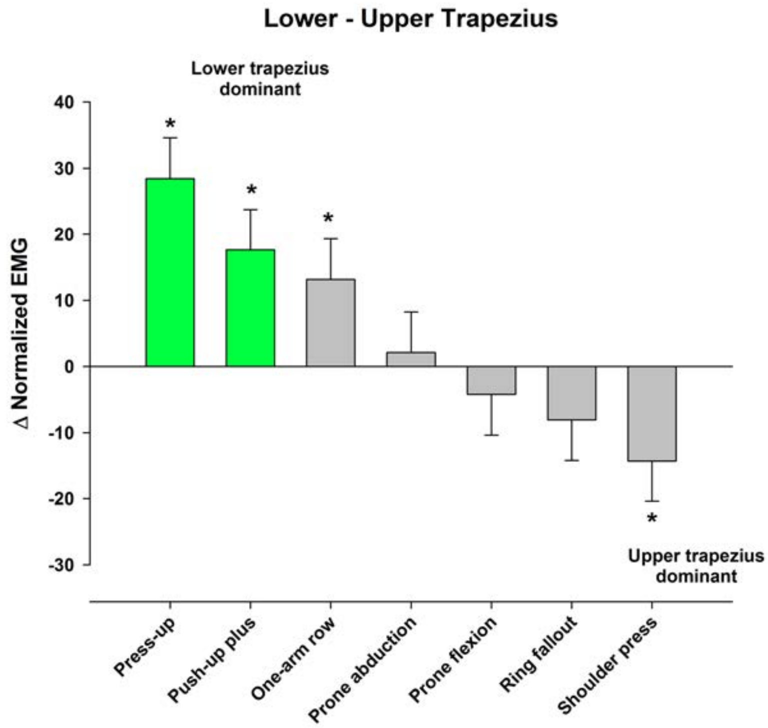

Figure 9: Difference in normalized electromyography (EMG) between lower trapezius and upper trapezius during the different exercises and intensities. Exercises chosen for Study B are marked in green. * indicates 10 % significantly different activation between muscles.

The intervention studies

Adherence

In Study B mean adherence to the training was 2.1 (0.5) sessions per week corresponding to 70% and an average total training time of 420 out of a possible 600 minutes.

Training adherence was slightly lower in Study C where 39 % of the participants participated 40-60 minutes per week, 18% participated 20-40 minutes per week. Converted to total training time the completers trained on average 789 minutes out of a maximally 1200 minutes during the 20 week intervention. This corresponds to 66% training adherence. Regular adherence - defined as participating at least 20 minutes a week during the 20 week intervention - was achieved by 56% of the participants. In both the 3WS and the 9WS group regular adherence was achieved by 60% of the participants, while 1WS only achieved 49% regular adherence which was significantly lower ($p < 0.05$).

Dropout

In Study B one of the participants in the SFT group dropped out after week four due to pain in the glenohumeral joint and one subject in the REF group dropped out due to job change. These two participants were still included in the ITT-analyses. In Study C, the 38% who did not reply to the follow-up questionnaire are classified as dropouts although the number of true dropouts might be lower.

Pain and disability

Shoulder Function Training (Study B)

At baseline the mean neck/shoulder pain the last month in the two groups were 5.4 (1.5) for REF and 5.7 (1.9) for SFT. The intention to treat analysis showed a significant difference in the change from baseline to follow-up in neck/shoulder pain between SFT and REF (between-group difference 2.0 [95%CI 0.4 - 3.6]) as shown in Figure 10.

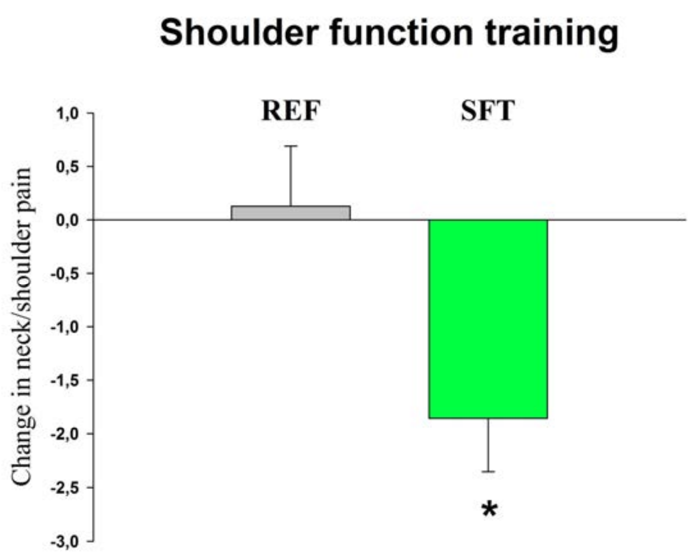

Figure 10: Difference in neck- and shoulder pain from baseline to 10 weeks follow-up. Values are means (SE). * p< 0.05.

Pressure pain threshold of the lower trapezius showed a significant difference in change from baseline to follow-up between the groups, where SFT had an increase of 129 kPa [95%CI 31 - 227 kPa] greater than REF (p< 0.01). There was no difference for the change from baseline to follow-up between the two groups in the other regions. However, from baseline to follow-up the pressure pain threshold increased averagely 44% in the four sites in the SFT group where the REF group did not change statistically (Table 4).

	REF					**SFT**				
	Baseline	SD	Follow-up	SD	p	Baseline	SD	Follow-up	SD	p
Upper trapezius	303 kPa	(127)	378 kPa	(143)	NS	277 kPa	(155)	405 kPa	(186)	**<0,05**
Lower trapezius*	383 kPa	(145)	399 kPa	(175)	NS	308 kPa	(162)	453 kPa	(204)	**<0,01**
Tibialis anterior	381 kPa	(135)	464 kPa	(193)	NS	321 kPa	(93)	446 kPa	(165)	**<0,05**
Sternum	254 kPa	(154)	291 kPa	(124)	NS	225 kPa	(128)	323 kPa	(137)	**<0,05**

Table 4: Changes in pressure pain threshold from baseline to follow-up at each site for REF and SFT. Values are means (SD). * denotes significant between-group difference from baseline to follow-up (p < 0.01).

