Exercise and work-related musculoskeletal disorders in neck, shoulders and low back
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Institute of Exercise and Sport Sciences, University of Copenhagen

PhD thesis

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PhD Thesis

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List of Abbreviations

ANOVA analysis of variance
EMG electromyography
LBP low back pain
MVC maximal voluntary static contraction force
RFD rate of force development
RCT randomised controlled study
SL sudden back loading
WMSDs work related musculoskeletal disorders
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Preface

This PhD project is the result of co-operation between the Institute of Exercise and Sport Sciences (IESS), Copenhagen, and the National Institute of Occupational Health (NIOH), Copenhagen (Department of Physiology). The first study (I) was also performed in collaboration with Clinic of Occupational Medicine, Glostrup Hospital. Senior researcher PhD Nils Fælten-tin, NIOH, associate professor DSc Kurt Jørgensen, IESS, and associate professor DMSc PhD Lars Bo Andersen, IESS, provided mentorship.

Study I was financed by the Danish Working Environment Fund. The Institute of Exercise and Sport Sciences and the National Institute of Occupational Health financed the other studies.

Study I was part of a large-scale prospective epidemiological study on work related musculoskeletal disorders (The PRIM study). Study II, III, and IV were parts of a major research project concerning occupational risk factors of low back disorders among health care workers.

The project has been approved by the ethical committee of Copenhagen and Frederiksberg, Denmark ((KF) 01-104/94 and (KF) 01-224/01).

Mogens Theisen Pedersen
Copenhagen, September 2003
I would like to thank my colleagues at the Department of Physiology at the National Institute of Occupational Health and at The National Institute of Exercise and Sport Sciences, who have all been kind and supportive throughout the project.

In particular I would like to thank the following people

• My supervisor Kurt Jørgensen for invaluable support and professional advice during the preparations of the PhD-study and for support and professional advice throughout.
• My supervisor Nils Fallentin for having always been there when I needed help and for a lot of invaluable professional help and advice.
• My statistics supervisor Lars Bo Andersen for professional advice.
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• Jørgen Skotte for invaluable technical support and computer programming.
• Morten Essendrop for close co-operation, practical help, numerous discussions, computer programming and for having always been helpful.
• Gisela Sjøgaard for discussions and for involvement in the project.
• Jesper Strøyer and Helene Garde for statistical help and discussions.
• Gunilla Harrit at Vordingborg Hospital for positive co-operation.
• Leaders, managers, participants and controls from Dansk Supermarked, FDB and Vordingborg Hospital.
The present thesis is based on four studies represented by 4 papers. In the text they will be referred to by their Roman numerals:

I: Pedersen MT, Mikkelsen S, and Fallentin N.

II: Skotte JH, Fallentin N, Pedersen MT, Essendrop M, Stroyer J and Schibye B.

III: Pedersen MT, Essendrop M, Skotte JH, Jørgensen K, Fallentin N.
Training can modify back muscle response to sudden trunk loading. *European Spine Journal* (The paper is submitted, and accepted (March 15th) on the condition of a minor revision including addressing comments of the reviewers. This has been done and send to the Editor (April 15th)).

IV: Pedersen MT, Essendrop M, Skotte JH, Jørgensen K, Fallentin N.
Back muscle response to sudden trunk loading can be modified by training among health care workers. *Spine* (Submitted).
Conceptual models illustrating factors that influence the development of work related musculoskeletal disorders (WMSDs) has been presented by e.g. Armstrong et al. (1993) and Westgaard and Winkel (1996, 1997). Basically, all models describe a causal relationship between certain generic work place risk factors (external exposure) and musculoskeletal health. The concept of exposure has, however, been somewhat broadened and recently defined as „any feature of the environmental and organizational context of the work and non-work situation that can be seen as external to the individual and might affect his or her health“ (Hagberg et al. 2001). At the same time focus has been on the exposure dose relationship emphasising that the target tissue dose of the hazardous exposure or injuring agent may vary widely from person to person, interacting with relevant characteristics of the individual that determine vulnerability or resistance (NRC Corporation 2001).
Taken together, the above examples represent a swing towards an increased attention regarding the importance of individual physiological- and psychological characteristics in the development of WMSDs. Figure 1 illustrates this development by highlighting the interaction of individual characteristics and mechanical stressors in the development of WMSDs (NRC Corporation 2001). Figure 2 is another recent model emphasising the physical and social context for work place health hazards, the complexity of exposure, and the influence of the individual characteristics of the worker.

This PhD-thesis adheres to this general way of thinking by focusing on training interventions and the modification of the physical characteristics of the individual worker as potentially efficient measures to prevent WMSDs.

Highlighting individual factors and the physical characteristics of the worker, e.g. training status, is not in discord with the view that physical (mechanical) work place risk factor are main determinants for WMSDs.
Two major reviews issued by NIOSH and the National Academy of Science in the US convincingly presents the epidemiological evidence for a causal relationship between physical work place risk factors and development of WMSDs:

For upper extremity disorders there is evidence of a causal relationship with the following risk factors: repetitive tasks, forceful tasks, the combination of repetition and force and the combination of repetition and cold (NRC Corporation 2001). The neck, shoulders and upper arms operate as a functional unit, which makes it difficult to estimate specific exposure factors for the neck/shoulder region beyond that of job or job tasks (NRC Corporation 2001). Still for the shoulder documented risk factors have been attributed to high repetitiveness, awkward work positions, static work, repeated or continued shoulder positions with more than 60 degrees flexion or abduction (Bernard 1997). For the neck documented risk factors have been attributed to high repetitiveness involving arm and hand movements and neck movements, forceful arm and hand movements, high static neck load, continuous static load and extreme neck-working-postures (Ariens et al. 2000; Bernard 1997; Viikari-Juntura et al. 2001).

Documented risk factors for work related low back pain (LBP) are heavy physical work, lifting and/or carrying heavy weights, forceful movements, awkward working postures (frequent bending and twisting) and whole body vibrations (Bernard 1997; NRC Corporation 2001). An important fraction of LBP-cases seem to be due to sudden back loading (SL) such as e.g. slips while carrying a heavy weight or catching a falling object (Manning et al. 1984; Marras et al. 1987). Cholewicki and McGill (1995) stated that even light burdens could be a risk factor for sudden LBP because of the risk of buckling in the relaxed state. Pope suggested in a post hearing comment on the Occupational Safety and Health Administration’s (OSHA’s) proposed standard on ergonomics, that the standard should recognize unexpected SL as an ergonomic risk factor (Pope 2000).

The concept of specificity of association – i.e. that a risk factor is associated with one specific outcome and not others – needs to be considered with caution in relation to WMSDs. There are, however, frequent observations indicating that jobs with characteristic exposure profiles exhibit a preponderance of WMSDs in certain body regions, and the two job groups studied in the present study (supermarket checkout workers and health care personnel) represent highly different exposure/response profiles.

There is a high frequency of WMSDs in the upper extremities (shoulder/neck) among supermarket checkout workers (Ayoub 1990; Harber et al. 1992;
Lundberg et al. 1999). The introduction of electronic scanning check-out systems seem to have increased the frequency of disorders due to an increased working pace (Grant and Habes 1995). Grant and Habes (1995) found based on a literature review that 37-56% of grocery cashiers experience regular pain in the upper extremity. Lundberg et al. (1999) found an incidence of 60-75% of neck and shoulder disorders among employees working at supermarkets.

Work-related LBP is more frequent among health-care personnel (Estryn-Behar et al. 1990; Jensen et al. 1995; Smedley et al. 1995). In a Danish study among health care workers 67% reported LBP within the last year against 45% among employees from various other occupations (Jensen et al. 1995). Patient handling including SL and lifting heavy weights were risk factors for LBP (Jensen et al. 1995).

