Musculoskeletal neck-shoulder pain
A new ambulant myofeedback intervention approach

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Contents

Chapter 1

General Introduction

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Introduction

Persisting musculoskeletal pain is a common cause of disability in Western industrialized countries. Large epidemiological studies investigating the prevalence and localization of musculoskeletal pain showed especially high prevalence rates of pain in the back, shoulders[1] and neck region[2]. Using a self-administered questionnaire, 43% of 6000 respondents reported neck pain; 48% in women and 38% in male. Among these, 19% report chronic pain[2]. Besides higher prevalence rates, females tend to report higher pain intensity and disability levels compared to males (see e.g.[1 3 4]), are less susceptible to natural recovery[4], and are more likely to seek care for their complaints[5]. Neck-shoulder pain is especially common among females at working age[2 3] who perform low-intensity, repetitive work, like for instance computer work (prevalence rates of about 15%)[6 7 8 9]. Neck-shoulder complaints also frequently emerge and persist after a trauma, like rear-end motor collisions, and are herewith important complaints ascribed to the Whiplash Associated Disorder (WAD)[10] (incidence of neck and shoulder pain about 84% immediately after trauma)[2 10]. In the Netherlands, General Practitioners (GP's) are consulted 101 times annually for neck and shoulder complaints per 1000 registered subjects[11]. Inherently, the health care and community costs associated with musculoskeletal pain are high: Work-related neck-shoulder complaints, for instance, cost about 2.1 billion euros in the Netherlands[6].

So far, the underlying mechanisms for the development and perpetuation of these musculoskeletal complaints are not fully understood. Several models and hypotheses are presented in medical literature and most of these ascribe a main role to abnormal muscle activation patterns, both from a purely physiological perspective as well as from a more integrated, biopsychosocial approach considering aspects like cognitions and behaviour as well. The normalisation of muscle activation patterns has been an incentive for intervention strategies in the prevention and treatment of musculoskeletal neck-shoulder pain. An appropriate method for this purpose could be myofeedback. Because of the different models and hypotheses explaining the pathogenesis of complaints in relation to abnormal muscle activation patterns, myofeedback approaches described in medical literature differ as well.

This thesis relates to musculoskeletal pain in the neck-shoulder region and the evaluation of the effectiveness of a new intervention approach for these complaints using Cinderella-based ambulant myofeedback training, in subjects with neck-shoulder complaints related to work or WAD. This first chapter provides an overview of the recent literature on abnormal muscle activation patterns in musculoskeletal complaints, and expounds models and theories originating from different perspectives. Furthermore, the new intervention approach is presented and the final section of this chapter elaborates the aim and content of this thesis.

Musculoskeletal neck-shoulder pain: Abnormal muscle activation patterns

Visser and van Dieën[12] reviewed the existing evidence for pathophysiology of musculoskeletal complaints in the upper extremity, especially focusing on the upper trapezius muscle as this muscle is often affected when neck-shoulder complaints are reported. An important research question here is how myalgia can develop and persist in conditions without high biomechanical load demands, like in low intensity (computer) work. One of the most influential hypotheses in this field is the **Cinderella-hypothesis** of Hägg[13]. This hypothesis states the fixed order of motor unit recruitment and de-recruitment in muscle activation: Low threshold, small, type I motor units are activated first and remain active until the muscle is totally relaxed. These motor units, also called Cinderella´s as she was the first to raise and the last to get to bed, are at risk of degeneration and damage due to long-term activation without periods of complete muscle rest called *gaps*. This damage might be the resultant of accumulating Ca^+ in the active motor units and a dysregulation of homeostatic processes due to impaired blood flow and transport of metabolites[12]. Morphological, physiological and biochemical studies support this reasoning: Impaired microcirculation, damaged mitochondria, high levels of energy phosphates[14], red ragged fibers[15], and reduced capillary supply[16] are found in biopsies of myalgic trapezius muscles. Evidence for the Cinderella hypothesis quantified as absent periods of complete muscle rest emerges gradually. Several authors[17] [18] [19] report the likely existence of those Cinderella motor units in the upper trapezius muscle as identified during arm movements and specific motor tasks. In a cross-sectional study, Sandsjö et al.[20] found reduced levels of muscle relaxation in female cashiers with complaints in the neck-shoulder region compared to those without complaints, and Hägg and Åström[21] reported comparable results in medical secretaries. From a longitudinal study it appeared that lack of trapezius relaxation was a good predictor for trapezius myalgia[22]. In contrast, Sjøgaard et al.[23] and Holte and Westgaard[24] did not find any differences in muscle relaxation between symptomatic and non-symptomatic subjects during working tasks, although findings from the latter study indicated that subjects with pain were less capable of relaxing during leisure time. Thorn and colleagues[25] were able to demonstrate reduced relaxation patterns during a specific mental stress task only. Besides in work-related myalgia[26] [27], evidence for lack of muscle relaxation has also been reported in patients with musculoskeletal pain diagnosed with fibromyalgia or WAD. In these studies a decreased ability to relax was not quantified into lack of gaps, but rather focused on the amplitude of the surface electromyography signal[26] [28]. Elevated muscle activation levels during for instance a resting period in subjects with complaints compared to healthy controls, are herewith considered abnormal.

The **pain-spasm-pain model** of Johansson and Sojka[29] [30], also referred to as the ´vicious circle model´, emphasises the relevance of these elevated muscle activation levels in pain. The model describes the genesis and general spread of increasing muscle activation induced by a painful stimulus in the agonist muscle. Muscle contractions mobilize nociceptor afferents type III and IV which activate gamma-motoneurons. This in turn elevates the activity of muscle spindles and subsequently muscle fibres which may spread to surrounding muscles as well. Recently, the model was slightly redefined by adding the knowledge that the increase in muscle spindle afferent activity also affects proprioception. This affected proprioception may induce less precise motor control and increased co-contraction as a compensatory mechanism to comply with specific movement demands. Evidence for this model was reflected in increased trapezius muscle activation patterns during motor tasks in chronic neck-shoulder pain of different etiologies[27 28 31 32], with a positive association between the level of trapezius activation and pain intensity[33], although not all studies report a difference between symptomatic and non-symptomatic subjects[34]. At first glance, the pain-spasm-pain model may seem reciprocal to the Cinderella hypothesis as muscle relaxation is commonly expressed as the percentage of time the activity of the muscle is below a certain threshold for at least a certain time interval (either normalised or absolute)[35]. But as relaxation is a timing parameter[36] the association between the two parameters appeared quite weak (≈ .30). This suggests two relatively independent mechanisms which may occur complementary[12 12 27 28 37].

In contrast to what can be expected from the pain-spasm-pain model, Arendt-Nielsen and colleagues[38] found reduced activity of the back muscles after injections of hypertonic saline in these muscles. Madeleine and colleagues[31] reported inhibited trapezius muscle activity in the active part of the contraction cycle after experimentally induced muscle pain[31] and Nederhand et al.[39] reported comparable findings in acute WAD patients. These findings fit well within the **pain-adaptation model** of Lund[40], which states inhibition of the agonist and excitation of the antagonist muscles in response to a painful stimulus. The direct consequences of this response are restrictions in movements and kinematics that can be considered preventive for evoking more pain. There is some preliminary empirical support indicating a change in motor control strategies during the chronification process[28 31 39]. While the pain-spasm-pain model has mainly been confirmed in the sub-acute and chronic phase of musculoskeletal pain, the pain-adaptation model might especially be valid in the acute stage, for instance immediately after a trauma, acting as a guarding mechanism to prevent from damage and more pain.

The definition of pain provided by the International Association for the Study of Pain (IASP)[41] stating that pain is 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage'[41], implies that the development and perpetuation of pain is more complex than purely the result of physiological abnormalities. This is clearly reflected in the biopsychosocial approach first described by Engel in 1977[42]. It is a holistic perspective in that mind and body are seen as automatically intertwined. Related to abnormal muscle activation, especially relevant models are the **fear-avoidance**[43 44] and the **avoidance-endurance model**[45]. These models ascribe an important role to catastrophizing, the tendency to magnify and ruminate about noxious stimuli, which contributes to fear and avoidance of activities anticipated being painful. Avoidance can result in physical inactivity, and the loss of essential social and / or vocational confirmation[46] is the likely consequence associated with a reduction in pain tolerance. As a consequence the perception of pain deteriorates maintaining a negative, vicious circle[47]. The avoidance-endurance model[45] additionally discriminates between several subgroups of patients based on maladaptive coping strategies, with an evident distinction between subjects who show avoidant behaviour related to catastrophizing (corresponding to the fear-avoidance model) and fear of movement, and subjects who avoid or overload dependent on denial or suppressive thoughts, in the absence of catastrophizing and fear of movement.

Both models integrate possible effects on the musculoskeletal system: Avoidance of behaviour may peripherally induce muscle atrophy because of disuse (the disuse syndrome[48]) while overloading results in a hyperactivity of muscles which causes stiffness and maintains complaints. The relation between cognitions and behaviour on one hand and physiological responses on the other hand is even more complex as these appear to be mutually related: A high level of fear of movement may serve as a stress factor that arouses the autonomic nervous system when the movement is performed, and results in an increased muscle response[49] [50] [51]. This is especially true for the upper trapezius muscle which is known to respond to mental stressors[52]. More generally, the sensation of pain and illness related behaviour is a strong stressors itself[53] [54]. In each subgroup described by the fear-avoidance and the avoidance-endurance models, cognitions and behavioural responses may thus affect muscular function and contribute to abnormal muscle activation patterns and muscular disorders[55] [56].

In short, there is evidence for altered muscle activation patterns in persisting musculoskeletal pain, and especially reduced muscle relaxation as described by the Cinderella-hypothesis is herewith considered an important determinant. This hypothesis was predominantly explored in subjects with work-related complaints but recent reports suggest that abnormalities in muscle activation patterns might be rather generic for musculoskeletal complaints in the neck-shoulder region independent of the origin of complaints[26] [57] [58] [59]. Further research should be conducted to clarify this. A purely physiological approach is however not tenable when studying musculoskeletal neck-shoulder complaints; in parallel evaluations of psychosocial aspects in terms of cognitions and behavioural characteristics could offer potentially relevant insights in the development and persistence of the complaints, also when the effectiveness of an intervention is evaluated.