Upper dominant training (Study C)

Intention to treat analysis

The neck-pain cases of Study C had a mean baseline pain intensity of 4.8 (1.6) with no difference between the groups. For the 256 neck pain cases the ITT analysis showed significant *group by time* interaction (p= 0.05). The subsequent post hoc analysis showed greater pain reduction in the 3WS group compared with REF ($p < 0.01$). None of the other groups were statistically different in pain reduction. For neck pain cases there was also a significant *group by time* interaction for DASH, with a significant difference between 3WS and the REF ($p < 0.01$). 3WS also showed significant greater reduction than 9WS ($p < 0.05$).

Completers

For the completers, analysis on neck-pain cases showed significant difference between the groups ($p < 0.001$). Compared with REF, a significant pain-reduction was found in 3WS ($p < 0.001$), 1WS and 9WS ($p < 0.05$) (Figure 11). There was no statistical significant difference between training groups.

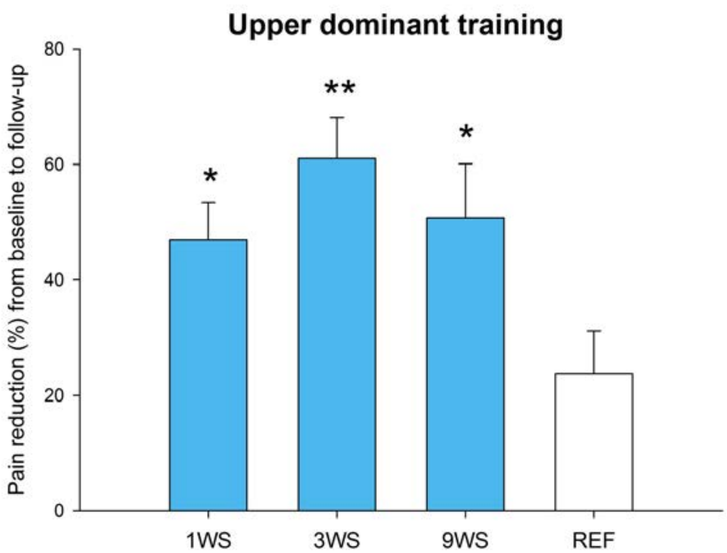

Figure 11: % change in neck pain in cases after the 20 week intervention period. Asterisks denote difference from REF. ** P < 0.01. * P < 0.05.

Our analysis also showed a significant *group by time* interaction for DASH, with a significant difference between 3WS and the REF ($p < 0.01$) (

Table 5).

Table 5

		Baseline	SD	1WS	95% CI	3WS	95% CI	9WS	95% CI	Training groups combined	95% CI
				Reduction compared with REF							
Pain	ITT Cases (neck)	4.8	1.6	0.6	[-0.1: 1.3]	**1.0***	**[0.3 - 1.7]**	0.5	[-0.3 - 1.2]	**0.7***	**[0.1 - 1.3]**
Neck	Completers Cases (neck)	4.8	1.6	**1.1***	**[0.2 - 2.1]**	**1.9****	**[0.9 - 2.9]**	**1.4***	**[0.2 - 2.5]**	**1.5****	**[0.7 - 2.3]**
Pain	ITT Cases (right shoulder)	4.7	1.7	0.7	[-0.2 - 1.7]	0.2	[-0.7 - 1.1]	0.6	[-0.5 - 1.6]	**0.5**	[-0.3 - 1.3]
Right Shoulder	Completers Cases (right shoulder)	4.7	1.7	**1.4***	**[0.2 - 2.5]**	**1.3***	[0.1 - 2.5]	1.3	[-0.1 - 2.6]	**1.3***	**[0.3 - 2.3]**
Pain	ITT Cases (left shoulder)	4.6	1.6	**1.3***	**[0.1 - 2.5]**	0.4	[-0.7 - 1.6]	0.9	[-0.3 - 2.1]	0.8	[-0.2 - 1.8]
Left shoulder	Completers Cases (left shoulder)	4.6	1.6	**2.2***	**[0.7 - 3.7]**	1.3	[-0.3 - 2.8]	**2.0***	**[0.4 - 3.6]**	**1.8***	**[0.6 - 3.0]**
DASH	ITT Cases (neck)	16	18	**5***	**[0 - 10]**	**8****	**[3 - 13]**	3	[-2 - 8]	**5***	**[1 - 9]**
	Completers Cases (neck)	16	18	7	[-1 - 14]	**12****	**[5 - 19]**	4	[-4 - 12]	**8***	**[2 - 14]**

Baseline values for pain and DASH score and reduction for each group compared with REF.

*p < 0.05, **p < 0.01

Correlation analysis

There was a positive correlation between the baseline-to-follow-up change in pain in the neck and in either shoulder and the upper back with a Spearmanĝs correlation coefficient of 0.44 for the right shoulder, and 0.33 for the left ($p<0.0001$).

Muscle strength

Shoulder Function Training (Study B)

From a baseline mean of 57.5 kg (17.8 kg) in SFT and 59.3 kg (11.3 kg) in REF, SFT increased shoulder elevation strength 7.7 kg [95%CI 2.2 - 13.3 kg] ($p< 0.01$) more than REF. The isometric protraction strength at baseline was 62.7 kg (23.9 kg) in SFT and 54.3 kg (14.1 kg) in REF. Although the mean difference in protraction strength at follow-up was 6.5 kg [95%CI -3.5 - 16.6 kg] higher in the SFT group compared to REF, this was not statistically significant.

Upper dominant training (Study C)

During the intervention 10RM in the lateral raise exercise increased steadily with an average of 0.10 kg pr week [0.08 - 0.13] for all participants (Figure 12). There was no significant difference between the training groups when the LOCF procedure was performed, although there was a tendency for the increase in training weights of 1WS to be higher than 9WS ($p=0.07$). Without imputation of missing values 1WS increased their training weights on average 0.16 kg pr week [0.11 - 0.21] which was significantly faster than 9WS who had an average increase of 0.07 kg pr week [0.03 - 0.12] ($p<0.01$). 3WS had an average of 0.12 kg pr week [0.09 - 0.16] and tended toward increasing faster than 9WS ($p=0.085$). Baseline neck pain was not correlated to the slope for the change in training weights.