**Individual risk factors for upper neck, shoulder and back pain**

Pinpointing individual characteristics expected to have the most prominent effect on musculoskeletal outcomes have hitherto focussed mainly on two inherent muscle characteristics: muscle strength (including lifting capacity) and muscle endurance. In recent years, however, more subtle aspects of motor control and local reflex mechanisms have received increased attention.

**The „traditional“ view: Muscle strength and endurance**

**Neck and shoulder**

The association between muscle strength/endurance and the frequency of musculoskeletal disorders in the shoulder and neck is not clear-cut. In a prospective study female care assembly-workers with low static shoulder strength and low muscle endurance had a greater risk for shoulder/-neck disorders compared to their colleagues (Kilbom 1988). Car assembly-workers performed their job standing and walking lifting weights up to 100N. In a study among female workers in the electronic industry there were no association between shoulder function and development of shoulder/neck symptoms (Kilbom 1988). These workers did precision work while being exposed to static postural load. A prospective study among bank caschiers (Takala and Viikari-Juntura 1991) did not show any association between shoulder strength and endurance and the development of neck/-shoulder symptoms.
Low back
Several prospective studies have examined the association between back muscle function and LBP. Maximal isometric back and abdominal strength failed to show any association to the development of LBP in a number of studies (Kujala et al. 1996; Nordgren et al. 1980). Likewise there was no association between development of LBP and maximal lifting capacity (Battié et al. 1989; Luoto et al. 1995; Newton et al. 1993; Newton and Waddell 1993).

Isokinetic measurements did not show the expected association between low strength and development of LBP (Newton et al. 1993; Newton and Waddell 1993; Takala and Viikari-Juntura 1997). On the contrary Masset et al. (1998) found that individuals performing dynamic trunk tests at high velocities appeared to be at greater risk of LBP.

Biering-Sørensen (1984) found that low static back endurance was associated with the development of LBP among men without an earlier history of LBP. This was supported by Jørgensen (1997). Luoto et al. (1995) showed that individuals with low static back endurance (from 4 different job categories) had a three-fold risk of developing LBP.

Studies have failed to document associations between dynamics back or abdominal endurance and development of LBP (Kujala et al. 1996; Leino et al. 1987; Luoto et al. 1995).

The „newcomer“: motor control aspects

Edwards (1988) presented a hypothesis suggesting, that improper motor control could be the key aspect in WMSDs. Eleven years later the motor control aspect has been the „hot topic“ in discussion of low back disorders and at Calgary McGill summarized the new trend by emphasizing: „New evidence points to the loss of fitness of the motor control system where the most appropriate motor patterns are not produced following injury leading to the risk of injury exacerbation. This leads to unstable shearing and bending motions which damage tissue“ (McGill 1999).

Lumbar stability models emphasize that the mechanical stability of the spine prior to loading, and the reflex response of the muscles immediately after loading combine to determine the kinematic response of the trunk and subsequent likelihood of injury (Cholewicki 1999; Ebenbichler et al. 2001; McGill 2001; Morris et al. 1961). In the absence of muscle contraction buckling of the lumbar spine occurs under compressive loads as little as 2 kg (Morris et
al. 1961)). The muscles have been shown repeatedly to be the most important factor in spinal stability under various conditions (Cholewicki and McGill 1995; Ebenbichler et al. 2001; Solomonow et al. 1998). The degree of muscle activity may be regulated by the gamma system and proprioceptive, kinesthetic, and nociceptive information from the spinal ligaments, disks and joint capsules play a key role in the control of back muscles (Ebenbichler et al. 2001; Johansson and Sojka 1991). Sjölander and Johansson (1997) stated that „proprioceptive triggering which is a feedback process by which proprioceptive input about the position and velocity of a moving joint can be used by the central nervous system to trigger other motor responses during the execution of a movement“. Feedback by proprioceptive triggering is supposed to function during fast movements (like trunk movements during sudden spine loading) in contrast to feedback servo regulation of slow movements (Sjölander and Johansson 1997).

Injury, fatigue, disturbed muscle metabolism, psychosocial stress, biomechanical constraints (e.g. in connection with precision work or conflicting motor programs (Ebenbichler et al. 2001; Oddsson et al. 1999)) will influence the quality – and/or the „interpretation“ – of information from the sensory system which is decisive of normal and appropriate motor control.

Magnusson et al. (1996) and Wilder et al. (1996) showed that low back patients had longer erector spinae EMG reaction times (or onset latencies) during a sudden back loading incident than their matched controls. During a quick-release test patients had longer reaction times for muscles shutting off (70ms) and switching on (83ms) and in addition patients had a different muscle response pattern (Radebold et al. 2000). A different muscular function accompanying low back pain has also been documented in other studies: delayed onset of specific torso muscles during sudden events (Hodges and Richardson 1996, 1999; Radebold et al. 2001); changes in torso agonist/antagonist activity during gait (Arendt-Nielsen et al. 1995) and asymmetric muscle output during isokinetic torso extensor effort (Grabiner et al. 1992). Luoto et al. (1996) and Taimela et al. (1993) found a decrease in eye-hand reaction time among low back patients compared to non-patients. These motor-control differences between patients and healthy controls can be a reaction to the injury itself, or it may, alternatively, reflect an individual predisposing factor to low back injuries.

The efficiency of reflexive motor patterns are thus vital for maintaining stability during sudden events (Cholewicki et al. 2000) and may also be of major importance in adapting the individual capacities to meet occupational demands.
Modification of individual physical capacity as a preventive measure: Results from intervention studies

Hypothetically a high level of fitness of the musculoskeletal and cardiovascular system in workers in physically demanding jobs could benefit the worker and prevent the development of WMSDs (due to a reduced relative work load compared to the load on less fit workers). Heavy occupational work does however not automatically promote the fitness and training status of the workforce – some studies actually indicate a degradation and reduction of fitness (Nygårud et al. 1994; Schibye and Hansen 1999) - and a number of intervention studies have tried to implement exercise training as a means of increasing individual physical capacity and reduce the incidence of WMSDs.

Shoulder and neck

There is conflicting evidence about the effectiveness of exercise programs for management of neck and shoulder pain. Results from studies of training programs initiated in order to prevent musculoskeletal disorders in neck and upper extremity are far from being consistent. Dyrssen et al. (1990) found a positive effect of intensive strength training (30 min 3 times a week for 3 months) on musculoskeletal complaints in neck and shoulder among office workers. Intensive neck strengthening (for 8-11 weeks) has been shown to decrease pain among female office workers and patients (Berg et al. 1994; Bronfort et al. 2001; Levoska and Keinanen-Kiukaanniemi 1993). In a randomized controlled study (RCT) among insurance workers Grønningsäter et al. (1992) found a significant effect of aerobic, strength, flexibility and relaxation exercises (10 weeks, 2 times per day, 55 min, 3 times a week) on neck pain at 6 months follow up. Silverstein et al. (1988), however, found no effect of combined strength, endurance and stretch training 14 minutes a day for one year on the incidence of complaints among assembly workers. Takala et al. (1994) found no effect of 45 minutes of light gymnastics a day for 10 weeks.

In conclusion, Barondes et al. (NRC Corporation 2001) and Mior (2001) summarized the results from literature reviews by stating „that the evidence of effectiveness of exercise in management of neck and shoulder pain was limited except for fibromyalgia (Mior 2001)“.
**Low back**

The evidence for a positive effect of exercise for management of LBP appears to be more consistent. The evidence, however, is mainly based on studies of rehabilitation and reoccurrence LBP. In the study by Grønningsäter et al. (described above) there was a significant effect of 10 weeks of aerobic, strength, flexibility and relaxation exercises on LBP.