Myofeedback as an intervention strategy for abnormal muscle activation patterns in musculoskeletal neck-shoulder complaints

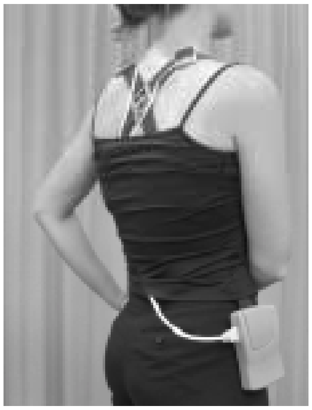
Abnormal muscle activation patterns in musculoskeletal neck-shoulder complaints have been the rationale for using biofeedback in treating these complaints. Biofeedback can be defined as 'the use of monitoring instruments (usually electrical) to detect and amplify internal physiological processes within the body, in order to make this ordinarily unavailable internal information available to the individual and literally feed it back to him in some form'[60]. Feedback based on the state of the muscle is usually called 'myofeedback'. Generally, feedback is important in the field of learning theories as it is a form of operant conditioning. A crucial component in learning is the reinforcement schedule that is being used[61]. This schedule describes the relation between a response, e.g. muscle activity, and a consequence, e.g. feedback, and can be either intermittent or continuous (also referred to as 'terminal' and 'concurrent' feedback[62]). The effects of these schedules on learning new motor skills are crucial: Continuous reinforcement may result in larger physiological adaptations compared to intermittent schedules[61 63] but is generally less resistant to extinction than intermittent schedules[61 63 64]. When applying intermittent schedules the definition of the interval duration may have a profound effect on the learning of skills[61].
In rehabilitation myofeedback has often been applied to reduce muscular tension in order to prevent or treat musculoskeletal complaints like back pain[65-69], fibromyalgia[70], or (work-related) neck-shoulder and forearm pain[61 68 71-76]. Muscle activity and/or pain intensity generally decrease immediately after myofeedback, although at follow-up the effects often extinguish[65 67 68 70 71 73]. Except for the findings reported by Flor and colleagues[65], myofeedback interventions usually showed equal or inferior effects with regard to outcome when compared to other treatments of musculoskeletal complaints, like cognitive-behavioural and relaxation training[67 69 71 76].

The traditional myofeedback approaches as mentioned above are based on the assumption that a reduction of muscle activity results in a reduction of pain intensity. Although reduced activity levels have been observed after myofeedback training, no clear evidence has been reported in literature that these reductions indeed are related to reduced pain intensity levels[70]. In fact, more often changes in psychosocial factors are related to outcome and may play a substantial role in the working mechanism of traditional myofeedback[67 77]. Especially coping strategies and the perception of control have been mentioned in this context[65 67 70 78]. These findings emphasize the importance of (changes in) psychosocial factors for outcome after myofeedback training, but also suggest that changes in muscle *activity* after the training are not crucial for positive outcome per se.

A new myofeedback intervention approach: Ambulant Cinderella-based myofeedback training

Considering the recent knowledge on the occurrence and continuation of musculoskeletal complaints that is provided by the Cinderella-hypothesis, myofeedback training might be more effective when aiming at increasing muscle *relaxation* rather than focusing on reducing muscle *activation*. Traditional feedback devices may not be suitable for training a muscle load pattern with frequent gaps[17 19 80] as this requires different algorithms for detection of undesired muscle activation patterns on which the provision of feedback is based. Another disadvantage of traditional myofeedback is that the devices used are solely applied in the training session with a maximum duration of about 30 – 60 minutes. It is likely that a more intensive training approach, i.e. continuous feedback, further improves outcome. This requires a portable feedback system that can be used during normal daily activities like work which makes the training more intensive. The application of a portable feedback system might also enhance a more effective integration of learned skills during the training to normal daily activities compared to the traditional myofeedback approach. These considerations were the starting points for the development of a new myofeedback intervention approach.

For this purpose, a two-channel ambulant feedback system combined with a garment incorporating dry sEMG electrodes to enable a stable recording of upper trapezius muscle activity was developed[72]. The harness is connected to a sEMG processing and storage system (see Picture 1.1) in which the sEMG signal is amplified (15x), band pass filtered between 30 and 250 Hz, sampled at 512 Hz, digitized (22 bits ADC), and smooth rectified with removal of the low frequency components. Embedded software provides the detection and calculation of muscle rest expressed as the sEMG parameter Relative Rest Time (RRT), which is defined as the percentage of time in which Root Mean Square (RMS) is below



Picture 1.1: Myofeedback device consisting of a harness with dry surface electrodes and a sEMG storage and processing unit

threshold (10 μV for at least 0.25 seconds). This threshold was based on the noise level of the myofeedback system including mounted electrodes at the skin. Sensory (vibration) and auditory (a soft sound) feedback is provided after a pre-defined interval when the relative duration of muscle relaxation in that particular interval is below 20%. The 20% threshold was chosen based on the work of Hägg and Åström[21]. Subjects should respond to the feedback by relaxing their upper trapezius muscles, and this relaxation is anticipated to contribute to recovery of the Cinderella motor units. Hermens and Hutten[72] defined an intervention protocol for myofeedback training in a prognostic cohort study with 17 subjects reporting computer-work related neck-shoulder complaints. Subjects wore the system for 4 weeks on average during their normal working days in the office. Once a week the subjects were visited at the work place by a therapist to download the data of the myofeedback system and to discuss progress. These discussions were guided by the diaries subjects filled out during the time the system was worn. In this way, periods of insufficient muscle relaxation were easily detected and related to activities. These activities were then examined to see whether the (ergonomic) performance of these activities could be improved to achieve more relaxation. About 60% of the participants showed a reduction in pain intensity in the neck-and shoulder region after four weeks of training. Also, muscle relaxation increased and muscle activation decreased during computer-related tasks and these results persevered even at 4 weeks follow-up[72]. Furthermore, the increase in muscle relaxation at follow-up was related to the change in pain intensity[81] but as the percentage explained variance was rather low ($R^2 = .36$) presumably other factors, like psychosocial characteristics, are also related to changes in outcome after myofeedback training.

Objectives and outline of the thesis

Although the results of Hermens and Hutten[72] are promising, no definite conclusions could be drawn with regard to the effectiveness of the ambulant Cinderella-based myofeedback training as no control group was included and the follow-up period was rather short. Besides this, the theoretical foundation and design of this myofeedback intervention suggests that the underlying working mechanisms may be different from traditional myofeedback interventions. Therefore, the primary objective of this thesis is to obtain insight into the effects and mechanisms of the new, Cinderella-based ambulant myofeedback intervention approach in subjects with persistent musculoskeletal neck-shoulder pain. For this purpose different studies were designed (parts of) which are described in the following six chapters.

The first study that was performed provides a scientific background for optimal feedback strategies of the Cinderella-based myofeedback training. Literature learns that the schedule of reinforcement that is used for feedback is highly relevant for outcome. In the prognostic cohort study[72] the feedback time interval, 10 seconds, was based on clinical experience with the myofeedback system but this needs scientific foundation. Therefore a multiple cross-over trial was designed to investigate the influence of three different, short-duration interval myofeedback schedules on learning relaxation of the upper trapezius muscles of healthy subjects during performance of a gross-motor task. The results of this study, described in **Chapter 2**, contribute to the selection of the optimal schedule and to optimize the effectiveness of the Cinderella-based myofeedback training that is used throughout this thesis.

The effect evaluation of ambulant myofeedback training was primarily performed with subjects with work-related neck-shoulder complaints (Chapters 3, 4, and 5). In parallel, it was explored whether the training could also be beneficial for subjects with complaints from different origin, like whiplash. These studies are described in the Chapters 6 and 7.

The Chapters 3, 4, and 5 describe a randomised trial enabling a comprehensive evaluation on the effect and mechanisms of the ambulant Cinderella-based myofeedback intervention in female computer workers with work-related neck-shoulder complaints. A common intervention strategy for this group of subjects concerns ergonomic counselling: Adjustment of the physical work environment and education about working posture according to ergonomic principles, as it is commonly accepted that an ergonomically correctly designed work place is a prerequisite for healthy working. There is some evidence regarding the effectiveness of ergonomic counselling, but in spite of attention to ergonomics musculoskeletal complaints remain a considerable problem (e.g.[82-86]). Furthermore, ergonomics is probably just one factor in the multifactorial pain disorder, and interventions focusing on multiple dimensions have shown to be associated with a decreased incidence of complaints[87]. A combination of ergonomic counselling with Cinderella-based myofeedback training was thus hypothesised to be more effective compared to ergonomic counselling alone. In **Chapter 3**, the immediate and lasting effects of the interventions (myofeedback combined with ergonomic counselling and ergonomic counselling alone) are presented in terms of pain intensity and disability.

Outcome after the intervention can also be described in terms of changes in muscle activation patterns and changes in cognitive-behavioural factors, for which indications were already provided in traditional myofeedback studies. **Chapter 4** aims at obtaining insight in the working mechanisms of myofeedback training by exploring these changes after ambulant Cinderella-based myofeedback training, combined with ergonomic counselling, and investigating the associations with outcome. Finally, in **Chapter 5** it is investigated whether a subset of factors recorded at baseline, i.e. prognostic factors, can predict the effectiveness of the myofeedback intervention. Hermens and Hutten[72] showed that myofeedback is effective in about 50% of the subjects while in the others it is not. This suggests that there are subgroups of subjects in whom the intervention is effective. Characterization of these subgroups in terms of psychological and socio-demographic characteristics before starting the intervention can potentially contribute to optimal patient allocation and clinical decisions regarding the choice of treatment.

The theoretical framework presented in this General Introduction learned that the Cinderella-hypothesis has especially been investigated in subjects with work-related complaints. However, it was also reported that the underlying mechanisms of persisting musculoskeletal neck-shoulder pain could be a common characteristic among patients with different diagnoses (e.g.[57 59]). Patients with work-related complaints might thus show comparable abnormal muscle activation patterns compared to other groups of subjects with persisting neck-shoulder complaints like WAD. In this specific group, especially muscle activation levels have been reported rather than muscle relaxation as defined in the Cinderella-hypothesis. In **Chapter 6** it is therefore explored whether muscle activation patterns are comparable between subjects with work-related complaints and subjects with WAD, especially focusing on evidence for the Cinderella-hypothesis in both groups. With the assumption of comparable muscle activation patterns in mind, myofeedback training may also be beneficial in WAD patients, and this was explored in **Chapter 7**.

The thesis ends with a chapter (**Chapter 8**) in which the findings of the different studies are evaluated and discussed in the light of existing models and theories. The second section of this chapter provides methodological considerations, implications for future research and a general conclusion.

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Chapter 2

The influence of different intermittent myofeedback training schedules on learning relaxation of the trapezius muscle while performing a gross-motor task

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Abstract

The aim of this study was to investigate the influence of different intermittent myofeedback training schedules as provided by a Cinderella-based myofeedback system on learning relaxation and resistance to extinction of the trapezius muscle, in subjects performing a unilateral gross-motor task. Eighteen healthy subjects performed the task without and with feedback to study baseline and learning relaxation. Subsequently, resistance to extinction was investigated by performing the task without feedback. The gross-motor task consisted of continuously moving the dominant arm between three target areas at a constant pace. Subjects were randomly assigned into three groups, characterized by the sequence of feedback schedules with which the task was performed at three consecutive days: Auditory feedback was provided after a 5, 10, or 20 seconds interval when a pre-set level of 80% rest was not reached. Bipolar surface electromyography (sEMG) recordings performed at the dominant upper trapezius muscle were quantified using Relative Rest Time (RRT) and Root Mean Square (RMS) parameters. Learning relaxation was defined as increased RRT and decreased RMS values. Results showed the highest RRT levels as well as a decrease in RMS for the 10 seconds schedule. Additionally, the 10 seconds schedule was unique in its ability to elevate muscular rest above the 20% level which may be considered relevant in preventing myalgia. None of the three schedules showed resistance to extinction. It was concluded that the 10 seconds interval is preferred over the 5 and 20 seconds schedules in learning trapezius relaxation in subjects performing a unilateral gross-motor task.