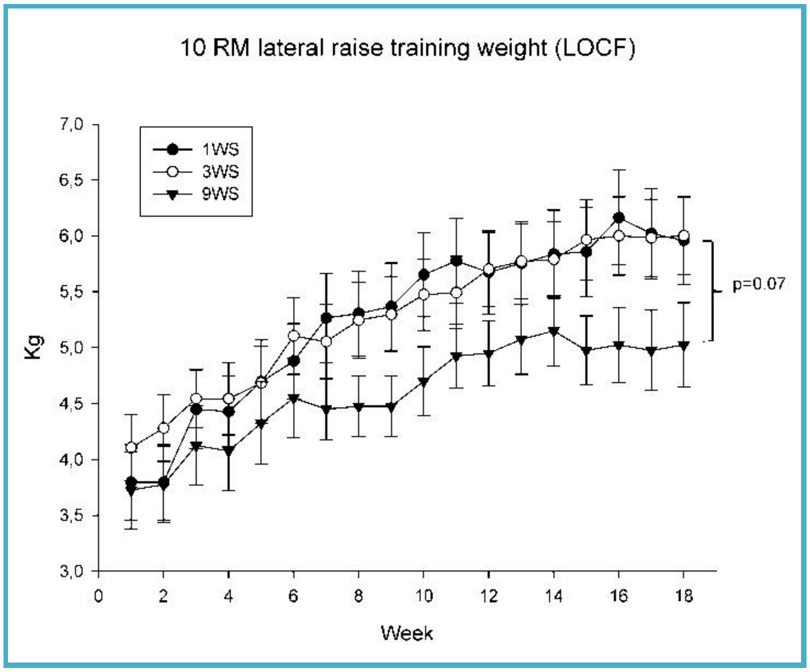

Figure 12: 10 RM training weights (LOCF) during the intervention.

Discussion

The main findings of the present PhD project are: 1) there is predominant activation of specific parts of the scapular musculature in selected training exercises during high intensity, 2) both SFT and UDT leads to clinically relevant reductions in neck/shoulder pain, 3) there is flexibility regarding time-wise distribution when implementing training at the workplace. These findings are discussed below.

Exercise selection

An important variable in muscle training is intensity, which is defined as the percentage of the maximal isometric muscle strength or the maximal number of repetitions that can be performed with the particular training weight (repetitions maximum; RM) for isometric and dynamic contractions, respectively (Ratamess et al., 2009). Whether the aim is strengthening specific tissues or improving neural activation, higher training intensities provide a stronger stimulus for the body to adapt. It is generally agreed that training intensities of at least 60 % should be used for effective muscular adaptations to occur and that higher intensities yield proportionately greater adaptations (Ratamess et al., 2009). Roughly, exercise intensity can be estimated as a percentage of the maximal EMG amplitude during MVC (Andersen et al., 2006). For most (smaller) muscles a linear force-EMG relationship is seen (Jensen et al., 1993,Basmajian and De Luca, 1985), thus any difference in normalized EMG amplitude between exercises reflects relative differences in levels of muscle force.

In Study A we found predominant activation of specific parts of the scapular musculature at high intensities during several of the exercises, and the statistical null hypothesis A - *For the investigated exercises there is no significant difference in normalized EMG between 1) serratus anterior minus upper trapezius and 2) lower* *trapezius minus upper trapezius*- was rejected. Five of the selected exercises produced activation of at least 60% for one of the targeted muscles and can formally be classified as strengthening exercises (Ratamess et al., 2009,Rhea et al., 2003). Furthermore Study A shows that specific scapular muscle activation difference between exercises can be determined based on EMG analysis.

Previous studies have investigated serratus anterior activation during different exercises (Decker et al., 1999,Ludewig et al., 2004,Ekstrom et al., 2003,Hintermeister et al., 1998,Moseley, Jr. et al., 1992). Although these studies recommend exercises inducing high serratus anterior activation, they do not consider the simultaneous impact of these exercises on the upper trapezius. In other words, these studies did not account for the activation difference between the serratus anterior and the upper trapezius. Only few previous studies have investigated the activation difference between the serratus anterior and the upper trapezius during exercises (Ben and Sciascia, 2008,Cools et al., 2007,Ludewig et al., 2004), and none of these investigated activation difference during high-intensity exercise. As strengthening specific muscles requires a high level of muscle activation, their proposed exercises may not effectively strengthen the serratus anterior.

Study A showed that the push-up plus exercise performed at high intensity strongly activates the serratus anterior while maintaining a low level of upper trapezius activity. We found that the press-up most efficiently activated the lower trapezius over the upper trapezius, as also shown by a upper trapezius / lower trapezius ratio of less than 0.5. However, even at high intensity the levels of lower trapezius activation are only moderate, indicating that in spite of the selective activation this exercise may not optimally induce strength gains. To our knowledge there are no scientific guidelines on minimal activation difference and activation ratio to make an exercise suited for effective selective strengthening. A limitation of Study A is that extrapolation of the results to individuals with chronic pain should be done with caution. We cannot be certain that the office workers in Study B had similar muscle activation difference performing the SFT exercises.

In a simulated training session in our laboratory we have examined shoulder muscle activation in untrained women during the four exercises used for UDT (Jakobsen et al., 2011) and in both that and another previous study from our lab we found that lateral raise, shrugs, and reverse flies induced levels of upper trapezius EMG amplitude that was above 70% of peak EMG during MVC (Andersen et al., 2008b). During all of the four UDT exercises examined by Jakobsen and co-workers, the muscle activation ratio between both upper trapezius and serratus anterior as well as upper trapezius and lower trapezius is above 1 (upper trapezius dominant). For both the front raise and lateral raise the two ratios are 1.1 and 1.5, respectively, whereas there is a strong upper trapezius dominance over the serratus anterior for reverse flies (ratio 8.6) and shrugs (ratio 7.7).

In both of the aforementioned exercise evaluation studies the lateral raise induced similar high levels of trapezius muscle activation compared with shrugs, in spite that the average training weight used during the lateral raise was only one fifth of that used during shrugs. This finding has practical relevance during rehabilitation of neck pain, since grip strength and low back strength may become limiting factors during heavy-load shrugs, especially for those with symptoms also in the low back and hip/knee.

At our laboratory we have examined the EMG response during the lateral raise with elastic resistance performed to failure. We found that normalized EMG for the examined neck and shoulder muscles increased throughout the set to failure in a curvilinear fashion - e.g. for the upper trapezius from 86% to 124% MVC ($P<0.001$) - and reached a plateau during the final 3-5 repetitions before failure with a resistance of approximately 15 RM (Sundstrup et al., 2011). Going to complete failure during strengthening exercises may thus not be necessary to recruit the entire motor unit pool in untrained women - i.e. muscle activity reached a plateau a couple of repetitions from failure. However, it is a balance between increasing the amount of time under high to complete motor pool activation without unnecessarily increasing the risk of injuries as exercise form typically worsens close to complete failure.