In a RCT among hospital employees Gundewall et al. (1993) found a positive effect of back muscle strength training (13 months, 2-6 times per week, 20 min) on low back complaints and the intensity of pain.

In another study among hospital workers Oldervoll et al. (2001) compared the effect of two different physical exercise programs on LBP. Both endurance and strength promoting training reduced pain compared to the changes in the control group with no difference between intervention groups.

In a RCT among a population with a history of LBP an active back school, comprising of 20 one hour lessons of 20 min theoretical and 40 min exercise part (35 min circle-strength training and 5 min stretching exercises), the re-occurrence and severity of new LBP episodes at 5 and 12 and 36 months follow up was reduced (Glomsrod et al. 2001; Lonn et al. 1999). Soukup et al. (1999) also in a RCT found a reduction in reoccurrence of new LBP episodes at 12 month follow up after 20 one-hour group sessions of a Mensendieck program among a population with history of LBP. The Mensendieck approach combined ergonomic education and strength and endurance exercises as well as coordination exercises for the hip, pelvic and upper body.

Mior (2001) concluded in a review that exercise is effective for the management of chronic LBP for up to one year after treatment, but no particular exercise program is favoured. Two of three recent high quality studies documented a positive effect of exercise on LBP (NRC Corporation 2001).

Magnusson et al. (1996) have demonstrated that training can alter the back muscle response to SL in patients: after 2 weeks of rehabilitation including specific training of coordination and posture control, EMG reaction time and amplitude decreased. The change in motor-control resulting in a quicker and „more efficient“ reaction to unexpected SL was supposed to reduce the mechanical load on the spine and thus decrease the risk of new back pain.

In a recent review Proper et al. (2003) stated that there is strong evidence for a positive effect of worksite physical activity programs on musculoskeletal disorders but more high qualitative studies are needed taking into account criteria such as randomisation, blinding and compliance.
Aims and hypotheses

Based on the information presented in the above sections the PhD-study was initiated with the aims of:
1) Providing new insight into the effect of a traditional muscle strength and endurance training program on shoulder/neck disorders in cashier checkout workers (study I).
2) Elucidating the potential possibilities of improving motor control aspects and the individual adaptive responses to SL among health care workers (study II, III, IV).

The hypotheses were:
1) In a well-designed and controlled study muscle strength and endurance training can be shown to be efficient in preventing the development of neck and shoulder complaints among cashier checkout workers.
2) Motor control training can improve neuro-muscular reactions and spinal protective mechanisms in individuals exposed to SL.
Material and methods

For an overall description of the methods readers are referred to the original papers. This section elaborates certain methodological aspects related to the physical training programs, the SL-measurements and the EMG-data analyses and describes shortly the use of questionnaires for evaluating the effect of training.

Overall design

Study I was designed to investigate the health effect of a muscle strength and endurance training program on shoulder/neck disorders in cashier checkout workers. The study was primarily initiated on the basis of conflicting evidence about the effectiveness of exercise programs for management of neck and shoulder pain combined with the fact that a negative association had been found between muscle strength and development of shoulder neck- pain among workers exposed to high repetitiveness including high loads (Kilbom 1988).

Study II was a method study necessary for carrying out study III and IV.

In study III and IV the effect of training on the response to SL among untrained healthy individuals (study III) and health care workers (study IV) was investigated. The studies were primarily initiated on the background that strength and endurance training has been effective for the management of chronic LBP, but studies on coordination training for improving the reaction to SL had only been performed in low back patients.

Cullen (1990) has published a model with four necessary steps required for building up the evidence base for nationwide prevention programs (step 5):

1. Etiological studies
2. Case studies
3. Controlled intervention trials.
4. Population studies
# Material and methods

<table>
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<tr>
<th>Intervention Studies</th>
<th>Subjects</th>
<th>Measurements</th>
<th>Measurements</th>
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<td><strong>training</strong></td>
<td><strong>control</strong></td>
<td><strong>before the intervention</strong></td>
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<tr>
<td>I 30 training sessions of 45 minutes muscle strength and endurance training during a 15-weeks period. The training was progressive resistance training with dumbbells for neck and shoulders.</td>
<td>29 cashier checkout workers</td>
<td>24 cashier checkout workers</td>
<td>Isometric strength in neck/shoulder</td>
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<td>10 sessions of 45 minutes of readiness training during a 4-weeks period. The training was focused on reactions to a variety of expected and unexpected sudden trunk loadings including balance and coordination exercises.</td>
<td>19 untrained healthy office workers and researchers</td>
<td>19 untrained healthy office workers and researchers</td>
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<td>18 sessions of 1 hour readiness training during a 9 weeks period. The training was focused on reactions to a variety of expected and unexpected sudden trunk loadings including balance and coordination exercises.</td>
<td>23 employees working at a geriatric ward</td>
<td>14 employees working at a geriatric ward</td>
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<td>Questionnaire about health and physical training (for inclusion)</td>
<td>Questionnaire about health and physical training (for inclusion)</td>
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<td>Reaction to sudden expected and unexpected SL(^1)</td>
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**Method Study**

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<tr>
<td>II 19 male construction site workers</td>
<td>Reaction to sudden expected and unexpected SL(^1)</td>
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\(^1\) EMG activity from the erector spinae muscles and trunk movement data were recorded during SL’s.
In this thesis study I represents a study at step 3 in the model. Study III and IV are also controlled trials, but represent a more basic approach focusing on mechanisms and potential etiologic factors (step 1 research).

In table 1 an overview of material and methods (including procedure) for the 4 studies is presented.

**Material**

In study I all 107 workers at the cashier checkouts in two supermarkets were invited to participate in the project. 75 (70%) accepted, 26 men and 49 women. Their average age was 25 years (range 18 to 61 years). Sixty-five had cashier checkout work only, while 10 were service workers with more varied work and only a few hours at the cashier checkout. The median working hours were 19 hours/week (range 8-40 hours/week). The median working hours at the checkout were 14 hours/week (range 0-40 hours/week). Eighteen (24%) worked at the checkout 0-9 hours, 20 (27%) 10-14 hours, 22 (29%) 15-34 hours and 15 (20%) 35 hours or more. Before the intervention started, the participants were allocated to a training group ($n=42$) and to a control group ($n=33$). The training group was made a little larger than the control group as more dropouts were expected in the training group. The allocation to the two groups was made at random from 4 complaint strata, recorded by the Nordic Musculoskeletal Questionnaire (Kourinka et al. 1987; Palmer et al. 1999): 1) subjects without any pain or discomfort in the neck or shoulders during the last 12 months; 2) subjects with pain or discomfort in one region (neck or one of the shoulders); 3) subjects with pain in two regions (neck and one shoulder or both shoulders); and 4) subjects with pain in all three regions (neck and both shoulders). However, the initial randomisation could not be strictly adhered to in practice. Five subjects selected for training were not at work during the training sessions. Therefore these persons were exchanged with subjects from the control group with similar complaints (complaints or not within 12 months in left-right shoulder and neck). It turned out that the substitutes in the training group had the same frequency of complaints as the planned participants, but the intensity of pain was higher. Also 2 persons, who had not filled the questionnaires before the intervention, were not randomised. But quantitatively the most important problem was that the dropout in the training group (13 subjects) was highest among persons without initial complaints.

These non-random events have introduced a skewed distribution of initial
complaints in the final training and control group, i.e. those of the original training group who participated in more than 50% of the training sessions (n=29) and those of the control group that participated in all examinations (n=24).