Introduction

Biofeedback can be defined as 'the use of monitoring instruments (usually electrical) to detect and amplify internal physiological processes within the body, in order to make this ordinarily unavailable internal information available to the individual and literally feed it back to him in some form'[1]. Feedback is important in the field of learning theories since it can be considered a form of operant conditioning as described by Skinner[2]. One of the most important topics of operant conditioning for the process of learning is the schedule of reinforcement[3]. These schedules describe the relationship between responses and their consequences[4] and can be classified into two groups: continuous reinforcement and partial, or intermittent, reinforcement. According to Schwartz and associates[5] continuous reinforcement, providing feedback after every correct response, is the most frequently used schedule. Intermittent reinforcement is characterized by interval or ratio reinforcement. With interval schedules feedback is given after a certain period that can be fixed or variable. Although several studies showed that continuous reinforcement results in larger physiological adaptations compared to intermittent schedules[3 6 7], it appeared to be less resistant to extinction[2 3 7 8].

In health care, biofeedback has frequently been used in breathing therapies[9], changing heart rate[10], the reduction of tension headaches[11], and hypertension[12]. In rehabilitation it could effectively be applied for neuromuscular re-education, for example improving muscular strength after stroke[13] or diminishing muscular tension in order to reduce[14 15] or prevent from work-related musculoskeletal complaints[16]. Biofeedback in neuromuscular re-education is usually called myofeedback. In case of reducing muscle tension most myofeedback interventions that are used in practice are directed at a muscular activity level (Root Mean Square, RMS), for instance feedback is given when muscular activity exceeds a certain level. The rationale behind this is the assumption that higher muscle tension affects the muscle blood flow and transport of supply and metabolites[17] resulting in myalgia. However, Veiersted et al.[18] showed the development of pain in 1% Maximum Voluntary Contraction (MVC), so the restriction of muscle blood flow can probably not be held responsible for muscular pain in, for instance, patients with work-related musculoskeletal disorders. The Cinderella-hypothesis formulated by Hägg in 1991[19] gives an alternative explanation for the development and persistence of myalgia. It encloses the idea of a fixed motor-unit recruitment and de-recruitment order in repeated muscle activation, also called Hennemans' size principle[20] for which evidence was found in patients with muscular disorders related to occupational static loads[21 22]. Too little relaxation will damage especially the low threshold motor units (type 1 or Cinderella motor units) as they are always recruited first and remain active until total relaxation of the muscle occurs[19]. The absence of short periods of muscular rest has been considered a potential risk factor in the development and persistence of muscular pain[23-25].

Based on this, one could conclude that feedback should be provided when muscular relaxation is lacking thereby learning subjects to increase their level of muscular rest. In a first study with a Cinderella-based myofeedback system in which feedback was based on lack of upper trapezius muscle relaxation instead of too high activation levels, it was shown that this form of myofeedback training results in an increase in muscular relaxation and a decrease in muscular activation and neck/shoulder pain in the majority of patients with work-related musculoskeletal complaints after a four-weeks period of training[26]. The feedback interval chosen in this study was 10 seconds, however, it was not investigated whether this was the most optimal time interval. More generally, no research has been performed investigating the reinforcement schedules for this form of myofeedback training at all. Therefore, the aim of this study was to investigate the influence of different intermittent myofeedback training schedules as provided by a Cinderella-based myofeedback system on learning relaxation of the trapezius muscle, as well as its resistance to extinction.

Methods

Subjects and design

Able-bodied subjects between the age of 18 and 60 were selected by means of a short checklist concerning complaints in the neck and shoulder regions during the last year, month, and week. Subjects were eligible when reporting a pain-free period of at least one month before measurement. In addition, neck-shoulder complaints were allowed to be present for a maximum of 7 days during the last year. Participants were excluded if they suffered from severe cervical arthrosis, joint disorder(s), latex allergy, or deafness. Recruitment was performed among employees at the National Institute for Working Life/West, Göteborg, Sweden and Roessingh Research and Development, Enschede, the Netherlands. The study was approved by the medical ethics committee.

This study was set up as a multiple cross-over trial. In total, 20 subjects were recruited and they were randomly assigned into three groups (A, B, or C) receiving a different order of the intermittent feedback schedules under investigation. After this randomization two subjects were excluded: One for motivational reasons and the other due to illness. In the end seven subjects were assigned to group A (5 female, 2 male), five subjects to group B (2 female, 3 male), and 6 subjects to group C (4 female, 2 male). Subjects were between 21 and 57 years of age (mean ± standard deviation; 30.3 ± 9.7) with a mean height of 1.80 meters (± 0.10; range 1.6 – 2.0) and a mean weight of 73.4 kilograms (± 8.9; range 63 – 89). The Body Mass Index (BMI) varied from 19.9 till 29.1 (23.1 ± 2.1). Two of the 18 subjects were left-handed.

Surface electromyography (sEMG) detection and myofeedback

Surface EMG was recorded from the dominant upper trapezius muscle. Besides a postural and supporting function, the trapezius muscle is important for adjustment of the scapula during elevation of the upper arm[27] and its superficial location makes it highly suitable for sEMG recordings and feedback applications.

Before electrode placement the skin was cleaned with alcohol. Adhesive surface electrodes (Arbo ® H93, solid gel, inter-electrode distance 2.5 cm) were placed 2 cm laterally to the midpoint between C7 and the lateral end of the acromion[28] and the position of the electrodes was marked with a semi-permanent marker to ensure identical placement of electrodes during measurements on the three consecutive days.

The sEMG signal was amplified (15X), digitised (22 bits ADC), and smooth rectified with removal of the low frequency components. Sample frequency was 512 Hz and the signal was bandpass filtered between 30 and 250 Hz. This specific filter setting was chosen in order to avoid the effects of movement artefacts in the calculation of Relative muscular Rest Time (RRT) and to avoid aliasing related to the low sample rate. Embedded software provided muscle rest detection and parameterisation. RRT was defined as the percentage of time in which Root Mean Square (RMS) was below threshold (10 μV for at least 0.12 seconds). This threshold was based on the noise level of the myofeedback system including mounted electrodes at the skin. Auditory feedback was provided after a fixed interval when the relative duration of muscle relaxation in that interval was less than 80%. The 80% threshold is based on earlier observations, which indicated that subjects who have the ability to relax in general showed RRT values above 80% during computer-related tasks, while subjects with an inability to relax showed RRT values below 20%. The system was connected to a computer and data were stored for off-line analysis.

Protocol

Three different interval schedules were chosen for providing feedback, i.e. 5, 10, and 20 seconds. This means that feedback was provided after 5, 10, or 20 seconds in case the relative duration of muscle relaxation was less than 80% during that interval. Taking the 5 seconds interval schedule to exemplify this, whether or not feedback should be provided was evaluated after each 5th second. When the level of relative muscle relaxation was below 80% during that 5 seconds period, auditory feedback was provided to the subject.

Each subject was exposed to each interval schedule at three consecutive days and the sequence of the feedback intervals was randomised. Figure 2.1 presents the order in which feedback intervals were presented to the three subject groups (A, B, and C) at the three consecutive days.

Participants were seated behind a table in a chair without arm support. The height of the table and the chair were then adjusted so that elbow flexion of the dominant arm was within a range of 90-95 degrees when the upper arm was held along the body with the forearm

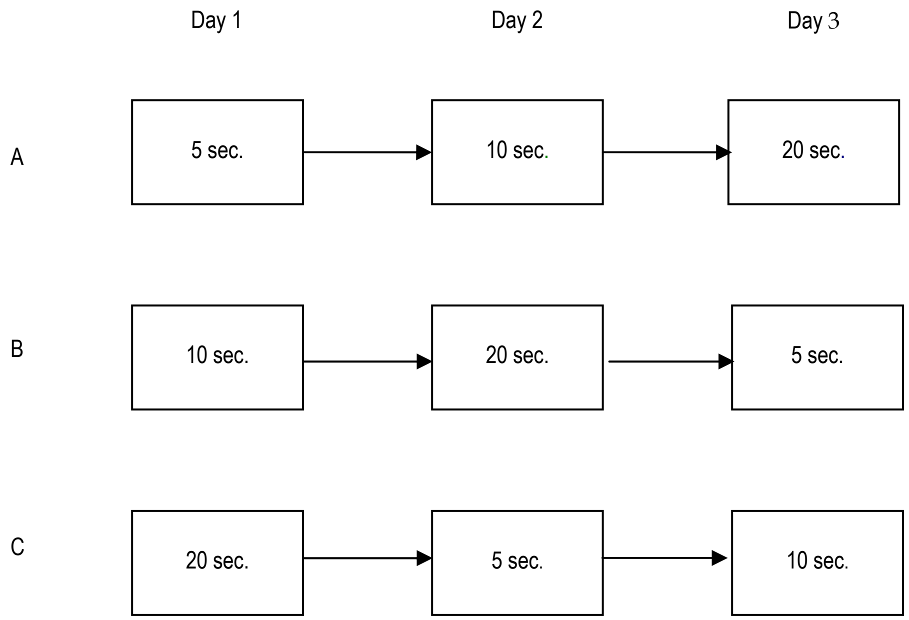

Figure 2.1: Schematic overview design

pronated and placed on the table, since an angle smaller than 90 degrees would cause undesired trapezius activation due to elevation of the shoulder when moving the forearm and hand above the table. Participants performed a unilateral gross-motor task in which they had to move the dominant arm continuously between three target areas by putting marks with a pencil in circles with a diameter of 12 mm (see Figure 2.2).

Right-handed subjects moved the dominant arm from the left target via the upper to the right target while left-handed subjects, in contrast, had to move the dominant arm from the left target via the right to the upper target to ensure anatomical similarity in movements

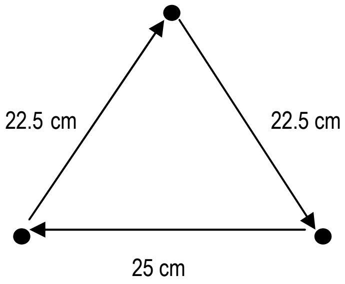

Figure 2.2: Gross-motor task, direction of moving the dominant arm in right-handed subjects

between these two groups. The upper target was right in front of the subject and the distance between the subject and the upper target was such that the elbow did not have to extend fully to reach the target. Pace was kept constant at 88 marks / minute with help of a metronome[29].

Subjects were informed that this study aimed at investigating the influence of different feedback schedules on muscular relaxation. They got no information about the different schedules used in order to avoid information bias. Subjects were not allowed to talk during recordings.

The sEMG recordings (see Figure 2.3) started with 4 reference contractions of the trapezius muscle performed according to the guidelines of Mathiassen et al.[30]. These reference contractions were followed by gross-motor task performance for 3 minutes without myofeedback to study baseline (Baseline; B). Subjects were instructed that they had to perform the task with the upper extremity (especially the dominant shoulder) as relaxed as possible with the non-dominant arm resting on the table. Subsequently subjects performed the gross-motor task with feedback during 4 minutes four times (Task; T1-4). In between each measurement there were two minutes of rest to prevent subjects from muscle overload. Subjects were instructed that they had to discover the way of performing the task that would result in the fewest feedback signals and that this could be reached by relaxation. Again, the non-dominant arm was resting on the table. These tasks were considered the learning phase.

A three minute gross-motor task without myofeedback was performed twice to study resistance to extinction (Extinction; E1-2) again with 2 minutes rest in between. Instructions were identical to those given during baseline.