In summary, the SFT exercises chosen for Study B and the upper dominant exercises for Study C are movements in the shoulder girdle and the muscle activation patterns are very specific to the type of training. Importantly, in Study A, we identified two SFT exercises to specific target the lower trapezius and serratus anterior while minimizing activity of the upper trapezius ï these exercises formed the basis of training intervention in Study B.

Considerations of program planning

Previous resistance training studies of similar duration and comparable baseline pain intensities reported 17-25 % reduction of neck pain in females with non-specific neck pain (Hagberg et al., 2000,Randløv et al., 1998), 25-39 % in women with trapezius myalgia (Waling et al., 2000) or no reduction in non-specific neck pain in comparison with a control group (Viljanen et al., 2003). A study of 1 year duration found almost 70% decrease in non-specific neck pain (Ylinen et al., 2003). Andersen and co-workers found similar effects in just 10 weeks in females with upper trapezius myalgia (Andersen et al., 2008c), and so did Zebis and co-workers in a 20 week study on a comparable subgroup of women with severe non-specific neck pain (Zebis et al., 2011). The markedly positive and rapid response in the studies by Andersen, Zebis and Study C compared with previous studies is likely caused by a multitude of factors. First of all, the basic training variables were different between studies. Most studies used training frequencies of 3-5 times per week with durations of 8-20 weeks (Waling et al., 2000,Viljanen et al., 2003,Hagberg et al., 2000,Zebis et al., 2011,Andersen et al., 2008c,Blangsted et al., 2008). However, there are noticeable differences in intensity, specificity, volume, and contraction mode. According to the American College of Sport Medicine guidelines, the most pronounced adaptations at the muscle cellular level are achieved in response to progressive and periodized dynamic strength training involving both concentric and eccentric contractions with a high intensity (8-12 RM for novices) and a high volume (multiple sets) (Ratamess et al., 2009). This is also supported in shoulder rehabilitation (Østerås et al., 2010,Fees et al., 1998). In Study B and C these variables were optimized by letting the exercises consist of both concentric and eccentric contractions (i.e. contracting and lengthening the muscles in a controlled manner) with a high intensity and in addition a high volume performed in a periodized and progressive manner. Importantly, the loadings were individually adjusted according to the individual strength capacity and level of pain.

Many studies have shown that a number of exercises can induce high levels of EMG in the neck and shoulder muscles, i.e. levels above 60% of maximal EMG (Andersen et al., 2011b,Andersen et al., 2008b,Escamilla et al., 2009,Jakobsen et al., 2011), implying that a wide variety of specific strengthening exercises can be used for targeted rehabilitation of neck and shoulder pain. Previous studies have used several different approaches. This includes high intensity concentric contractions (Waling et al., 2000), high-intensity isometric training (Hagberg et al., 2000,Ylinen et al., 2003), low intensity training (Viljanen et al., 2003,Randløv et al., 1998), low total training volume (Hagberg et al., 2000) and non-periodized training (Ylinen et al., 2003,Waling et al., 2000,Randløv et al., 1998,Hagberg et al., 2000,Blangsted et al., 2008). One study concluded that strength training is not more effective in reducing neck pain compared with a control group (Viljanen et al., 2003). Intensity was not reported in this study, but based on absolute loadings of less than 3 kg compared with up to 25 kg in Study C and two previous interventions (Andersen et al., 2008c,Zebis et al., 2011) training intensity was likely low. It is not possible to draw conclusions regarding the effect of high-intensity training on neck and shoulder pain based on those studies. Previous studies using true high-intensity strength training all found positive effects on pain reduction (Kadi et al., 2000,Ahlgren et al., 2001,Waling et al., 2000,Ylinen et al., 2003,Hagberg et al., 2000).

Considerations in relation to training adherence

In the following, adherence is defined as the number of actual training sessions performed as a percentage of the number of intended training sessions. A general principle of exercise physiology is that regular training on a continuous basis is important for optimal results regardless of the training program. However, several studies report that adherence to exercise is often a serious problem (Sluijs et al., 1993,Friedrich et al., 1998,Kolt and McEvoy, 2003). The adherence in both Study B and C was 70% and 66% respectively. Thus, Study B & C are comparable regarding training adherence. Even though the training frequency and duration of training sessions is roughly similar in most previous studies, training adherence varies widely. Some studies have had high training adherence: 87% (10 weeks)(Andersen et al., 2008c), approximately 70% (20 weeks)(Zebis et al., 2011), some had medium adherence: 64% (10 weeks)(Andersen et al., 2011e), 60% (10 weeks)(Ylinen et al., 2003), 57% (52 weeks)(Viljanen et al., 2003) and, some had low training adherence: 39% (12 weeks)(Hagberg et al., 2000) and 31% (12 weeks)(Viljanen et al., 2003). Depending on differences in the definition utilized for adherence and its measurement, estimates of how many persons complete their exercises according to the intended number vary, but is typically less than half of the intended sessions (Medina-Mirapeix et al., 2009). Training adherence in Study B and C can thus be classified as high. Because effectiveness of exercise for managing musculoskeletal pain is proportional to adherence (Nikander et al., 2006), knowledge of prognostic factors for adherence is essential for optimally implementing exercise at the workplace. Prior to the interventions we gave barriers towards training much consideration. This involved both the organizational implementation as well as a more pragmatic approach in relation to the actual training areas and training sessions.

ñLack of timeò is cited as a major reason for not being physically active (Trost et al., 2002), and consequently we tried to make the training sessions as time-effective as possible alternating sets between the training exercises in a staggered fashion. During the initial contacts with the decision makers at the participating companies we strongly emphasized the importance that all participants of the training groups were given the full weekly hour for training. To maximize the effect of the exercise intervention we collaborated closely with the employees at the local work sites and tried to involve the participants in the intervention with respect to instructor schedule, training location etc. (Driessen et al., 2010). RCTôs often suffer from poor organizational implementation and thereby lack of ownership from all stakeholders (Neumann et al., 2010). To make the interventions as effective as possible there were several elements we wanted to integrate into the training protocol. Without compromising training efficacy, we wanted the training program to be structured in a simple and easily comprehendible way in an effort to increase participant self-efficacy as this is related to high training adherence (Andersen, 2011,Rhodes and Fiala, 2009,Kaewthummanukul and Brown, 2006). This is important as how ñexercises fit daily routineò has been reported as a predictor of training adherence with an odds ratio of 7.4 (Medina-Mirapeix et al., 2009). In relation to the physical environment, training locations were placed as close as possible to the actual work station for the respective departments/ clusters, thereby minimizing distance and travel time as a barrier (Trost et al., 2002). We wanted the participants to bond socially and therefore encouraged the participants to train in groups (Bandura, 2004). When this was not possible we encouraged them to train on their own or with one or more colleagues. Further, each participant was given a training log with illustrations of exercises and clear instructions regarding sets and repetitions to be performed in the individual session. The participants would register the training loads used thereby making progress in training performance apparent. The training logs also provided a simple way to periodize the training programs.