In study III 19 subjects in the training group (3 men and 16 women; mean age 35 years, range 23-54 years) were matched on the bases of age, anthropometrical measurements, job function and physical activity to 19 controls (5 men and 14 women; mean age 35 years, range 24-52 years). All were untrained office workers and researchers at the National Institute of Occupational Health. Study IV included 23 participants (21 women 2 men; mean age 41, range 24-58) and 14 controls (14 women; mean age 44, range 22-58) working at a geriatric ward as nursing aides, orderlies, physiotherapists or occupational therapists. Working schedules was the key factor for allocating subjects to the control or training group. Randomisation or matching was not possible. A bias due to the distribution of participants and controls was not expected because the job functions and the amount of spare time physical activity in the control and training group were comparable.

In study II there was one group of 19 male construction site workers (mean age 39, range 27-55).

**Training**

In all training studies the control group worked as usual and was not offered any form of training. In study I the training group was given the opportunity to participate in 30 training sessions two times a week during working hours. The training was done in small groups of 6-8 people and each session consisted of 5 minutes of warming-up to music and 30 minutes of strength and muscle-endurance training with dumbbells. At each session the same 6 shoulder/neck muscle exercises (figure 3) were done twice with a repetition maximum (RM) of 10-15 repetitions. If a participant could do more than 15 repetitions in an exercise, the weight was increased at the next performance of the same exercise. An instructor supervised the training each time.

At every training session participants filled in a training-diary with information about training load and number of repetitions for each exercise. The relative increases in load for each exercise during the intervention period are illustrated in figure 4. The increase is relative to the starting load at the third training session (after getting used to the training).
Material and methods

Figure 3. Training exercises

Townsend et al. (1991) showed by EMG-measurements that abduction in the scapular plane with thumbs down (shoulder inward rotation) increased the activity of m. supraspinatus compared to the same exercise without shoulder-inward rotation. This exercise was therefore chosen as an exercise for strengthening the supraspinatus muscle.
The contents of the motor control training programs in study III and IV was the same, except that the duration and intensity was increased in study IV (moderately trained health care workers) compared to study III (untrained office workers and researchers). In study III the participants completed 10 sessions of 45 minutes during 4 weeks. In study IV the training group participated in a total of 18 sessions of 60 minutes during 9 weeks. Each training session consisted of 10-15 minutes of standardized warm-up exercises for the whole body including static and dynamic endurance exercises for abdominal and back muscles. The warming-up was followed by 30-40 minutes of exercises focusing on expected and unexpected trunk loadings (readiness training). Finally 5 minutes were used for cooling down and stretching. The difficulty and intensity of the program was adjusted to the individual and increased progressively during the 9 weeks of training. In order to maintain intensity and motivation most exercises were accompanied by music. Below is a description of 6 typical trunk-loading exercises.

Figure 4. Progression in training load. Changes are relative to the mass of the dumbbells used for each exercise. Bars represent 1 SD.
Material and methods

Figure 5ab. Boxing match. A competition in pairs about which participant was able to touch the shoulder of the opponent most frequently without being hit.

Figure 6ab. Quick-reaction-jumping. During vertical jumping the participants were instructed to react to a sudden sound in the air-phase of the jump. On first ground contact after the sound they should perform a certain move as fast as possible. In this sequence they were instructed to jump to the right.

Figure 7ab. Jumping with rubber-band-connection. Participants were tied together with a rubber band at the chest and instructed to jump in a predefined pattern and frequency (beat of music) hitting marks on the ground with the feet. Every second participant had a different jumping pattern causing varied disturbances to the nearest persons.
Material and methods

Figure 8ab. Goal-keeper-exercises. Numerous „goal keeper“ exercises were used including exercises with heavy balls (3-5 kp). The figure shows one example: As a reaction to a sound signal the participant was instructed to turn around and catch a ball, which was thrown at the instant of the sound signal.

Figure 9ab. Balance exercises sitting on a teeterboard. Progression was introduced by crossing the arms around the chest or by catching and throwing a ball while balancing on the board.

Figure 10ab. Quick-back-load competition. Participants competed in pairs. One person started lifting the stick above the head as fast as possible, and the opponent should try to overtake the move (try to finish the same movement faster than the starting opponent). After 10 trials the tasks were changed between the two persons. The winner was the person who was able to overtake the move most frequently.
Sudden back loading (SL)

In study II the method developed for imposing a SL on the subject (subsequently used in study III and IV) is described in detail. Briefly, the set-up for creating the SL was constructed as a load (58N) that momentarily could be attached to a wire (figure 11). The wire was running over a reel hereby transmitting the gravitational force of the load as a horizontal force applied to the trunk. The movement of the trunk was measured by a potentiometer mounted on the reel. The subject was fixed at the hip to obtain isolated trunk movements, and to avoid any changes related to maintenance of postural stability. The set-up was controlled by a computer, which triggered the SL either on request by the investigator (expected SL; study IV) or with a random delay between 10 and 30 seconds unknown to both the subject and the investigator (unexpected SL; study III and IV). The subjects were asked to stand as relaxed as possible and informed that they would experience a sudden, moderate force pulling them forward, which they were asked to resist in order to maintain their posture. Each subject was exposed to a set of 11 unexpected trials (study III and IV). This was in study IV followed by 11 expected SL elicited 1-2 s after asking the subject to be ready.

Figure 11. Set-up for generating a sudden forward pull to the upper part of the subject’s trunk.
**Electromyography**

In study II, III & IV pre-gelled Ag/AgCl surface electrodes were used to record the EMG activity of the erector spinae muscles during the SL trial. The electrodes were placed 3 cm apart on both sides of L3, approximately 3 cm lateral to the spinal column in the middle of the muscle belly. EMG signals were pre-amplified (25 times), high-pass filtered with a cut-off frequency of 10 Hz (1st order), further amplified (variable gain) and low-pass filtered with a cut-off frequency of 400 Hz with an 8th order Butterworth filter. The amplified and filtered EMG signals were sampled with 1000 Hz. The EMG recordings were high pass filtered (2nd order) with a cut-off frequency of 25 Hz and rectified. In study III the EMG-signal was rectified and normalized according to EMG-signals obtained from a standardized sub maximal static back extension, which was performed at the test before and after the training intervention. In order to analyse EMG-amplitude the normalized signal was integrated in time intervals of 25 ms in the period from 50 ms to 325 ms after the SL. Below is a detailed description of how the differences in the time wise distribution of the EMG response in subjects before and after training were analyzed:

Figure 12a shows the normalized rectified EMG signal (R-erector spinae) for one trial before the intervention. The columns illustrate the area under the EMG-curve (integrated EMG) in intervals of 25 ms from 50-325 ms after the SL. Column 1b represents the area under the EMG-curve from 50ms to 75 ms, column 2b the area from 75 ms to 100 ms... In the same way figure 12b shows the EMG signal and integrated EMG for one trial for the same subject after the intervention. Figure 12c shows the differences (after-before) in integrated EMG illustrated in intervals of 25 ms for one trial. The bars illustrate differences in integrated EMG calculated as the differences of the bars in figure 12b and 12a e.g:

$$75-100 \text{ ms}: \text{differences in integrated EMG} = 2a-2b$$

The means of the differences in intervals of 25 ms for all trials of unexpected SL for the subjects in the training group in study III are illustrated in fig 12d (as also seen under results in figure 13).