Data analysis

Learning trapezius relaxation was defined as an increase in relaxation as well as a decrease in activation expressed in sEMG outcome parameters RRT (in %) and RMS (in µV). RRT was defined as the percentage of time in which RMS was below 10µV for at least 0.12 seconds. sEMG was continuously recorded during baseline, tasks, and extinction measurements and both RRT and RMS were calculated in consecutive periods of 20 seconds. This resulted in 9 baseline values, 4*12 task values, and 2*9 extinction values for each parameter. These values

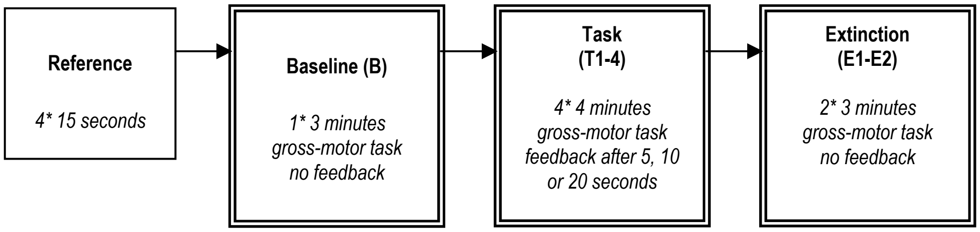

Figure 2.3: Schematic overview sEMG recordings

were subsequently averaged resulting in one value for baseline (B), one for each task (T1, T2, T3, T4), and one for each extinction measurement (E1, E2) for each parameter per subject.
RMS values of the reference contractions were computed for the middle ten seconds of each contraction (Mathiassen et al. 1995) and the mean value was used for normalization. This means that RMS values during baseline, tasks, and extinction measurements were expressed as percentages of this mean reference value. After this normalization procedure, individual values were averaged to obtain group results: n=18 for the 5, 10, and 20 seconds intervals for RRT and n=13 for RMS. RMS values of 5 subjects were missing due to technical problems with the recording system.

Statistical analysis

Surface EMG parameters were tested for normality using the Shapiro-Wilk test indicating a non-normal distribution for RRT values ($p<0.05$) and a normal distribution for RMS values ($p>0.05$).
Statistical analysis was divided into two parts. Firstly, it was investigated whether the three different interval training schedules resulted in different RRT and RMS values at B, T1-4, and E1-E2. For RRT values a non parametric method based on rank statistics was used and for RMS a test for multiple cross-over trials based on Linear Mixed-Effects modelling was used. Secondly, for each feedback interval separately it was investigated whether RRT and RMS values changed during the tasks (T1-T4) compared to baseline (B) to study the learning pattern for each interval, and whether E1 and E2 differed compared to B and T4 to study resistance to extinction. For RRT Friedman tests (k Related Samples) and Wilcoxon Signed Ranks tests (2 Related Samples) were used while RMS analysis required Paired Samples T-tests. Alpha was set at 0.05 for statistical significance.

Results

Muscular relaxation

Figure 2.4 represents the course of RRT for each interval. Additionally, median RRT values and corresponding 25-75% quartiles are presented in Table 2.1. Results showed a tendency of increased RRT values during the feedback tasks (T1-T4) compared to baseline (B) for the 5, 10, and 20 seconds interval schedules. During the extinction measurements (E1 and E2) RRT values were comparable to baseline for each interval.
Overall statistical testing for interval and measurement as independent factors showed significant differences. Post hoc testing revealed no significant differences in RRT values between the three intervals during baseline, tasks, and extinction measurements (p-values range 0.40 - 0.95). However, significantly changed RRT values were found for each interval during the tasks compared to baseline ($p = 0.00$). The 5 seconds interval induced significantly increased RRT values during the tasks (T1-T4) compared to baseline ($p \leq 0.05$).

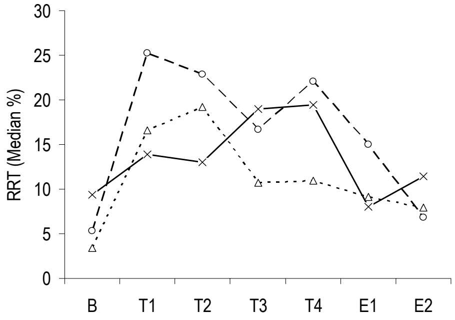

Figure 2.4: Median RRT values of the trapezius muscle induced by the three interval schedules during gross-motor task performance

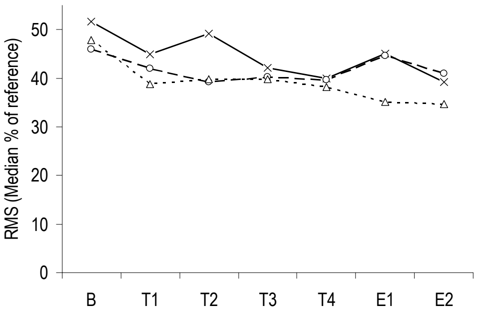

Figure 2.5: Mean RMS values of the trapezius muscle induced by the three interval schedules during gross-motor task performance

B = Baseline; T = Task; E = Extinction; -x - = 5 seconds schedule; -o- = 10 seconds schedule; –Δ- = 20 seconds schedule

For the 10 seconds interval RRT values at T1 and T2 were significantly higher compared to baseline ($p \leq 0.01$), and for the 20 seconds interval relative muscular rest time values were significantly increased compared to baseline only at T1 ($p \leq 0.02$).

Looking at the absolute levels of rest time, the 10 seconds feedback interval resulted in the highest RRT values (25%) compared to the other two schedules and also the steepest increase at the beginning of the measurement. When the gross-motor task was performed after the learning period without feedback in order to study resistance to extinction, RRT values were identical to baseline for each interval (p values range 0.31 - 0.88). This suggests that none of the three schedules was effective in retaining muscular relaxation as learned during the tasks. Compared to T4, muscular relaxation at E1 and E2 was significantly lower for the 5 seconds schedule ($p \leq 0.01$), while only E1 was significantly lower at the 10 seconds schedule ($p = 0.02$) and E2 for the 20 seconds schedule ($p = 0.03$).

Muscular activation

Figure 2.5 represents the course of RMS for each interval. In addition, mean RMS values as well as the corresponding standard deviations are displayed in Table 2.2 for each interval separately. Results showed a trend of decreased RMS values during the tasks (T1-T4) compared to baseline (B) for the 5, 10, and 20 seconds interval schedules. After ending the feedback, muscular activity increased considerably for the 5 and 10 seconds interval schedules but not for the 20 seconds schedule.

Linear mixed-effects modelling showed no statistical differences between the three intervals at baseline, T1-T4 and E1-E2 ($F = 0.121$; $p = 0.89$). However, significant differences were found within intervals between baseline, tasks, and extinction measurements ($F = 2.892$; $p = 0.01$). Post hoc testing showed that for the 5 seconds interval muscular activation during the tasks was not different compared to baseline (p range 0.08 - 0.16). The 10 seconds schedule

Table 2.1: Relative Rest Time: Median (25% - 75% quartiles) per interval for Baseline, Task 1-4, and Extinction 1-2 measurements

	Baseline	Task 1	Task 2	Task 3	Task 4	Extinction 1	Extinction 2
5 seconds interval							
	9.4 (0.3-17.9)	13.9 (2.5–49.7)	13.1 (8.1-30.2)	19.0 (10.2-47.5)	19.4 (8.4-54.1)	8.0 (3.7-46.8)	11.5 (1.6-39.3)
10 seconds interval							
	5.3 (0.5-39.7)	25.2 (3.3-53.9)	22.8 (5.7-63.2)	16.7 (4.5-42.4)	22.1 (2.9-51.7)	15.0 (2.6-36.2)	6.9 (1.4-35.3)
20 seconds interval							
	3.4 (0.3-45.4)	16.6 (2.3-54.0)	19.2 (5.1-53.6)	10.7 (1.7-45.5)	10.9 (4.7-52.5)	9.1 (1.6-44.6)	8.0 (1.0-42.7)

Table 2.2: Root Mean Square: Mean (± 1 standard deviation) per interval for Baseline, Task 1-4, and Extinction 1-2 measurements

	Baseline	Task 1	Task 2	Task 3	Task 4	Extinction 1	Extinction 2
5 seconds interval							
	51.7 (± 34.0)	39.9 (± 23.2)	47.6 (± 28.9)	42.2 (± 21.0)	39.7 (± 25.1)	45.1 (± 29.5)	38.5 (± 17.6)
10 seconds interval							
	45.9 (± 27.1)	42.0 (± 35.8)	39.8 (± 31.2)	42.2 (± 31.2)	39.7 (± 32.0)	44.6 (± 33.8)	44.1 (± 27.6)
20 seconds interval							
	47.8 (± 37.6)	37.3 (± 27.3)	39.8 (± 31.6)	39.9 (± 26.1)	39.1 (± 24.7)	34.9 (± 21.9)	34.7 (± 18.0)

resulted in significantly changed RMS values during T2 compared to baseline (p = 0.04) but not during the other tasks (p range 0.09 - 0.43). Providing feedback after 20 seconds resulted in changed muscular activation levels at T1 and T2 compared to baseline (p = 0.03 and p = 0.02 respectively). The level of trapezius activation during both extinction measurements was for each interval not significantly different from baseline (p values range 0.14 - 0.70). For the 5 seconds interval RMS values were significantly different compared to T4 at E1 (p = 0.04) but not at E2. The 10 seconds interval resulted in significantly higher E1 values compared to T4 (p = 0.01) but this change was absent during the second extinction measurement (p = 0.53).

Finally, for the 20 seconds schedule there were no differences in muscular activation after the feedback training compared to T4.

Discussion

This multiple cross-over study aimed at increasing knowledge about the influence of different intermittent myofeedback schedules on learning relaxation of the trapezius muscle during gross-motor task performance, as well as its resistance to extinction using a Cinderella-based myofeedback system.

The 10 seconds schedule resulted in the highest level of muscular relaxation (RRT). This schedule also appeared to be unique in its ability to increase RRT above the 20% level. Based on the study of Hägg and Åström[19] in which EMG recordings were performed at the upper trapezius muscle in medical secretaries with and without complaints, this 20% level of muscular relaxation may be considered as relevant in preventing from the development of myalgia. Muscle activation patterns were least affected by the 20 seconds schedule. The change in muscular activation (RMS) was limited during the feedback training and also the initial effect of increased relaxation (RRT) disappeared during the continuation of the measurements which might indicate that the postulated effect of feedback was limited with this interval.

One hypothesis to explain lack of learning occurring under partial, or intermittent, reinforcement schedules is the invariance hypothesis of Williams[31] suggesting that the reduced number of reinforcement stimuli obtained during the learning phase is responsible for the learning deficit. In this study, the maximal number of feedback stimuli for the 20 seconds schedule is 12 per task while for the 5 and 10 seconds schedule maximal number of stimuli is 48 and 24 per task respectively. The limited duration of the learning period in this study might well be responsible for the absence of learning effects with the 20 seconds schedule.

Based on this invariance hypothesis[31], one could suggest that the 5 seconds schedule would be preferred over the 20 and 10 seconds interval schedules. Furthermore, the duration of this interval is that short that it approaches continuous feedback which in several studies has shown to be more effective in inducing physiological changes than intermittent feedback schedules[3 6 7]. However, although the 5 seconds schedule induced increasing trapezius relaxation during the training period, median values were still below 20%. Furthermore, this schedule resulted in the highest level of trapezius activation compared to the 10 and 20 seconds schedules. A cause may be the evoked mental stress by this relatively high number of feedback stimuli. Lundberg et al.[32] showed that mental stress does increase the level of activation in the trapezius muscle and as such this was also reported by the subjects after the tasks. This suggests that the 5 seconds schedule may be less effective in myofeedback training aimed at learning trapezius relaxation in stress sensitive subjects, which concerns probably the majority of subjects with work-related myalgia.