In the follow-up questionnaire 27% of the participants reported that ñthe training programò was a motivating factor (unpublished data). Other motivating factors were ñthere was an instructor presentò (27%), ñI trained as part of a groupò (26%), and ñthe training area was close to my officeò (26%). The largest barrier in relation to training adherence seemed to be ñtimeò, which was reported by 20% of the participants. Thus, to effectively implement training at workplaces, fitting the training sessions into the organizational routine in a flexible manner is important.

In summary, based on the current literature we considered that a combination of muscle-specific exercises, a high training intensity and a relatively high total training volume would be important for an optimal physiological response to the training. In Study B & C these factors were optimized providing a strong training stimulus to reduce neck and shoulder pain. According to the participant feedback in Study C we managed to succeed in a number of areas, but according to participant responses training adherence was still compromised due to time-constraints.

Shoulder function training

In Study B we found a between-group difference in pain intensity of 2.0 from baseline to 10-week follow-up, thus rejecting hypothesis B -*There is no difference between a shoulder function training group and a reference group for the change in neck/shoulder pain from baseline to follow-up at week 10*. Other studies using high-intensity training with several different neck/shoulder exercises targeting the deltoids, upper trapezius, neck extensors etc reported pain reductions between 1 and 3 on a 10-point scale (Andersen et al., 2008c,Zebis et al., 2011,Ylinen et al., 2003). Change in pain is considered clinically relevant for neck pain when a statistically significant reduction of at least 1.5 on a 10-point scale occurs (Kovacs et al., 2008,Todd, 1996). Our results thus show that 10 weeks of SFT can be added to the clinically relevant treatment strategies for neck/shoulder pain. This broadens the evidence based treatment options for these disorders, e.g. some patients may not be able to directly train their upper trapezius due to severe pain but can still get clinically relevant reductions of neck pain from SFT.

All of the above mentioned intervention studies applying intensive muscle training have used exercises which targeted the painful muscles (Escamilla et al., 2009). To our knowledge, Study B is the first intervention study on neck and shoulder pain using only SFT exercises. This approach with SFT exercises is also a practice that has been used targeting other disorders such as impingement syndrome, rotator cuff dysfunction, and shoulder instability (Ellenbecker and Cools, 2010,Cools et al., 2007). A recent study found that specific training of the deep cervical flexor muscles in women with chronic neck pain also reduces neck pain (Falla et al., 2011), and this supports that training other muscles than the painful ones can have good clinical effect on pain.

Considering the benefits of many different types of neck/shoulder training for reducing neck/shoulder pain the mechanisms of pain reduction should be investigated further. Although the present PhD study did not investigate the mechanisms of pain reduction it indicates that pain is a phenomenon that can be modulated by exercising muscles adjacent to the painful area. It can be speculated that input from receptors in muscles, tendons and joints from the neck/shoulder region modulates the neural circuitry of the CNS responsible for sustaining pain. The results from the present thesis combined with previous studies certainly suggests that stimulating areas of the body close to the pain region can reduce pain ï regardless whether directly training the painful muscle or the surrounding muscles.

In summary, several training programs targeting different muscles in the neck and shoulder region are effective for reduction of neck pain. This implies flexibility for clinicians prescribing exercises and for individual preferences among companies and employees when implementing training programs against neck pain. However, it also warrants further research of the mechanisms of pain reduction.

PPT

At baseline, in Study B, we found a lower PPT in the upper trapezius than in the lower trapezius. Both this pattern and the absolute threshold values are in agreement with an earlier study on pressure pain sensitivity maps of the neck-shoulder and the low back regions (Binderup et al., 2010). Although direct comparison of PPT between different body regions may not be valid, these results at least indicate that tenderness existed in the upper trapezius of the subjects in Study B.

Because blinding of participants is not an option in training studies, the results on changes in subjective pain of Study B and C may be influenced by placebo. Participants scored pain on subjective rating scales, which are inherently prone to placebo effects (Price et al., 1999,Andersen and Mikkelsen, 2012,Hrobjartsson and Gotzsche, 2010). Therefore, in Study B we measured PPT to get a more objective pain rating ï or actually pain threshold - in contrast to the purely subjective VAS measure. It should be noted that PPT may only be considered ñsemi-objectiveò, because the participant still rates the pain threshold but is unaware of the actual figure when the threshold is met. Thus, this measurement is likely less prone to placebo effects. Compared with REF, in the SFT the PPT recordings showed that pain sensitivity decreased selectively in the lower trapezius which was the only measurement site that had been trained. It has previously been shown that mechanical hypoalgesia can be induced in painful muscles by exercising the muscle, regardless of exercise mode (Slater et al., 2010,Nielsen et al., 2010). Although only specific exercise seems to increase PPT of a painful muscle, one study showed that the PPT of a pain-free reference muscle was increased in response to both specific and non-specific training, indicating a general effect of physical activity on pain perception (Nielsen et al., 2010,Arendt-Nielsen and Graven-Nielsen, 2008). This is also supported by Study B where PPT in the SFT group increased in all regions after the intervention, although between-group differences were only statistically significant at the lower trapezius. The sample size calculation for Study B were based on pain intensity and not PPT, thus Study B may have been underpowered to detect between-group differences in PPT of all the investigated body regions. Results from the present thesis along with previous findings at least indicates that subjects with musculoskeletal pain may be able to modulate general pain perception in other body areas by training non-painful muscle groups (Graven-Nielsen, 2006). Further supporting this notion, Study C showed that the change in pain in the two regions neck and shoulder were positively correlated and this is accordance with previous studies (Andersen et al., 2010b,Blangsted et al., 2008). Thus, pain in different regions of the body may change in parallel ï indicating a strong influence of central sensitization on perception of pain in general.