In study III and IV the differences (after-before) in the relative time wise distribution of the EMG signal were also presented (figure 14 and 15) as it was considered to be less sensitive to differences in background EMG noise. In addition it is a sensible way to compare the effect without interfering with normalization problems (as described in study IV).
Material and methods

The relative values for the integrated EMG-data presented in figure 12a for one trial before the intervention was calculated as:

- **50-75 ms**: \( \frac{1b}{1b+2b+3b+4b+5b\ldots+11b} \)
- **75-100 ms**: \( \frac{2b}{1b+2b+3b+4b+5b\ldots+11b} \)

In the same way the relative values for the EMG-data presented in figure 12b for one trial after the intervention were calculated as:

- **50-75 ms**: \( \frac{1a}{1a+2a+3a+4a+5a\ldots+11a} \)

The difference in relative area for one trial was calculated as:

- **50-75 ms**: \( \frac{1a}{1a+2a+3a+4a+5a\ldots+11a} - \frac{1b}{1b+2b+3b+4b+5b\ldots+11b} \)

The mean of the relative differences in rectified normalized EMG for all trials of unexpected SL for the subjects in the training group in study III and IV is presented under results in figure 14 and 15.

**Neck-shoulder complaints**

In study I participants filled in a questionnaire on shoulder-neck complaints immediately before and one week after the intervention. For each of the 3 regions (neck, right shoulder and left shoulder) the participants were asked 4 questions about the intensity of complaints: 1) worst complaints within the last 3 months; 2) average complaints within the last 3 months; 3) functional impairment due to complaints within the last 3 months; and 4) complaints within the last 7 days. The intensity of complaints was registered on a scale from 0 to 9, where 0 indicated no complaints at all and 9 indicated the worst possible pain. For each region a complaint score for the four questions was computed as the sum of the 4 scores (0-36) (Brauer et al. 2003).

**Questionnaires about training and the effect of training**

After the training interventions participants in study I and IV filled in a questionnaire about training and the effect of training (Appendix 1, 2). Included were some joint questions to the training and control groups. In study III participants were asked to send a mail containing information about their perception of the training and the effect of the training program.
Material and methods

Figure 12. EMG responses to sudden back loading before and after training. Methods for calculating differences in normalized integrated EMG. See pp. 30-31 for details.

Statistics

Readers are referred to the original papers for a detailed description of the statistical methods used.

In study I differences between the training group and the control group from the 1st to the 2nd examinations of normally distributed outcome variables (isometric muscle strength, static and dynamic endurance) were examined in regression analyses with the following independent variables: training (yes/
Material and methods

no), value of the variable at the 1st examination, age and sex. A change in musculoskeletal complaint score from the 1st to the 2nd examination was considered to be present if the difference in the complaint score was 2 or more. The results were dichotomised and depending on the direction, the change was considered either an improvement or deterioration. Fisher’s exact test was used to assess the effect of training on improvement and deterioration of complaints.

In study II, III and IV a two-way ANOVA with subjects (random) and trials (fixed) as factors were used to look for differences between trials, and multiple comparisons were carried out by the post hoc Tukey method.

In study III and IV the effect of training on stopping time, distance moved before stopping, EMG-latency and integrated EMG was analysed by a mixed model ANOVA with subjects as random factor and group (training/control) and time (before/after) as categorical fixed factors with interaction term between group and time.

If variables could not match the conditions of normal distributed residuals and variance homogeneity a Box-Cox transformation was used in the two-way and mixed model ANOVA. Paired sample t-tests were used to test for difference between the 2 test protocols.

The level of significance used was p< 0.05.
This section presents the main findings from the studies. For a complete presentation of the results readers are referred to the papers.

Training effect on muscular complaints

The number of participants with improvement and deterioration of complaints in the neck and shoulders are shown in table 2 and table 3 (study I). Significantly more subjects with improvement and fewer with deterioration of neck complaints were found in the training group compared to the control group. There were no significant differences for the shoulders.

Table 2. Study I. Improvement in complaints during the intervention

<table>
<thead>
<tr>
<th>Region</th>
<th>Improvement</th>
<th>No improvement</th>
<th>Fisher’s Exact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Training</td>
<td>Control</td>
<td>Training</td>
</tr>
<tr>
<td></td>
<td>n (%</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>Neck</td>
<td>15 (65)</td>
<td>3 (19)</td>
<td>8 (35)</td>
</tr>
<tr>
<td>Right shoulder</td>
<td>6 (50)</td>
<td>5 (45)</td>
<td>6 (50)</td>
</tr>
<tr>
<td>Left shoulder</td>
<td>6 (33)</td>
<td>3 (33)</td>
<td>12 (67)</td>
</tr>
</tbody>
</table>

Table 3. Study I. Deterioration in complaints during the intervention
Training effect on muscle strength, muscle endurance and mechanical motor control variables

The differences in the training group in muscle strength, muscle endurance and mechanical motor control variables before and after the 3 different training interventions (study I, III, IV) are shown in table 4.

For study I figures presented are isometric strength in 8 different exercises

Table 4. Training Group. Differences in strength, endurance and reaction to sudden expected and unexpected loading before and after the training interventions. Effect size = \( \frac{\text{mean before} - \text{mean after}}{\text{SD}} \) (SD is the mean of the standard deviations of means before and after the intervention) (Cohen 1969). See text below for more details.

<table>
<thead>
<tr>
<th></th>
<th>Mean Before Intervention</th>
<th>Mean After Intervention</th>
<th>Difference (%)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n =29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-shoulder lift (N)</td>
<td>421</td>
<td>571</td>
<td>35,7</td>
<td>0,71</td>
</tr>
<tr>
<td>L-shoulder lift (N)</td>
<td>436</td>
<td>574</td>
<td>31,8</td>
<td>0,59</td>
</tr>
<tr>
<td>R-abduction (Nm)</td>
<td>40,1</td>
<td>45,7</td>
<td>14,0</td>
<td>0,28</td>
</tr>
<tr>
<td>L-abduction (Nm)</td>
<td>39,4</td>
<td>44,7</td>
<td>13,5</td>
<td>0,28</td>
</tr>
<tr>
<td>R-inward rotation (Nm)</td>
<td>34,0</td>
<td>42,2</td>
<td>24,1</td>
<td>0,52</td>
</tr>
<tr>
<td>L-inward rotation (Nm)</td>
<td>31,4</td>
<td>38,0</td>
<td>21,0</td>
<td>0,49</td>
</tr>
<tr>
<td>R-outward rotation (Nm)</td>
<td>22</td>
<td>25,2</td>
<td>14,5</td>
<td>0,39</td>
</tr>
<tr>
<td>L-outward rotation (Nm)</td>
<td>20,7</td>
<td>24,11</td>
<td>16,5</td>
<td>0,42</td>
</tr>
<tr>
<td>Dynamic endurance (s)</td>
<td>82</td>
<td>108</td>
<td>31,7</td>
<td>0,58</td>
</tr>
<tr>
<td>Study III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n =19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopping time (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexpected</td>
<td>338</td>
<td>311</td>
<td>-7,9</td>
<td>0,53</td>
</tr>
<tr>
<td>Study IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n =20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopping time (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexpected</td>
<td>322</td>
<td>279</td>
<td>-13,4</td>
<td>0,62</td>
</tr>
<tr>
<td>Expected</td>
<td>281</td>
<td>258</td>
<td>-8,2</td>
<td>0,35</td>
</tr>
<tr>
<td>Distance moved (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexpected</td>
<td>4,7</td>
<td>3,8</td>
<td>-18,8</td>
<td>0,57</td>
</tr>
<tr>
<td>Expected</td>
<td>3,7</td>
<td>3,3</td>
<td>-10,3</td>
<td>0,29</td>
</tr>
</tbody>
</table>
and dynamic endurance for shoulder abduction. For study III and IV all figures represent measurements of reactions to SL (see study III+IV for more details). All differences in the three studies were significant compared to the differences in the control groups except for R-shoulder lift, L-outward shoulder rotation and expected SL.