Although intermittent reinforcement schedules are assumed to be more resistant to extinction[2 3 7 8], none of the three schedules used in this study proved to be resistant to extinction. This means that although subjects were able to increase relaxation and reduce activation levels during the feedback tasks, it did not result in a skill which they could use in a consecutive task without feedback. An explanation may be that the training period was too short to learn the motor skill which would result in a change of muscle activation patterns.

It can be questioned whether the content of the feedback used in this study results in optimal learning effects. The content of feedback was based on the knowledge of results principle, i.e. externally information was provided about the outcome of the performance, implicating that feedback only gave information about whether the pre-set level of relaxation was reached or not[33]. The theoretical counterpart is knowledge of performance, for example providing subjects additional information about why they were not able to switch off the feedback by telling them that they may need to suppress the shoulder or reduce the amplitude of arm movement. Although some studies conclude that knowledge of performance is more influential in learning[34], others report that both ways of providing feedback are equally effective in general[35]. However, knowledge of performance appeared to be especially effective when subjects have to adopt specific muscle activity[36].

In order to earn the fewest amount of feedback subjects used different strategies while performing the gross-motor task, varying from suppression of the shoulder to restricting the amplitude of arm movement. This could suggest that other muscles were activated in order to enable relaxation of the upper trapezius muscle. Evidence for this was found by Palmerud et al.[37 38], who investigated whether subjects could effectively reduce trapezius muscle activity induced by continuous visual feedback techniques, and whether this relaxation was reflected in an increased activity of other muscles involved in shoulder movements. They showed that the m. rhomboid major, the m. rhomboid minor, and the transverse part of the trapezius muscle showed significantly increased activation levels (232%, 175%, and 201% respectively) while the m. trapezius pars descending was relaxed[38]. This was similarly true for the m. infraspinatus[37]. Clinically, this implies the need for careful monitoring during myofeedback training in order to prevent generating complaints in other upper-extremity regions. From another perspective, the use of different strategies may have been responsible for the relatively large inter-subject variability as was also found by Hermens and Hutten[26].

One would expect that changes in RRT are reflected in changes in RMS e.g. a longer duration of relaxation directly means lower RMS values in that interval, since RRT is calculated based on RMS. A close look at Figures 2.4 and 2.5 only shows that indeed RRT and RMS often change in an opposite way, especially when the changes are relatively large like between baseline and T1. In other areas of the curves this is less clear. An explanation is that RRT is a highly non-linear parameter in the sense that it will only be correlated with changes in RMS when these changes occur around the threshold used for calculation of RRT. Changes in RMS at a much higher level than the threshold for muscle rest will not affect RRT. It should be noted that these two parameters represent different physiological processes. RMS reflects a global indication of the muscle activation level whereas RRT reflects the relative time in which the muscle is relaxed. According to the Cinderella hypothesis it is not the activation level that is related to the development of myalgia, but the amount of relaxation. This obviously requires a different strategy in preventing myalgia.

One methodological comment should be made. The multiple cross-over design used in this study was not a complete design since only three of all six combinations of the order in which the different feedback intervals could be provided were used. Inherently, this raises the question whether comparison between and within intervals as performed in this study is justifiable and methodologically correct. Visual inspection of the results however, learned that the three separate groups showed close to identical learning patterns over the three days thereby justifying the use of only three out of six sequence combinations.

In conclusion the results indicate that Cinderella-based myofeedback is best provided with the 10 seconds interval schedule instead of the 5 or 20 seconds schedules in learning muscular relaxation during a gross-motor task. The 10 seconds interval schedule showed clinically relevant increases in muscular relaxation as well as reduced muscular activation levels during the feedback training. For each interval, however, the effect of the training did not last when feedback was removed. Based on these findings, it is recommended to investigate the effects of long-duration exposure to feedback training, in a larger subject sample.

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Chapter 3

Effects of ambulant myofeedback training and ergonomic counselling in female computer users with work-related neck-shoulder complaints: A randomised controlled trial

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Abstract

This study aimed at investigating the effects of ambulant myofeedback training including ergonomic counselling (Mfb) and ergonomic counselling alone (EC), on work-related neck-shoulder pain and disability. Seventy-nine female computer workers reporting complaints in the neck and/or shoulders were randomly assigned to Mfb or EC and received four weeks of intervention. Pain intensity in neck, shoulders, and upper back, and pain disability, were measured at baseline, immediately after intervention, and at three and six months follow-up. Pain intensity and disability significantly decreased immediately after four weeks Mfb or EC, and the effects remained at follow up. No differences were observed between the Mfb and EC group for outcome and subjects in both intervention groups showed comparable chances for improvement in pain intensity and disability. It was concluded that pain intensity and disability were significantly reduced after both interventions and this effect remained at follow-up. No differences were observed between the two intervention groups.

Introduction

Work-related musculoskeletal complaints in the upper extremity are common among workers in Western industrialised countries. In the Netherlands, about 15% of the working population report complaints in the neck, shoulders and arms[1] defined as pain, numbness, or tingling, resulting in loss of productivity, sick-leave, or even disability. In 1998, about 8% of all Dutch employees were absent from work due to work-related musculoskeletal complaints, and 2% of the employee population was absent from work for more than four weeks[2]. Apart from the individual suffering, these complaints impose a substantial economic burden in compensation costs, lost wages and productivity within member states of the European Union[3].

Work-related musculoskeletal complaints are multifactorial in origin and involve biomechanical, psychosocial, and individual components[4-6]. As a consequence different intervention approaches exist. Most often interventions address alterations of the physical work environment by adjustments of the work station and/or education about working posture according to ergonomic principles[7 8-10]. There are several studies reporting on the effectiveness of ergonomic approaches[11 12] and it is commonly accepted that properly designed work stations are prerequisites for healthy working. However, in spite of attention to ergonomics musculoskeletal complaints remain a considerable problem[13-15] and this is the rationale for developing innovative interventions.

A relatively new intervention approach addressing neck-shoulder complaints is myofeedback training based on the Cinderella-hypothesis[16]. The Cinderella-hypothesis is one of the most influential hypotheses explaining the process of development and persistence of pain in low intensity jobs[17] like computer work, and states that lack of sufficient muscle relaxation is a crucial factor in this process. Continuous muscle activity, even at low intensity levels, may result in homeostatic disturbances of the activated motor units due to affected blood flow and removal of metabolites[17]. Several studies have found an association between absence of moments of complete muscle rest and myalgia, especially for the commonly affected descending part of the trapezius muscle[18-20]. Warning subjects when their muscle relaxation is insufficient could thus contribute to recovery, and this is the rationale for the Cinderella-based myofeedback training. This approach is different from traditional myofeedback training[21 22] in which feedback is provided when muscle activity exceeds a certain level thereby aiming at decreasing muscle activation. As the Cinderella-hypothesis suggests however that muscle *relaxation* is more relevant than muscle *activation*, a myofeedback intervention aiming at increasing muscle relaxation may be more beneficial.

The Cinderella-based myofeedback system[23] consists of a harness incorporating dry surface electrodes and a feedback unit. The system is ambulant and subjects can wear the harness under their clothes during working days. The harness is connected to a feedback unit worn at the waist which provides feedback by means of vibration and a soft sound when muscle relaxation is insufficient. A feasibility study using this equipment for four weeks in subjects reporting work-related neck-shoulder complaints resulted in significantly decreased levels of pain intensity and also changed muscle activation patterns. These effects were still at hand four weeks after the myofeedback training ended[23]. However, as the study did not contain a control group and only investigated the lasting effects of the intervention for a short follow-up period (4 weeks), further research is needed.

Proper ergonomics are indispensable for healthy working and therefore the myofeedback training is preferably applied in combination with an intervention approach aimed at improving ergonomics. Thus, the present study aimed at investigating the immediate and lasting effects of Cinderella-based myofeedback training including ergonomic counselling, compared to ergonomic counselling alone, on pain intensity and disability in females with work-related neck-shoulder complaints. Because especially interventions focusing on multiple factors have shown to be related to a decreased incidence of complaints[24], it was hypothesised that 4-weeks myofeedback training combined with ergonomic counselling would be more effective in reducing pain intensity and disability than the intervention based on ergonomic counselling alone.

Methods and materials

Design and subjects

A randomized controlled trial was performed to assess the effects of 4-weeks Cinderella-based myofeedback training combined with ergonomic counselling (together referred to as Mfb), compared to ergonomic counselling alone (EC), on pain intensity and disability. Measurements were performed prior to the intervention but before randomisation (Baseline), immediately after four weeks of intervention (T0), and at three (T3) and six (T6) months follow-up.

Participants were recruited in Sweden (area of Göteborg) and the Netherlands (area of Enschede) between March 2003 and June 2005. Computer workers like job counsellors (Sweden) and (medical) secretaries (Sweden and the Netherlands) were approached by telephone and announcements, and volunteers were subsequently sent a screening questionnaire[25] which was developed within the EU-funded NEW project (Neuromuscular assessment in the Elderly Worker)[26]. Subjects eligible for participation were symptomatic female computer workers, predominantly over the age of 45 as the prevalence of complaints is especially high in this age category[27], working for at least 20 hours a week, and reporting perpetuating work-related musculoskeletal complaints in the neck and/or shoulder region for at least 30 days during the last year.

Subjects were excluded when they reported pain in more than 3 body regions, when they suffered from severe arthrosis or joint disorders, when they used muscle relaxants, or when reporting other complaints in the upper extremity not related to (computer) work.

Power calculation, based on the results of Hermens and Hutten[23], indicated that at least 35 subjects should be included in each intervention group (estimated proportion of subjects showing an effect on pain intensity was set at 0.6 in the Mfb group and 0.2 in the EC group; 1- β = 0.90; α = .05). Block randomization was used to assign subjects to either Mfb or EC: When a new group of subjects started the intervention, half of them were assigned to Mfb and half of them were assigned to EC. The study was approved by the local medical ethics committees and all participants gave their informed consent prior to participation.

Interventions

The interventions were provided by three different therapists: one physiotherapist in Sweden and two health scientists in the Netherlands. They were thoroughly trained and practiced together prior to the start of the study to ensure that they would provide as identical interventions as possible. The character of the intervention made blinding of the therapists and the subjects to the intervention impractical. Subjects were informed that the aim of the current study was to compare the effects of two interventions and that there was no evidence favouring one of these interventions, to reduce information bias.

Ergonomic Counselling (EC)

Subjects received four weeks of intervention during which they kept a diary of activities and pain intensity scores. During this four weeks period, they were visited weekly by their therapist. The first visit comprised an ergonomic workplace investigation by means of the risk inventory of Huppes et al.[28]. This checklist contains questions to evaluate work tasks, working hours, work load, work station, and work methods. Based on the outcome, possible improvements were discussed with the subject. With regard to the work station, the focus was primarily on modifying the existing workstation rather than providing new equipment. The remaining visits were used to further discuss the ergonomic aspects, the consequences of possible ergonomic adjustments, etc. according to a manual to guarantee a uniform intervention.