In summary, SFT significantly increases PPT specifically over the targeted muscles ï in the present thesis the lower trapezius - but also have a general effect in distant non-trained parts of the body, although in the present study this latter finding did not reach statistical between-group differences.

Upper dominant training

Study C confirms that upper dominant training leads to clinically significant pain reduction among pain cases, thus rejecting null-hypothesis D -*There is no difference between the three training groups 1WS, 3WS,and 9WS for the change in neck and shoulder pain from baseline to follow-up at week 20 compared with a reference group, REF* . These findings are in accordance with previous studies (Andersen et al., 2008c,Blangsted et al., 2008,Viljanen et al., 2003,Hagberg et al., 2000,Ylinen et al., 2003,Randløv et al., 1998,Zebis et al., 2011,Waling et al., 2000,Andersen et al., 2011e). In our study, the mean pain reduction among completers ranged from 47% (1WS) to 61% (3WS). Although a direct comparison between studies is difficult due to methodological differences regarding inclusion and exclusion criteria, specific pain questions, length and type of intervention etc, the marked pain reduction for neck cases in Study C is only surpassed with 79% reduction over 10 weeks by Andersen et al (Andersen et al., 2008c), who used a similar UDT protocol in women with trapezius myalgia, and 69% reduction in clinical neck pain patients over one year period by Ylinen et al. (Ylinen et al., 2003).

As a novel finding, Study C shows that the three time-wise distributions of UDT were not significantly different in reducing pain. Thus, 1WS, 3WS, and 9WS resulted in an average reduction in neck pain of 47-61%. Study C is the first to specifically compare effects of different time-wise distributions of a fixed 1 hr per week strength training program with equal volume. This adds detail to the observations by Coury and coworkers that both short and frequent sessions as well as longer and less frequent session can lead to satisfactory results (Coury et al., 2009). However, as 3WS showed numerically higher pain than 1WS and 9WS, we cannot rule out a statistical type 2 error. Coury and coworkers reviewed that there was lack of evidence related to the specific frequency and duration of sessions needed to provide relief of symptoms. In that review, the longer sessions (40 minutes to 1 hour) were associated with lower frequencies (two to three times a week), and shorter sessions (5 to 6 minutes) were associated with higher frequency (daily), with positive results in both cases (Coury et al., 2009). Most training studies in relation to neck pain have utilized three weekly sessions (Zebis et al., 2011,Randløv et al., 1998,Viljanen et al., 2003,Ahlgren et al., 2001,Hagberg et al., 2000,Blangsted et al., 2008). Two studies used five weekly sessions (Ylinen et al., 2003,Andersen et al., 2011e), but differences in exercise selection and training volume makes comparison to these two studies difficult.

In summary, Study C suggests that several combinations of a total of one hour of strength training per week are effective for pain reduction. The results from Study C also imply a large degree of flexibility for companies and employees regarding time distribution when implementing specific exercise into a weekly schedule. This is important knowledge as how ñexercises fit daily routineò has a large influence on training adherence (Medina-Mirapeix et al., 2009). At some companies a few long training sessions each week may be most suitable, whereas at other companies several short bouts of exercise may be a better approach.

DASH

In Study C we also asked questions concerning how pain in the shoulder, arm and hands influenced the work (DASH). The rationale behind the use of one outcome measure for different upper extremity disorders is that the upper extremity is a functional unit. In this respect, the DASH is suitable because of its property of being a measure of pain-related disability of the arm, shoulder and hand specifically in relation to work. Thus, while questionnaires on pain quantify intensity of symptoms, DASH provides information on the consequences of pain. It is of great relevance for individual employees as well as for companies that pain does not to a large extent limit the ability to perform daily work. DASH provides useful information on this matter. Estimates for minimal clinical important difference for DASH are approximately 15 pointes (Law and MacDermid, 2008) but a recent review argues that a value of at least 10 is sufficient for a clinical important difference (Roy et al., 2009). In Study C, 3WS provided the largest effect size for DASH with 9WS being generally less effective across the groups in the analyses. Only in 3WS the DASH reduction exceeded 10. However, as baseline DASH scores were 16 (18) there might be a floor effect as there is only little room for disability improvement in this population. Also discussing the term clinical important difference in relation to the average disability would be more appropriate in a more severely affected population.

In pain cases with regular adherence (at least 20 min per week) reductions in DASH range from 6 (14) in 9WS to 10 (21) in 3WS. Differences between groups for change in DASH is may be due to other factors than the physiological response to the training itself but group sizes between 16 (9WS) and 24 (3WS) may underpower the study

It thus seems that even though DASH evaluates the functional aspect of upper extremity disorders and generally is considered a good tool for measuring responsiveness of a treatment, in this context DASH is a less sensitive measure than neck pain intensity ï likely due to a floor effect. For individuals with severe chronic neck pain UDT can lead to clinically significant reductions in disability caused by pain, but the observed effect sizes were small.

Comparison of Study B and Study C

The participants in Study B and the pain cases in Study C were selected on identical criteria, had similar job exposure, and the SFT and 3WS had 3 × 20 minutes training weekly. Thus, on a number of outcomes a cautious comparison can performed in a meaningful way.

It appears that UDT leads to similar pain reductions in the neck as was seen after 10 weeks SFT. Compared with the reference groups the 3WS in Study C led to a reduction of 1.9 vs. 2.0 in SFT. However, it is unknown whether SFT would have produced larger pain reduction and surpassed the effect of the UDT if the intervention period was extended by another 10 weeks to match the length of Study C. It must also be considered that the participants in Study B reported pain intensity in the neck/shoulders (i.e. one question) while participants in Study C reported pain for each body part separately. The baseline pain was 0.9 higher in the SFT group than in the 3WS neck cases and this might have led to slightly larger absolute pain reduction. On an exploratory basis we have analyzed the group in Study C that were pain cases in either the neck or shoulders (neck/shoulder cases) and taken the highest pain score from either region. The 3WS group then had a slightly higher number of pain cases (n=175) and had a baseline neck/shoulder pain score of 5.0 where the neck pain was 4.3. In Study C, reduction in the combined neck/shoulder pain compared to REF was -1.6 [95% CI; 0.6 ï 2.6] and thus still quite similar to the reduction found in Study B.

The outcomes from this analysis in relation to DASH and time-wise distribution support the conclusions made from the neck cases.