Training effect on EMG in the motor control studies

In study III and IV the EMG-reaction-time (EMG-onset-latency) was unaffected by training.

In study III the faster reaction to unexpected SL in the training group compared to controls after the intervention was associated with significant differences (after-before) in the distribution of the integrated EMG-signal. The integrated EMG increased significantly in the time band 125 - 225 ms and decreased in the band from 225-325 ms when the training group was compared to controls (mixed ANOVA analysis). Figure 13 and 14 show the time wise distribution of these changes in the EMG-response in participants with improved (shortened) stopping time (absolute and relative, see methods for details).

![Figure 13. Study III. Unexpected sudden loading. Changes in rectified normalized integrated EMG in the training group (n=14). Differences (after–before) are illustrated in intervals of 25 ms. Only participants with faster stopping times after the intervention are included. 2 participants (with faster stopping times) were excluded (from the figure) because of severe EMG-noise.](image-url)
A similar pattern was seen for unexpected SL in study IV. Figure 15 shows the time wise distribution of the relative changes in the EMG-response in participants with improved (shortened) stopping time (absolute and relative, see methods for details). From 50 to 200 ms there was a significant increase in the relative integrated EMG in the training group compared to the changes in the control group. From 200-325ms there was a significant decrease in the training group compared to the changes in the control group (mixed model ANOVA). For expected SL there were no significant changes in the distribution of the relative integrated EMG.

Participants perception of the training programs and the effect of training

Study I

Below is a summation of the answers of the training group ($n = 29$) to the questionnaire about training and the effect of training, filled in one week after the intervention (Appendix 1):

- 77% of the participants reported that the training program was hard to perform, and 19% reported that it was easy.
Figure 15. Study IV. Unexpected sudden loading, differences in rectified integrated EMG relative to total rectified integrated EMG (from 50 ms to 325 ms) in the training group (n=15). Differences (after–before) are illustrated in intervals of 25 ms. Five subjects from the training group were not included because their EMG data had severe noise.

- 73% reported that the training was exciting, and 27% found it a bit boring
- A total of 92% of the participants had the perception that they felt better immediately after the training. 42% indicated fewer musculoskeletal problems generally as a result of the training, 8% reported more headaches as a result of training (especially in the first weeks of training).
- 69% of the participants perceived work as less strenuous after the training period, no one indicated the opposite.
- 75% indicated that they could notice that they had become stronger after the training period.
- All except one indicated that the training had been a good variation in everyday life, and 64% indicated that training had affected their relationship with colleagues in a positive way.
- Both in the training and control group around 90% indicated that they would like to continue training at the work place.
Study III
Below is a summation of the qualitative information received in e-mails (from the participants, $n = 19$) containing information on their perception of the training and the effect of the training program:

- The training had been exciting and amusing
- Training had affected participant’s relationship with colleagues in a positive way.
- Training had been a good variation in everyday life, and the participants wanted to continue training at the work place. Training was a good start of the day (2 times a week in the morning).
- Training had influenced their working hours and spare time in a positive way like: better mood, improved fitness generally, better balance

Study IV
Below is a summation of the answers of the training group ($n = 20$) to the questionnaire about training and the effect of training, filled in a few days after the intervention (Appendix 2).

- 50% of the participants reported that they perceived the training as easy and, 50% perceived it as somewhat hard.
- 80% found the training exciting and 85% found it amusing. None perceived the training as boring.
- 75% reported that training had affected their relationship with colleagues in a positive way. 25% indicated no change.
- 60% reported that the training had improved their fitness generally, and 55% indicated stronger back and abdominal muscles. 25% indicated no change in physical capacity. 35% indicated more springiness as a result of training and 35% reported better balance.
- 50% indicated that training had influenced their working hours and spare time in a positive way like:
  - Better mood
  - More well-being
  - More happiness
  - Better balance
- All indicated that the training had been a good variation in everyday life and wanted to continue training at the work place.
Discussion

Effect of training on physical capacity

The 3 training studies (paper I, III, IV) demonstrated that work place training could improve the physical capacity of the employees (table 4).

A useful way to describe the meaningfulness of findings is to estimate a standard value, the effect size \( ES = \frac{\text{mean}_\text{before} - \text{mean}_\text{after}}{\text{SD}} \) (Cohen 1969). Cohen classified the effect sizes as small (<0.41), moderate (0.41-0.70), and large (>0.70). In this way differences between groups can be compared across studies using different methods and variables. Studies with large effect sizes often have greater theoretical and practical value (Thomas et al. 1991). In addition Thomas et al. (1991) pointed out that \( n \) is an additional factor to consider as studies with small sample sizes (e.g. \( n=8 \)) have resulted in insignificant results in spite of large effect sizes.

Table 5. Increase in static shoulder strength and endurance. Results from 3 studies with shoulder strength training intervention (Ahlgren et al. 2001; Bang and Deyle 2000; Dyrssen et al. 1990). All figures represent significant findings.

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>% change</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bang &amp; Deyle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n=27 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction</td>
<td>192</td>
<td>225</td>
<td>17</td>
<td>0.30</td>
</tr>
<tr>
<td>Outward rotation (Nm)</td>
<td>122</td>
<td>159</td>
<td>30</td>
<td>0.60</td>
</tr>
<tr>
<td>Inward rotation (Nm)</td>
<td>169</td>
<td>192</td>
<td>13.7</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Ahlgren et al.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n=29 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder elevation (N)</td>
<td>428</td>
<td>484</td>
<td>13.2</td>
<td>0.62</td>
</tr>
<tr>
<td>Shoulder flexion 30° (N)</td>
<td>49.4</td>
<td>57.7</td>
<td>16.8</td>
<td>0.94</td>
</tr>
<tr>
<td>Shoulder flexion 60° (N)</td>
<td>31.1</td>
<td>36.8</td>
<td>18.3</td>
<td>1.10</td>
</tr>
<tr>
<td><strong>Dyrssen et al.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n=26 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevation (N)</td>
<td>376</td>
<td>568</td>
<td>50.8</td>
<td>1.45</td>
</tr>
<tr>
<td>Abduction (N)</td>
<td>126</td>
<td>181</td>
<td>44.4</td>
<td>1.63</td>
</tr>
<tr>
<td>Extension (N)</td>
<td>126</td>
<td>162</td>
<td>28.6</td>
<td>1.09</td>
</tr>
<tr>
<td>Endurance Static abduction (sek)</td>
<td>70</td>
<td>100</td>
<td>42.7</td>
<td>0.92</td>
</tr>
</tbody>
</table>
Table 5 shows the results including $n$ and effect size from 3 supervised shoulder strength training intervention studies with exercises comparable to the ones used in study I:

1. Dyrssen et al. (1990): 3 months 3 times 30 min a week for 3 months, office workers in work. All had at some time within a year consulted the company physician for pain in shoulders, neck and/or upper back. All were at work during the intervention.
2. Ahlgren et al. (2001): 1 hour 3 times a week for 10 weeks, workers with trapezius myalgia, but still at work.

The results presented in table 4 for study I can be compared to the 3 studies just mentioned (table 5). All studies showed significant improvements in strength and Dyrssen et al. also measured increased muscle endurance. The absolute differences (14-35%), and differences in effect size (mostly moderate (0.28-0.71)) in study I, are comparable to the results Bang & Deyle. The huge increases and effect sizes shown by Dyrsen et al. might be due to methodological problems as the control group also increased significantly in strength and endurance (13-19%). Genaidy et al. (1992) in a literature review (aiming at „reviewing techniques available in exercise physiology literature for increasing human capacity in industry“) reported improvements in upper extremity dynamic endurance and concluded that a short muscle endurance program could improve static and dynamic endurance significantly.