Myofeedback (Mfb)

Subjects randomized to the Mfb group received Cinderella-based myofeedback training on top of EC. A two-channel ambulant myofeedback system combined with a harness incorporating dry surface Electromyography (sEMG) electrodes to enable a stable recording of upper trapezius muscle activity was used. The harness was connected with a sEMG processing and storage device (see Picture 1.1). The sEMG signal was amplified (15x), band pass filtered between 30 and 250 Hz, sampled at 512 Hz, digitized (22 bits ADC) and smooth rectified with removal of the low frequency components. Embedded software provided the detection and calculation of muscle rest, expressed as the sEMG parameter Relative Rest Time, which was defined as the percentage of time in which Root Mean Square was below a threshold (10 μV) for at least 0.12 seconds. This threshold was based on the noise level of the myofeedback system including mounted electrodes at the skin. Sensory feedback by means of vibration and a soft sound was provided after each 10 seconds interval when the relative duration of muscle relaxation in that particular interval was below 20%. The choice for a 10 seconds interval was based on the results of Voerman et al.[29], and the 20% threshold was chosen based on the work of Hägg and Åström[30]. Subjects were instructed that they should respond to the feedback by relaxation of the trapezius muscles, which could be reached by slightly depressing the shoulders, or by sitting down quietly with the eyes closed, the hands in the lap while breathing deeply. Another relaxation strategy subjects were instructed was to maximally elevate the shoulders for three seconds to build up muscle tension and then to let loose this tension. When there was no adequate response to the feedback, i.e. relaxation, the duration of the feedback signal progressively increased.

Immediately after Baseline, subjects assigned to the Mfb group were given the myofeedback device and they were explained the working mechanism and background of the myofeedback training. Subjects wore the system for four weeks, for at least eight hours a week (distributed over two hours a day and two days a week as a minimum) while performing their regular work. During the weekly visits the sEMG-data from last week were scrutinized and discussed to give the subject insight in their relaxation patterns and to identify possible situations of concern. This procedure was facilitated by means of the diary.

Assessment of pain intensity and disability

Pain intensity in the neck, left and right shoulders, and upper back at time of the measurement was assessed by means of four Visual Analogue Scales (VAS)[31]. Subjects were instructed to rate their subjectively experienced level of pain intensity at that moment for each body region. The VAS consists of a 10 cm horizontal line with 'no discomfort at all' at the left and 'as much discomfort as possible' at the right endpoint of the line. Psychometric properties of the VAS have been shown to be sufficient[32-34].

The level of subjectively experienced disability was assessed with the Pain Disability Index, a self-rating scale that measures the impact of pain on the abilities to participate in life activities[35]. The Pain Disability Index contains 7 items, one for each domain, i.e. 1) family and home responsibilities, (2) recreation (sports and leisure time activities), (3) social activity (participation with friends and acquaintances), (4) occupation (activities partly or directly related to working), (5) sexual behaviour (frequency and quality of sex life), (6) self care (personal maintenance and independent daily living), and (7) life-supporting activities(basic life-supporting behaviours). Answers are provided on a categorical 11-points scale with ‘not disabled’ and ‘fully disabled’ at the extremes. In a chronic pain population, psychometric properties of the Pain Disability Index appeared to be sufficient[36].

Analysis

For each subject, VAS scores for the neck, left shoulder, right shoulder, and upper back were summed and averaged resulting in a combined neck-shoulder pain intensity score. Data inspection showed non-normal distributions for VAS and Pain Disability Index scores, so data were log transformed enabling parametric analyses. Analyses were performed both on the group as well as the individual level.

Differences between the two interventions, i.e. Mfb and EC, for VAS and the Pain Disability Index were investigated using a linear mixed-model analysis technique for repeated measurements. The following variables were included in the model as fixed factors: Time of measurement (i.e. Baseline, T0, T3, and T6), intervention type (i.e. Mfb and EC), and study group (i.e. Sweden and the Netherlands). The factor study group comprises variance due to possible (socio)demographic differences as well as variance caused by the different therapists, organizations, and job characteristics in the two countries. The factor subject was included in the model as a random factor. Two-factor interactions were additionally included in analysis to study effect modification. Paired and independent samples t-tests were used for Post Hoc analysis.

At the individual level the percentages of subjects improving and the odds for improvement in both intervention groups were investigated. First, individual differences were calculated between Baseline and T0, Baseline and T3, and Baseline and T6 for pain intensity in the neck-shoulder region (i.e. the averaged VAS score for neck, left and right shoulders, and upper back) and Pain Disability Index. These differences were then dichotomized into 'clinically relevant improvement' or 'equal/deteriorated' for pain intensity and disability. The cut-off point for a clinically relevant improvement in VAS was defined at 13 mm which corresponds to the upper limit of the confidence interval of clinically relevant changes in VAS scores in acute and non-acute pain patients as reported by Kelly in 2001[37]. This cut-off point was also the result of the study of Todd[34]. Cut-off points for clinically significant changes in the Pain Disability Index scores have not been provided in literature. For a comparable measure, the Neck Disability Index which is a 10 items scale with 6 answering options resulting in scores varying from 0 to 50, the cut-off point was set at 5 which is 10% of the maximum score[38]. Using this as a starting point, a clinically relevant change was defined as a change of ≥ 10% of the maximum score of 70 of the Pain Disability Index, i.e. ≥ 7 units of the Pain Disability Index score.

Logistic regression analyses providing Odds Ratios were performed to investigate whether the two intervention groups differed in terms of chances for clinically relevant improvements in pain intensity and disability. Three different models were investigated: Model I represents the crude Odds Ratio describing only the relationship between intervention type and odds for improvement without adjustment for confounding factors. The factors study group and baseline pain intensity / baseline disability were assumed potentially confounding factors. To correct for these factors, two additional models were built as extensions of model I: Model II incorporates study group as confounding factor, and model III is an extension of model II incorporating also the factor baseline pain intensity or baseline disability level. For models II and III interaction effects were additionally included in the analysis, to study effect modification, but these remained only included when significant. -2 Log Likelihood tests were used to compare the models. Odds Ratios including 95% Confidence Intervals were calculated and presented for each of the models.

Statistical Package for Social Sciences 11.5 was used for statistical testing and alpha was set at .05 for statistical significance.

Results

Subjects

Seventy-nine subjects with work-related neck-shoulder complaints were included in this study: Forty-two subjects were assigned to the Mfb group and 37 to the EC group. Mean age was 52.0 (± 1 sd 5.8) years in the Mfb group and 50.7 (± 5.5) years in the EC group. Mean duration (days between Baseline and T0) of the interventions was 37 (± 8) days for the Mfb group and 36 (± 7) days for the EC group. Forty-one of the 79 subjects were recruited in Sweden and the remaining 38 in the Netherlands. The number of subjects at Baseline, T0, T3, and T6 and the number of drop-outs are shown in Diagram 3.1.

Drop-outs did not differ in age, weight, height, BMI, VAS, or Pain Disability Index scores from those fulfilling the intervention (p > .08). Table 3.1 provides an overview of sociodemographic characteristics of the subjects in the Mfb and EC groups. Thirty-eight subjects reported complaints in both the neck and shoulder, while 41 subjects reported complaints either in the neck or in the shoulder at the time of recruitment. Comparison of the characteristics between the Mfb and the EC group indicated that subjects assigned to the Mfb group reported more years within the same job compared to the EC group (p < .05).

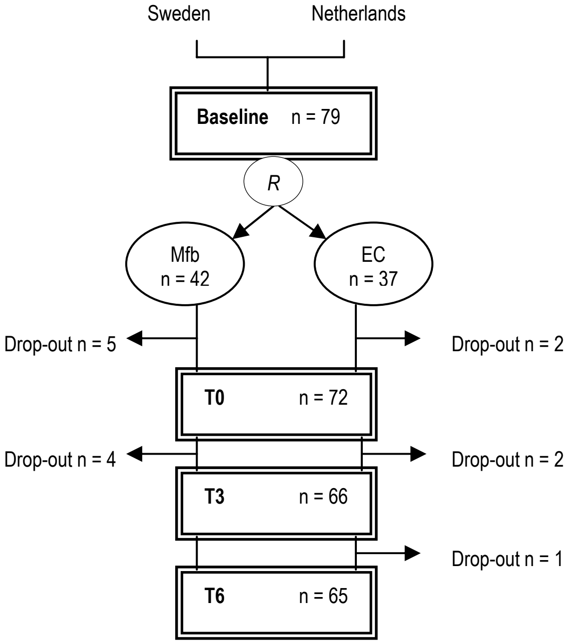

Diagram 3.1: Flow chart for subject recruitment, randomisation (R), and drop-outs

Table 3.1: Characteristics of subject population

		Mfb (n = 42)	**EC (n = 37)**
Sociodemographics			
Body Mass Index		25.2 (3.9)	25.2 (3.7)
Side dominance	Right-handed	95%	97%
Living situation	Living alone	16.7%	10.8%
Working hours per week		32.8 (7.8)	32.8 (8.3)
Working hours per week since (in years)		17.0 (11.4)*	12.0 (8.9)*
Complaints			
Trouble in neck last year	Yes	92.9%	91.9%
Trouble shoulders last year	Yes, both shoulders	36.6%	32.4%
	Yes, right shoulder	36.6%	43.2%
	Yes, left shoulder	12.2%	13.5%
Trouble in upper back last year	Yes	66.7%	48.6%
Was work performance affected	Yes	31.7%	18.9%

* Significant at the .05 level

Analysis at group level

Pain intensity

Baseline (geometric) mean VAS scores for each region separately were 27 mm (neck), 15 mm (left shoulder), 14 mm (right shoulder), and 13 mm (upper back) in the Mfb group and 24, 14, 19, and 18 mm in the EC group respectively.

Figure 3.1 shows box plots of VAS scores in the neck-shoulder region at Baseline, T0, T3, and T6 for the Mfb and the EC group. A clear decrease was observed at T0, T3, and T6 compared to Baseline, although at T6 pain intensity seemed to increase slightly in both groups.

Mixed linear modelling showed that pain intensity in the neck-shoulder region significantly changed over time ($F = 12.08$, $p \leq .01$), without additional effects for the type of the intervention ($F = 1.54$, $p = 0.22$), study group ($F = .48$, $p = .49$), or interaction effects ($F \leq .87$, $p \geq .35$). Post Hoc comparisons revealed that VAS score was significantly reduced at T0 ($t = 4.37$, $p < .01$), T3 ($t = 5.10$, $p < .01$), and T6 ($t = 3.54$, $p < .01$) compared to Baseline but also the reduction between T0 and T3 was significant ($t = 2.85$, $p = .01$).

Disability

Figure 3.2 shows box plots of Pain Disability Index scores at Baseline, T0, T3, and T6 for the Mfb and the EC group. A comparable pattern to what was observed for pain intensity was found, with decreased disability levels at T0, T3, and T6 compared to Baseline.

Disability levels significantly changed over time ($F = 17.68$, $p < .01$) and were significantly different between the two study groups (i.e. Sweden and the Netherlands) ($F = 5.30$, p .02).