The UDT performed in Study C was effective in reducing pain in the shoulders in shoulder cases. However, in Study B asking only a single question on combined neck/shoulder pain, it is unknown whether the SFT worked equally well in both regions or primarily was effective in either the neck or the shoulders. It can be speculated that the UDT was better suited for rehabilitation of shoulder pain as the glenohumeral joint was taken through both flexion (front raise), abduction (lateral raise), and extension (reverse flies) and these movement patterns are recommended in rehabilitation of a range of shoulder pathologies (Reinold et al., 2009). Contrary, in the two SFT exercises there was only minor movement in the glenohumeral joint.

Chronic neck pain symptoms are known to display seasonal variation, worsening in the autumn and decreasing in the spring (Takala et al., 1992). Thus, a general increase in neck pain symptoms could be expected in Study B as the study ran from October to December and a decrease could be expected in Study C as the study ran from January to June. These patterns were confirmed in the reference groups of Study B and C, respectively. As previously mentioned, another consideration in training studies like Study B and C is the effect of placebo as subjective rating scales are inherently prone to placebo effects (Price et al., 1999,Andersen and Mikkelsen, 2012,Hrobjartsson and Gotzsche, 2010). Consequently, training studies should include also objective measures. For this reason we included PPT and muscle strength measurements in Study B. However, in Study C, practical circumstances did not allow us to include objective measures of the 449 participants from worksites across Denmark.

Muscle strength

With intense muscle training as used in both intervention studies an increase in strength would be expected (Fleck et al., 2004,Peterson et al., 2005). Strength was evaluated directly through measurement of maximal strength (Study B) and indirectly through the progression in training weights used (Study C).

It has been suggested that musculoskeletal disorders in the neck and shoulder region may be linked to weakness of the scapulothoracic muscles (Andersen et al., 2008c,Cools et al., 2004,Glousman, 1993) or strength imbalance of these muscles (Sahrmann, 2005,Cools et al., 2005,Ellenbecker and Cools, 2010). In Study B the reference group experienced an approximately 10% increase in neck pain and decrease in shoulder elevation strength during the intervention period which can be contributed to progression of their painful condition, seasonal variation (Andersen et al., 2008a,Takala et al., 1992) and the inherent influence of pain inhibition on muscle strength (Andersen et al., 2008d).

In Study B, hypothesis C - *There is no difference between a shoulder function training group and a reference group for the change in protraction strength and for the change in elevation strength from baseline to follow-up at week 10* - is partially rejected. We expected that SFT would lead to a specific increase in shoulder protraction strength ï as this was trained - but not elevation strength which was not trained. In sharp contrast, we found an increase in elevation strength but not in protraction strength. The lack of increase in protraction strength leads us to question whether the training intensity in practise was as high as intended and therefore not sufficient for strength gain although the participants were urged to keep the intensity high. This may also be due to low statistical power as the protraction test showed lower test-retest reliability than the shoulder elevation test. The increase in shoulder elevation strength on the other hand may be caused a reduction in pain inhibition of the non-trained upper trapezius. Since we did not include pain free participants we can only speculate in this regard.

In Study C we evaluated strength gains indirectly through logbooks with registration of training weights. Although this may be associated with overestimation of strength gains, it provides a rough comparison in strength gains between 1WS, 3WS and 9WS. As pointed out by Rutherford and Jones (Rutherford and Jones, 1986), measuring strength gains from a RM load lifted in a specific strength training exercise, may indeed be markedly biased by the effect of learning a technical difficult maneuver (e.g. improved stabilization from synergist muscles, decreased antagonist muscle co-activation). Hence, more complex exercises are inherently associated with greater potential for learning effects. Thus, increases in training load in a specific exercise may often double or more within a few months in healthy novice trainees (Rutherford and Jones, 1986,Jones and Rutherford, 1987,Roig et al., 2009). Study C contributes to these previous findings by showing that individuals with and without pain experience similar progression in training loads, i.e. pain at baseline did not significantly halt progression in training loads. We observed that a doubling of training load was not uncommon (Figure 12 page 16). Although decreasing number of repetitions as the training progressed could account for some of the increases in training load, the estimated 10RM (LOCF) increased on average 46 % (from 3.9 to 5.7 kg, $p<0.001$) (Figure 12 page 16). Thus, from increases in training load that could be lifted a given number of times, it is impossible to determine the true gain in muscle strength, as this result is influenced by the biasing effect of learning a specific task. Our null-hypothesis E was that *There is no difference between the three different training groups 1WS, 3WS, 9WS for the progression rate in training loads during the intervention*, and this was rejected as the average increase in 10RM for the lateral raise was significantly higher for completers in 1WS compared with 9WS ($p< 0.01$). The average increase in 10RM had a tendency to be higher in 3WS compared with 9WS ($p= 0.08$). With ITT analysis there was a tendency that the progression rate was higher in 1WS compared with 9WS (p=0.07). These results were in contrast to our initial thoughts as we expected that 9WS would experience the greatest increase in training weights as the participants in this group would be less fatigued during each 7-minute session and thus be able progress faster. This can have several explanations. One can speculate that the participants were cautious to use the heavier weights in the first sets and due to the short sessions did not get a chance to ówork upô to these weights. Another reason could be that a certain amount of fatigue and muscular metabolites has to be accumulated during a training session for optimal progress. However this is not supported by EMG analysis of a training session performed in our lab where we found no change in EMG amplitude and mean power frequency from first to third set in any of the exercises (Jakobsen et al., 2011). On the other hand, the EMG being a measure of electrical activity travelling across the muscle membrane may not well reflect metabolic fatigue with the muscle fibers. In the 10 week intervention described by Andersen et al 2008 participants had increase in training weights in lateral raises of 104% (unpublished data) and in the shrugs exercise training weights were increased by 154% (Andersen et al., 2008c). However, the increase in isometric shoulder elevation strength was only 34% (Andersen et al., 2008c) underlining the difficulties comparing data from training weights with a non-related maximal strength test.

In summary, SFT may ï contrary to our expectations - lead to increased strength of the non-trained upper trapezius (shoulder elevation strength), without increase in the trained serratus anterior (protraction strength). Individuals with and without pain experience similar progression in UDT loads, i.e. pain at baseline did not significantly halt progression in training loads. Fewer and longer sessions of UDT have the greatest effectiveness in relation to increasing training weights.

***Perspectives for future research*:**

Both shoulder function training and upper dominant training of high intensity seem to have high efficacy on rehabilitation of neck/shoulder pain, but further knowledge about possible benefits from combining the two training modalities could provide deeper insight. If pain is reduced through different mechanisms a combination of shoulder function training and upper dominant training could provide optimal pain relief.