The fact that patients with shoulder impingement syndrome participating in very few strengthening exercise sessions can increase strength considerably (Bang and Deyle 2000) supports the established fact that untrained individuals have a greater potential for improvement than more well trained individuals (Aastrand and Rodahl 1986). Similarly in study III among untrained office workers a 4 weeks readiness training program had a significant impact on stopping time comparable to the effect of a more long lasting and intensive training program among more well trained hospital workers (study IV, table 4). Study III and IV are the first studies to examine the effect of training on the reaction to SL among healthy individuals. The results in table 4 for study III and IV are in line with other studies of training of physical capacity among healthy individuals with typical improvements between 10-30% after 3 months of training (Aastrand and Rodahl 1986).
Changes in musculoskeletal complaints; Intervention study design

In study I the allocation to the training and control groups was made by means of the Nordic Musculoskeletal Questionnaire (Kourinka et al. 1987; Palmer et al. 1999). Palmer et al. (1999) assessed the repeatability and validity of the Nordic-style questionnaire for upper limb and neck complaints and found that symptom reports for pain in the upper limb and neck (pain interfering with physical activities and neurological symptoms) were highly reliable (kappa = 0.63-0.90). They concluded that the Nordic questionnaire is reliable and sensitive.

In study I the effect of training on muscular complaints was studied. There was no clear pattern in the changes in the degree of shoulder complaints for the training group compared with the control group and no significant differences were found. However, the figures were small, and reliable conclusions could not be made. In the case of the neck, significant differences in the complaints in the training group and control group could be observed. This is suggestive of a positive effect of weight training on neck complaints in line with the results from Dyrsen et al. (1990), Bang and Deyle (2000) and Ahlgren et al. (2001). However, the results from the neck disorders are difficult to interpret because of the skewed distribution of initial complaints in the final training and control groups. The observed improvement indicated a training effect, but could have been due to differences in the baseline. The training group had greater chances of improvement because of a higher base level of neck complaints. This underlines the importance of successful randomisation in training intervention studies (Westgaard and Winkel 1997) and raises the question whether the randomisation in study I could have been more successful?

The initial skew-ness in the allocation of the subjects to the training and control groups could probably have been reduced, but quantitatively the most important problem was, that the dropout in the training group (13 subjects) was highest among persons without initial complaints introducing an even more skewed distribution of initial complaints in the final training and control groups. It is impossible to be well guarded against these circumstances. The compliance to training was influenced by the amount of pain in neck and shoulders. Subjects with pain from start in the training group were motivated to stay in the training group due to the expected or perceived health effect of the training. It thus appeared that a natural change not under influence of the researchers was the main reason for the skewed distribution of initial complaints. Compliance is a general concern in intervention studies, and intervention stu-
Discussion

Studies should generate measures with a tangible impact on the worker (Westgaard and Winkel 1997). The effect of training might not have been sufficiently tangible for participants without initial pain.

The gold standard of study design for evaluation of treatment in clinical trials includes random selection of subjects to intervention and control groups, with blinding of the subjects and researchers to group membership and placebo treatment of the control group (Westgaard and Winkel 1997), but this design is generally not achievable in ergonomic intervention research. The blinding of subjects and researchers was not possible in the intervention studies (I, III, IV) and randomisation was only attempted in study I. Study III and IV were training intervention studies aiming at improving the response to SL.

In study III subjects in the training group were matched to subjects in the control group. In study IV practical considerations in relation to working schedule was the key factor for allocating subjects to the control or training group.

This raises some problems concerning the validity of the studies (already mentioned for study I). Concern was mainly on age, job function and training background as better-trained individuals (or individuals at different ages) were expected to react differently to physical test and training. In study III and IV bias due to the distribution of participants and controls was not likely as the distribution of age, job functions and the amount of leisure time physical activity in the control and training group were comparable.

Participants perception of the training programmes

In study I the qualitative analysis of the answers to the questionnaire showed that 69% perceived their job as less strenuous as a result of training. Additionally they felt better immediately after training. In all 3 training intervention studies participants reported a positive social effect of training. The indication of a positive psychosocial effect of the intervention might have important consequences in a longer perspective, as there is evidence of associations between psychosocial work factors and musculoskeletal disease (Bongers et al. 1993). Lundberg (1999) showed an association between work stress, psychosomatic symptoms and musculoskeletal pain among supermarket cashiers. One hypothesis explaining this is that psychological stress may induce sustained activation of small, low-threshold motor units that may lead to degenerative
processes, damage, and pain. Analysis of short periods of very low muscular electrical activity (EMG gaps) show that female workers with a high frequency of EMG gaps seem to have less risk of developing myalgia problems than do workers with fewer gaps (Lundberg et al. 1999).

There are thus indications that, in the future, it will be necessary to distinguish more precisely between the expected effect of the physical training (on e.g. strength, endurance and motor control) and the effect of the actual activity (psychosocial effect). Griffiths (1996) points out, in a review article about the advantages of physical training programmes for employees, that there is some support for the hypothesis that physical activity in itself (irrespective of the physical training effect) has a positive influence on mental health and mood. Thus it seems to be important to evaluate physical training programs by including a psychological health point of view, rather than to concentrate in a goal-directed way on increases in the physical capacity.

In study I, III and IV there were mainly positive expressions about the training sessions being integrated in the working schedules (on the job training). A Swedish study (Josephson M et al. 1995) where an exercise room had been fitted out for medical secretaries to be used freely for one hour weekly during working hours showed a very low percentage of participation (12% regularly went to training, in spite of 95% interest in participation). A guilty conscience (or other problems) about leaving work was the most important reason for not training! One of the conclusions after interviewing the participants in study I (Pedersen et al. 1998) was that if training is to function in connection with work, it was important that training was scheduled at fixed times and guided by an instructor.

Implications of the effect of readiness training

A shorter stopping time is supposed to reduce the risk of low-back injuries because a faster reaction can decrease the amount of kinetic energy accumulated in the trunk before the slowing down of a forward movement. This indicates that a training intervention (as in study III and IV) has the potential to modify the risk of low-back injuries in e.g. nursing personnel exposed to sudden trunk perturbations during patient handling.

The reaction to SL (study II, III, IV) was measured as the reaction to a sudden stepwise increase in the loading of the low back with a peak force around 75N (study II). This peak force is rather low compared to the expected
peak forces during SL-situations at work, e.g. accidents during patient handling. The type of reaction to these "real" situations could therefore be somewhat different from the reactions studied (paper II, III, IV). At present studies are being carried out at the National Institute of Occupational Health to investigate the reactions to sudden trunk loading with very high loads (Essendrop et al. 2003). The participants are judo fighters that are used to sudden trunk loadings with very high impacts.

The observation that a 9 week training intervention without increments in muscle force generating capacity (MVC and RFD, (study IV)) can modify the response to unexpected SL to the extent were response patterns are as efficient as seen during expected perturbations of the trunk has a number of implications for the risk management in the health care sector. Unexpected sudden loading accidents during patient handling occur infrequently as episodic events that are very difficult to prevent. If a training intervention can reduce the risk of sudden low back trouble due to SL the cost benefit ratio could be favourable. A large-scale epidemiological study is however needed to document the expected preventive effect of readiness training on the incidence of LBP.