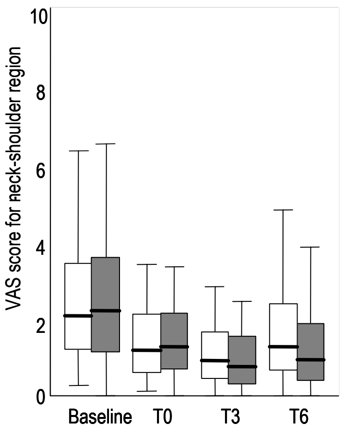

Figure 3.1: Box plot for averaged VAS scores in the neck-shoulder region at Baseline, T0, T3, and T6 for Mfb (□) and EC (■)

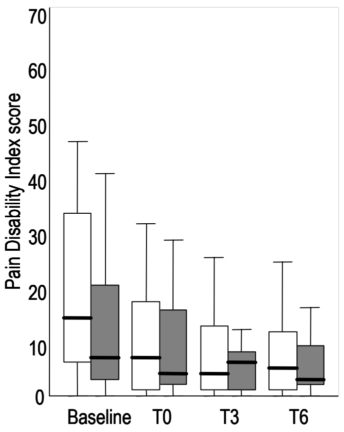

Figure 3.2: Box plot for averaged PDI scores in the neck-shoulder region at Baseline, T0, T3, and T6 for Mfb (□) and EC (■)

No additional effects were found for intervention type (F = .86, p = .35) or interaction (F ≤ 1.97, p ≥ .12).

Post Hoc comparisons showed subjects in the Swedish study group had lower Baseline values and reported reductions in disability only between Baseline and T0 (t = 2.20, p = .04) with a trend for reductions at T3 (t = 1.89, p = .07) and T6 (t = 1.81, p .08). Subjects in the Dutch study group showed a significant decrease at T0 (t = 3.26, p <.01), T3 (t = 3.58, p < .01), and T6 (t = 3.51, p < .01) compared to Baseline.

Analysis at the individual level

Pain intensity

Figure 3.3 gives an overview of the percentage of subjects in the Mfb and the EC group showing an improvement in pain intensity in the neck-shoulder region. About half of the subjects showed a clinically relevant improvement in pain intensity in the neck-shoulder region, with slightly more subjects in the Mfb group compared to the subjects in the EC group immediately after the intervention period (T0) and at 6 months follow-up (T6). Crude Odds Ratios (Model I) for improvement showed higher odds for clinically relevant improvement in the Mfb group at T0 and T6 compared to Baseline, while between T3 and Baseline subjects assigned to EC were more likely to show improvements (see Table 3.2). However, Odds Ratios were not significant (p ≥ .36) also not when corrected for potential confounding factors (p > .19)

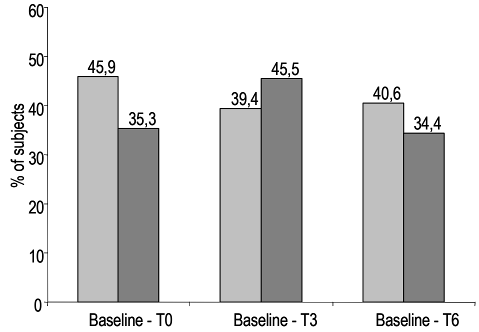

Figure 3.3: Percentage of subjects showing improvements in averaged VAS score at T0, T3, and T6 compared to Baseline for Mfb (■) and EC (■) [without correcting for confounding factors]

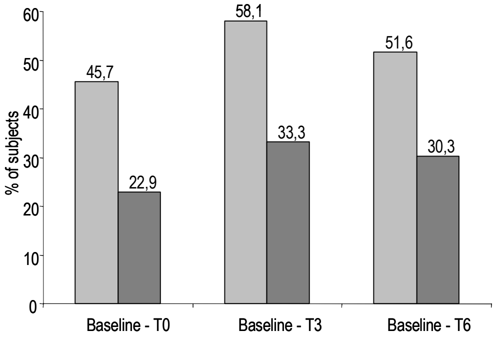

Figure 3.4: Percentage of subjects showing improvements in averaged PDI score at T0, T3, and T6 compared to Baseline for Mfb (■) and EC (■) [without correcting for confounding factors]

-2 Log Likelihood tests indicated that Model III, adjusting for the factors study group and baseline pain intensity / disability level, superimposed the models I and II (-2 LL; $p < .05$). As no significant interaction effects were found ($p > .08$) these were excluded from the final Models as presented in Table 3.2.

Table 3.2: (Adjusted) Odds ratios (95% Confidence Interval) for improvement in pain intensity in the neck-shoulder region in the Mfb group compared to the EC group

	Model I	**Model II**	**Model III**
VAS Baseline – T0	**1.56** (.60 – 4.05)	**1.59** (.71 – 4.14)	**3.42** (.55 – 21.11)
VAS Baseline – T3	**.78** (.29 – 2.08)	**.78** (.29 – 2.09)	**.40** (.08 – 1.99)
VAS Baseline – T6	**1.31** (.47 – 3.60)	**1.31** (.47 – 3.64)	**.29** (.29 – 3.77)

Model I: *Odds Ratio Crude*
Model II: *Odds Ratio Adjusted for factor study group*
Model III: *Odds Ratio Adjusted for factor study group and VAS at Baseline*

Disability

An overview of the percentage of subjects in the Mfb and EC groups showing an improvement in disability is provided in Figure 3.4. Immediately after the intervention period about twice as many subjects in the Mfb group showed clinically relevant improvements in disability compared to the EC group. This share of subjects increased

Table 3.3: (Adjusted) Odds ratios (95% Confidence Interval) for improvement in disability (PDI) in the Mfb group compared to the EC group

	Model I	Model II	Model III
PDI Baseline – T0	**2.70** (.97 – 7.54)	**2.72** (.97 – 7.60)	**1.48** (.39 – 5.62)
PDI Baseline – T3	**2.77** (1.00 – 7.65)*	**2.99** (1.03 – 8.65)*	**1.64** (.34 – 7.97)
PDI Baseline – T6	**2.54** (.88 – 6.82)	**2.64** (.91 – 7.47)	**1.48** (.37 – 5.88)

Model I: *Odds Ratio Crude*
Model II: *Odds Ratio Adjusted for factor study group*
Model III: *Odds Ratio Adjusted for factor study group and PDI at Baseline*
** significant at .05*

somewhat in both groups after three months and then showed a small decline after six months where about one third of the subjects of the EC group and half of the Mfb group showed clinically relevant improvements in disability.

Subjects assigned to the Mfb group had higher odds for improvement in disability at T0, T3, and T6: At T3, the odds for improvement in disability was 2.77 times higher in the Mfb group compared to the EC group which was significant (model I; 95% CI 1.00 – 7.65; $p = .05$). When corrected for confounding variables, however, Odds Ratios for improvement were still higher for the Mfb group compared to the EC group, but this was not significant ($p \geq .057$) except for model II for changes between Baseline and T3 ($p = .04$). Baseline disability levels significantly affected Odds Ratios: Model III was preferred over the models I and II (-2 LL; $p < .05$). As no significant interaction effects were found ($p > .08$) these were excluded from the final models as presented in Table 3.3.

Discussion

This randomised controlled trial investigated the effects of 4-weeks ambulant myofeedback training combined with ergonomic counselling in subjects with work-related neck-shoulder complaints relative to ergonomic counselling alone, on pain intensity and disability. The effects were evaluated immediately after the interventions, and at three and six months follow-up. Mean pain intensity and disability levels significantly reduced after both interventions (i.e. Mfb and EC). The effects were clinically relevant in a large part of the subjects: About 30 – 50% of the subjects showed clinically relevant improvements in pain intensity and/or disability. No difference was found for the effect of the intervention on outcome and after correction for confounding factors subjects in both intervention groups did not differ with regard to chances for clinically relevant improvements in pain intensity and disability.

Several studies have shown the beneficial effect of myofeedback training on pain reduction[21 39-43] although Faucett and colleagues[22] reported changes in muscle activity rather than changes in pain intensity. The feedback approach used in these studies is different from the ambulant Cinderella-based myofeedback approach in that the traditional feedback methods provide feedback when muscle activation is too high[21 22 42 44-47], rather than when the time the muscle has relaxed is too short[23]. Two previous studies applying the Cinderella-based myofeedback training in subjects with work-related complaints[23] and subjects with a whiplash associated disorder[48] reported induced reduced pain intensity and disability levels. The results of the current study indicate a comparable percentage of subjects reporting clinically significant reductions in pain intensity, i.e. between 35 and 50% of the subjects, even though the cut-off point for VAS used here was more conservative compared to the study of Hermens and Hutten[23]. This consistency in results adds to evidence for the effectiveness of (Cinderella-based) myofeedback training on pain intensity and disability in musculoskeletal neck-shoulder complaints.

In line with existing literature (e.g.[8 10 49 50]) also subjects in the ergonomic counselling group reported reduced pain intensity and disability. It was however hypothesised that a treatment approach including both myofeedback training and ergonomic counselling (Mfb) would be more effective than treatment comprising only ergonomic counselling (EC) as especially interventions focusing on multiple factors have shown to be related to decreased incidence of complaints[24]. In the current study the two types of interventions did not differ in terms of outcome. Other studies (e.g.[8 10 51-53]) also concluded that different occupational interventions have generally comparable effects, although these studies did not include myofeedback interventions. Newton-John and others[43] compared myofeedback with cognitive-behavioural therapy and a wait-list control group and found that both interventions showed favourable outcome in terms of pain intensity and disability compared to the wait list control group without a difference between the two interventions.

There are possible explanations for the absence of differences between the two groups. One concerns the presence of subgroups in which the intervention is beneficial. Results showed that the effect is clinically relevant in about 30 – 50% of the subjects. Main question to be addressed here is whether, and how, these subjects can be characterised in terms of cognitions and behavioural characteristics and whether this characterisation can contribute to predict outcome of the intervention. This could substantially improve the efficiency and effectiveness of the interventions. Further, differences between the two groups may have been masked by using rather generic outcome measures. For instance, coping and patient-rated parameters may better represent the difference in outcome between different kinds of interventions[54]. Investigation into the specific working mechanisms of both interventions could clarify this. Finally, initial VAS and disability levels were low in both the Mfb and the

EC group, especially in the study group from Sweden. This results in a smaller potential for improvement (floor effect) and as a result a smaller chance for finding differences between the Mfb and the EC group.

Methodological considerations

This study did not include a non-intervention or placebo control group (for instance randomly administered feedback) which makes it hard to control for non-specific effects like time effects, regression to the mean, or the Hawthorne effect. This Hawthorne effect was already described in 1933 by Mayo[55], and is reported as a significant positive effect without causal basis in the theoretical motivation for the intervention, but is related to the effect on the participants of knowing themselves to be studied in connection with the outcomes measured. An argument against such effect is that although it might occur in immediate connection with the intervention (i.e. at T0) it is not likely that this effect would remain after three to six months[56]. In addition, the study population also contained subjects with chronic complaints (i.e. duration > 6 months) who received a variety of treatments in the past which were not sufficiently successful. It is likely to expect that any non-specific effects of treatment would already have occurred during past treatments and that this effect in the current study would thus be small. Furthermore, results from previous studies learned that pain reduction in myofeedback-trained subjects were higher compared to a wait-list control group[43], a no intervention group[46], or subjects receiving a placebo[57]. Furthermore, an attention-only group showed no changed outcome in terms of disability and pain intensity[58].