In order to increase intervention effectiveness and reach high training adherence it is important to take both individual and workplace barriers into account and in collaboration with all stakeholders fit the intervention to the organisation. There is detailed knowledge of risk factors for developing neck and shoulder pain but the knowledge of effective workplace implementation is still limited. Figure 13 presents a possible framework containing individual (capacity) and workplace (exposure) risk factors and barriers to training that can affect development and management of work-related neck pain. However, evidence on how to systematically minimize the effect of these and other barriers in workplace implementation is still lacking.

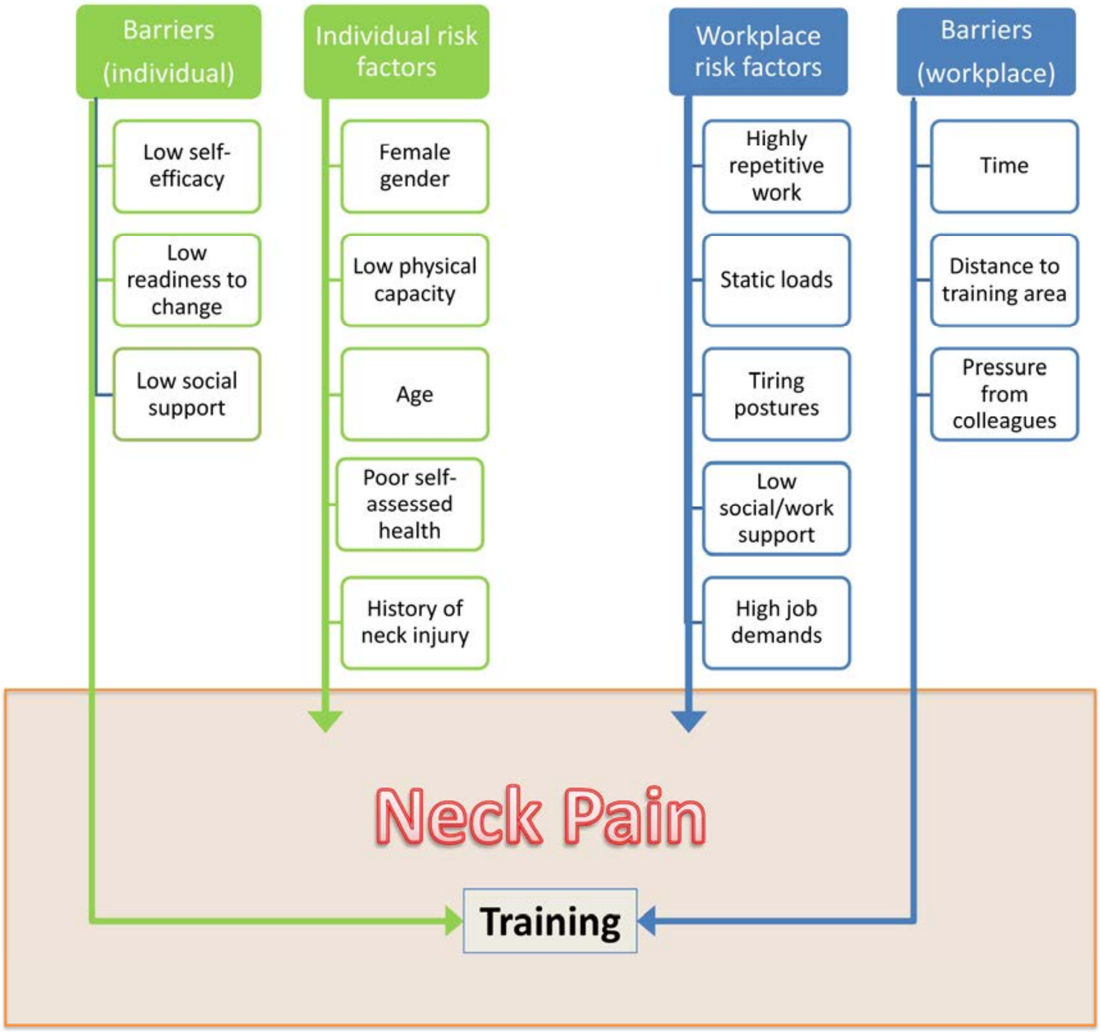

Figure 13: Risk factors of neck pain which may contribute to the development of neck pain and barriers to training which can effect management of neck pain. Inspired by Armstrong et al 1993 (Armstrong et al., 1993)

Conclusions

Study A is the first to demonstrate predominant activation of specific parts of the scapular musculature in selected training exercises at high intensities ï thus rejecting null-hypothesis A of this thesis. This has implications for rehabilitation, injury prevention, and performance training. We have identified two high-intensity shoulder function training exercises ï push-up plus and press-up - to specific target the serratus anterior and lower trapezius while minimizing activation of the upper trapezius.

In Study B and C, shoulder function training and upper dominant training of different time-wise combinations, respectively, effectively reduced non-specific neck/shoulder pain in office workers with baseline pain intensities of at least 3 (scale 0-9) ï thus rejecting null-hypotheses B and D of this thesis. Further, in Study B, 10 weeks of shoulder function training led to increased pressure pain threshold over the targeted muscle groups as well as indications of a general effect in distant non-trained parts of the body. Study B also showed ï in contrast to our expectations - increased strength of the non-trained upper trapezius (shoulder elevation strength), but not of the trained serratus anterior (protraction strength) ï thus partly rejecting null-hypothesis C of this thesis. Disinhibition of pain inhibition may explain this unexpected finding. Further, we found that 20 weeks of upper dominant training reduced disability in the arms, shoulders and hands (DASH). In Study C, the progression rate in training load was faster when performing fewer and longer sessions as opposed to more and shorter sessions.

Altogether, the result of the present thesis suggest that traditional strength training exercises for the neck and shoulder (Study C) as well as exercises commonly recommended by physical therapists (Study B) effectively relieves neck and shoulder pain. Furthermore, the present thesis adds to existing knowledge on the influence of frequency and duration of training by showing that both fewer and longer as well as more and shorter sessions of high-intensity training provides pain relief. Importantly, the results of the present thesis implies flexibility for companies and employees regarding individual preferences for exercise selection and time-wise distribution when implementing specific training exercises in an effective manner into a weekly work schedule.

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