The effect of training – physiological changes

The increase in strength among the cashier workers after 15 weeks of training (study I) can be explained either by adaptive changes within the nervous system or by changes within the trained muscles (Sale 1988), or both. Probably the early increases observed in the start of the training program were due to neuronal changes such as increased activation of prime movers. Later on hypertrophy of the muscle fibres involved in the progressive resistance training may have followed, as in e.g. Andersen and Aagaard (2000) who found a hypertrophy of 16% in type II fibres after 3 months of heavy-load resistance training. In study I, though, the training load was not quite as high as in the study by Andersen & Aagaard.

In study III and IV the time elapsed until stopping after a SL decreased significantly in the training group compared to the control group. In study IV there were no differences in strength or maximal rate of force development (not measured in study II) before and after training. Differences in these strength characteristics were not expected in these two studies because the training was focused on development of coordination (not strength). The differences observed are therefore likely to be explained mainly by changes in motor
control aspects. The importance of training induced modulation of motor responses for the improved mechanical responses found in the studies was clearly reflected in the EMG analysis - characterized by an increase in the early parts of the response (up to around 200ms) and a subsequent decrease later on (study III+IV, figure 13, 14, 15). Readers are referred to the original papers for a detailed discussion of the relative changes in EMG levels in different time bands shown in figure 14 and 15. Considering an electromechanical delay of erector spinae muscle around 130 ms (van Dieen et al. 1991) the shift to the left of the integrated EMG – with peak changes around 175-200ms – fits nicely with an improved stopping time of around 300 ms after training.

In study III+IV readiness training induced improvements in response characteristics to unexpected SL took place without concomitant decreases in EMG latency. These findings appear to be in discord with results from training studies with low back patients where patients decreased EMG-latency after training rehabilitation (Magnusson et al. 1996). It is, however, conceivable that low back patients respond to training in a different manner than normal individuals and may have pre-training latencies that are longer than in healthy controls. Part of the discrepancies may however be due to the methodological difficulties in assessing EMG latencies in the presence of high EMG activity prior to the SL event (Skotte et al. 2002). As subjects suffering from low-back disorders are known to show higher pre-EMG activity than healthy subjects (Pope et al. 2000), it is possible that part of the measured improvement in these studies (Magnusson et al. 1996; Wilder et al. 1996) in EMG reaction time has been biased by a simultaneous reduction in pre-EMG activity as a result of less pain.

Data suggesting that training can modify different components of the stretch reflex has previously been presented by Nielsen et al. (1993) – looking specifically at H-reflexes – and Mortimer and Webster (1983) studying the M3 component in karate trained subjects. Study III+IV, however, appear to be some of the first to demonstrate that the response to SL can be improved in normal subjects without an increase in pre-activation and associated trunk stiffness (Lavender et al. 1993).

Part of the reflex response to SL seem to be pre-programmed (Magnusson et al. 1996). The widest definition of a motor program is „a set of muscle commands that is structured before a movement sequence begins, and that allows the entire sequence to be carried out uninfluenced by peripheral feedback“ (Keele 1968). In accordance with study III & IV Lofthus and Hanson (1981) found a decrease in reaction time with no difference in EMG firing
latencies after training of quick arm-flexion as reaction to a light stimulus. On the bases of the unchanged EMG-latencies they suggested a motor program responsible for the quick move. Kizuka et al. (1997) showed that the degree of long latency reflex modulation (M2) directly reflects the individual motor control to perform quick wrist movements. The motor cortex seems to play an important part in the pre-programming of long latency reflexes. Capaday et al. (1991) also showed evidence for a contribution of the motor cortex to the long latency reflex of human thumb. Capaday et al. (1991) and Latash et al. (2003) found support for the hypothesis that transcranial magnetic stimulation can activate cortical neurons interposed in a transcortical long latency loop leading to pre-programmed reactions to perturbations.

The plasticity in motor control and motor systems of the spinal cord and cortex has previously been demonstrated in well-trained athletes and professional dancers, but this study has demonstrated that motor control aspects may also be of importance in adapting the individual capacities to meet occupational demands. Changes in the responses have been documented, but the exact nature of the changes in the motor control system is difficult to distinguish.
Conclusions

- It is possible to develop strength, endurance and coordination of employees considerately by on the job training.
- Training can lead to work being perceived as less stressful.
- In study I no effect of training on shoulder complaints could be shown. An improvement of neck complaints seemed to indicate a positive effect of training, but could also be due to the fact that the training group had more neck complaints before the training than the control group.
- Successful randomisation is important in training intervention studies.
- Back muscle response to SL can be improved by on the job training in healthy subjects without an increase in pre-activation and associated trunk stiffness.
- The results indicate a possibility for a training induced modification of the risk of low back injuries in e.g. health care workers exposed to sudden trunk perturbations during patient handling.

A large-scale epidemiological study is needed to document the preventive effect of readiness training on the incidence of sudden LBP.

This Ph.D. study was initiated to:
1. Investigate the effect of a traditional muscle strength and endurance training program on shoulder/neck disorders in cashier checkout workers.
2. Elucidate the potential possibilities of improving motor control aspects and the individual adaptive responses to SL among health care workers.

Unfortunately it was not possible to confirm or reject a positive effect of muscle strength and endurance training on the development of neck and shoulder complaints among cashier checkout workers. The evidence of the effectiveness of exercise in management of neck and shoulder pain remains limited except for fibromyalgia (Mior 2001; NRC Corporation 2001). The hypothesis that „motor control training can improve neuro-muscular reactions and spinal protective mechanisms in individuals exposed to SL“ was confirmed,
but the practical implication that this kind of training can „reduce the risk of sudden LBP due to sudden loading accidents“ needs more research before a large scale exercise based intervention can be implemented.
References


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Individual physiological- and psychological characteristics may play a major role in the development of work related musculoskeletal disorders. The aim of this thesis was to provide new insight into the preventive effect of a traditional muscle strength and endurance training program on shoulder/neck disorders in cashier checkout workers and to elucidate the potential possibilities of improving motor control aspects and the individual adaptive responses to sudden back loading among health care workers. An improved reaction to sudden trunk loading is supposed to reduce the risk of work related low back pain.

Study I was a physical training intervention study among cashier checkout workers with measurements of neck and shoulder complaints before and after the intervention. Study II was a method study focusing on recording the reactions to sudden trunk loading. Study III and IV were training intervention studies aiming at improving the reaction to sudden trunk loading among untrained workers at the National Institute of Occupational Health (study III) and among health care workers (study IV). The three training studies were all controlled studies.

It was possible to develop strength and endurance considerately by on the job training among cashier checkout workers, in addition training resulted in work being perceived as less stressful (study I). In this study no effect of training on shoulder complaints could be shown. The improvement of neck complaints indicated a positive effect of training, but could also be due a non-successful randomisation explained mainly by dropouts in the training group, especially among participants without neck-complaints. In study III and IV participants improved their reaction to sudden trunk loading. The results indicate a potential for a training induced modification of the risk of low back injuries in e.g. health care workers exposed to sudden trunk perturbations during patient handling. A large-scale epidemiological study is needed to document the preventive effect of „readiness“-training on the incidence sudden low back pain.

Summary
I de senere år er der kommet øget fokus på sammenhængen mellem individuelle fysiske- og psykosociale faktorer og udviklingen af arbejdsrelateret muskuloskeletalt besvær. Formålet med dette ph.d.-projekt var dels at undersøge helbredseffekten af styrke- og muskeludholdenhedstræning på udviklingen af nakke- og skulderbesvær hos kasseassistententer dels at undersøge om specifik træning kunne forbedre evnen til at reagere på pludselige rygbelastende hændelser. En forbedret evne til at reagere på pludselige rygbelastninger forventes at kunne reducere udviklingen af arbejdsrelateret lænderygbesvær.