The present study included a rather specific subject population: Participants were females, predominantly over the age of 45, still at work, and characterised by relatively low pain intensity and disability levels. Interpretation and extrapolation of results to other populations therefore requires caution. Comparable effects of Cinderella-based myofeedback training have, however, also been shown in mixed, younger subject populations[23 48] and in a sample of patients who were on sick leave because of their neck-shoulder complaints[48], generalisation of findings might be legitimate. The subjects in the present study were selected based on self-reported complaints rather than a clinical examination. In a previous study with female computer users above the age of 45, applying the same inclusion criteria as the present study, it was found that in subjects with neck-shoulder complaints the following clinical diagnoses were most prevalent: Trapezius myalgia (38%), tension neck syndrome (17%), and cervicalgia (17%)[60]. These diagnoses were found in 60% of the subjects reporting complaints. There were cases with supraspinatus tendinitis, frozen shoulder and biceps tendinitis, but they were less common. This general pattern of clinical signs is likely to be at hand also in the present study. It could be hypothesised that myofeedback may be particularly relevant and helpful in cases with muscular pain syndromes.

Despite extensive standardisations, the recruitment of subjects in two different study groups (Sweden and the Netherlands) resulted in heterogeneity of the subject population with regard to age, working hours, seniority, and working posture. To correct for this, the factor study group was considered a confounder needed to control for during analysis. This reduced the power of the study. An additional potential confounding factor is the compliance of the patient and therapist to the intervention. This is an often uncontrolled factor in occupational intervention studies[59] that may result in underestimation of the effect of an intervention. It is known that changes in knowledge and skills do not necessarily result in a behavioural change. In the Mfb group, the compliance was partly controlled as the number of hours the system was worn was recorded by the system itself, but the compliance to ergonomic knowledge and skills is hard to register objectively. This definitely is a challenge in future occupational intervention studies.

The drop-out rate in the Mfb group was higher than in the EC group (i.e. nine compared to five), which probably was related to the myofeedback system itself. Some subjects found the system inconvenient and disturbing in daily working activities. This may have suppressed the effect of the intervention. Improvement of the current device in terms of usability is therefore required to optimise the myofeedback training.

Conclusions

Myofeedback training combined with ergonomic counselling is beneficial for female computer workers over the age of 45, reporting pain and disability in the neck-shoulder region and these effects are lasting up to six months after the intervention, but no evidence was found favouring myofeedback training combined with ergonomic counselling over ergonomic counselling alone. Future research should aim at identifying possible subgroups of patients in which the interventions are especially beneficial. This may enhance the efficiency and the effectiveness of the interventions. Finally, as non-specific effects may have interfered with outcome, future studies could include a placebo control group for more insight in the specific effects of ambulant myofeedback training combined with ergonomic counselling.

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Chapter 4

Changes in cognitive-behavioural factors and muscle activation patterns after ambulant myofeedback training and ergonomic counselling in work-related neck-shoulder complaints: Relations with pain and disability

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Abstract

Knowledge regarding the working mechanism of an intervention is essential in obtaining a better understanding of the intervention and for optimising outcome. This study aimed at investigating whether changes in cognitive-behavioural factors and muscle activation patterns after myofeedback training and ergonomic counselling were associated with outcome in subjects with work-related neck-shoulder complaints. Seventy-nine symptomatic subjects received either myofeedback with ergonomic counselling (Mfb) or ergonomic counselling alone (EC). Outcome measures pain intensity and disability, and process factors catastrophizing, control, fear-avoidance beliefs, and muscle activation patterns, were assessed at Baseline, after the interventions (T0) and at 3 months follow-up (T3). Mixed modeling techniques were used for analysis. Catastrophizing was significantly reduced and fear-avoidance beliefs about work slightly increased after the interventions, but no consistent changes in muscle activation patterns were observed. Changes in pain intensity were especially associated with changes in catastrophizing at T0 and T3, but R^2 was low (< 0.14). Reduced catastrophizing at T0 and T3, and also reduced fear-avoidance beliefs about work at T3, were related to reduced disability (R^2 between 0.30 - 0.40). No differences between the two intervention groups were observed. Rather than muscle activation patterns, cognitive-behavioural factors underlie the working mechanism of myofeedback training and ergonomic counselling, interventions for work-related neck-shoulder complaints. Emphasizing these factors during therapy may increase the beneficial outcome of the interventions in this specific subject population.

Introduction

Musculoskeletal neck-shoulder complaints related to work, or pain more generally, are multifactorial in nature involving both physiological factors, psychosocial factors and cognitions[1]. Several different interventions exist, and these are mainly based on ergonomics including the adjustment of the physical work environment and education about working posture according to ergonomic principles[2 3]. But in spite of attention to ergonomics, the prevalence of work-related musculoskeletal complaints is still high[4-6]. Interventions to reduce these complaints might benefit from expanding their current focus from a purely ergonomic approach to including also knowledge on the underlying physiological abnormalities in work-related neck-shoulder complaints. There is increasing evidence that lack of muscle relaxation is related to work-related musculoskeletal complaints[7 8] according to the Cinderella hypothesis[9]. This hypothesis comprises the idea of a fixed order of motor unit recruitment in muscle activation and subsequent sustained activation of the low threshold motor units that are activated first, possibly contributing to pain. Hermens and Hutten[10] developed an ambulant myofeedback device based on this hypothesis. The device consists of a garment with incorporated dry surface electrodes that can be worn during the working day. The electrodes enable continuous recording of the surface electromyography (sEMG) of the upper trapezius muscles and this data is stored and processed at a small box worn at the hip. The box provides feedback by means of vibration and a soft sound when muscle relaxation is insufficient (i.e. less than 20% of a specific time interval). On two aspects this myofeedback approach is clearly different from traditional myofeedback: [1] It is provided when muscle relaxation is insufficient rather then when muscle activation exceeds a certain threshold, and [2] being ambulant, it enables continuous monitoring over days and weeks instead of weekly sessions of up to 60 minutes maximum. After four weeks of training clinically relevant pain and disability reductions were found in about half of the subjects with work-related neck-shoulder complaints receiving myofeedback, together with enhanced muscle relaxation and decreased muscle activation levels[10]. Similar results were found in subjects with Whiplash Associated Disorder (WAD) grade II[11]. The effectiveness of the myofeedback training was also evaluated in a randomized trial, and findings indicated that combining myofeedback training with ergonomic counselling (referred to as Mfb) resulted in reductions in pain intensity and disability that were rather similar in size compared to when ergonomic counselling was provided alone (referred to as EC)[12].

Besides investigating outcome of an intervention in terms of pre- and post-intervention measures it is also interesting to describe outcome by its underlying working mechanism, as it increases our understanding and enables optimization of the intervention. Evidence on this topic is scarce, especially for effects of occupational interventions[13]. For the Cinderella-based ambulant myofeedback training as described above, it can be hypothesized that changes in muscle relaxation underlie changes in outcome measures pain intensity and disability. Vollenbroek-Hutten and colleagues[14] found first empirical support for this hypothesis by showing significant associations between increased muscle relaxation and decreased pain intensity levels after four weeks of ambulant myofeedback training. The maximum percentage explained variance in pain intensity was however 36%, leaving a considerable part of variance unexplained. This remaining variance might be attributed to cognitive changes induced by the myofeedback training[15] especially with regard to perceived control[16 17]. Sarnoch et al.[18] found an association between an increased sense of control and a reduction in pain intensity after traditional myofeedback training in patients with fibromyalgia. More generic, when looking at working mechanisms of intervention programs for chronic pain, changes in coping strategies like catastrophizing, pain-related fear, and fear-avoidance beliefs appear related to outcome (process factors) (e.g.[19-24]). There is no literature available investigating whether these factors are also involved in outcome after occupational interventions like Mfb and EC, although knowledge on this issue is necessary for our understanding of exactly how these interventions work.

This study further explores the findings reported in Voerman et al.[12], and aims at investigating:

1. whether cognitive-behavioural factors and muscle activation patterns (entitled process factors) change, and
2. whether these factors are related to outcome (pain intensity and disability)

both immediately after Mfb and EC as well as at follow up, in subjects with work-related neck-shoulder complaints. It was hypothesized that especially Mfb induces an increased sense of control over pain and enhances muscle rest in subjects with work-related neck-shoulder complaints and that changes in these factors are related to reduced pain intensity and disability. Furthermore it was hypothesized that both Mfb and EC would contribute to reduce catastrophic thoughts and fear-avoidance beliefs and that these factors would be relevant process factors for outcome after the interventions.

Methods and Materials

Design and subjects

This study further explores the results of the randomized controlled trial evaluating the effects of 4-weeks ambulant myofeedback training combined with ergonomic counselling (Mfb) and ergonomic counselling alone (EC) as described by Voerman et al.[12]. Participants were randomly assigned to either the Mfb or the EC group (considered the control intervention group), based on a randomisation schedule that was adopted from Pocock[67]**.** A block randomisation procedure was used: Each new group of subjects starting with the study was considered a block, and half of the subjects in this block were assigned to the Mfb group. Measurements were performed prior to intervention but before randomization

(Baseline; B), immediately after four weeks of intervention (T0), and at three (T3) months follow-up.

Participants were elderly (predominantly over the age of 45) female computer workers who were recruited in Sweden (area of Gothenburg) and the Netherlands (area of Enschede) between April 2003 and June 2005. Only females were included because of the high prevalence of complaints in this group[25-27]. They were approached by telephone and announcements and ultimately selected based on the findings in a screening questionnaire[28]. This questionnaire contains general questions regarding sociodemographics, as well as detailed questions related to the musculoskeletal status and (work) factors that are believed to affect musculoskeletal health. Subjects eligible for participation were working for at least 20 hours a week and reporting persistent work-related musculoskeletal complaints in the neck and/or shoulder region for at least 30 days during the last year. These complaints were thus subjectively assigned to computer work, reported in the questionnaire, and give a fairly good impression of whether there is an underlying disorder which can clinically be assessed[29].

The study was approved by the medical ethics committee and all participants gave their informed consent prior to participation.

Interventions

The interventions were provided by three different therapists who were trained together to ensure that they would provide as identical interventions as possible. The character of the intervention made blinding of the therapists and subjects to the interventions impractical. For full specifications of the interventions and procedures the reader is referred to Voerman et al.[12].

Ergonomic Counselling (EC)

Subjects received four weeks of intervention during which they kept a diary of activities and pain intensity scores. During this period they were visited weekly by their therapist. The first visit comprised an ergonomic workplace investigation by means of the risk inventory 'RSI in computer related work: Prevention and integration' of Huppes et al.[30]. This checklist contains questions to evaluate work tasks, working hours, work load, work station, and working methods, which are potentially relevant risk factors for work-related musculoskeletal complaints. Based on the results of the checklist, possible improvements were discussed with the subject. The remaining visits were used to further discuss ergonomics according to a manual. This manual had specifically been developed for this study and contains standard instructions for beginning and ending of the visits, and structured questions regarding the ergonomic changes that were performed during or after previous visits, the consequences of these changes in terms of discomfort, and individual goals and appointments for the following week.

Myofeedback training (Mfb)

Subjects assigned to the Mfb group received myofeedback training on top of EC. A two-channel ambulant feedback system combined with a garment incorporating dry sEMG electrodes to enable recording of upper trapezius muscle activity was used[10]. The harness was connected with a sEMG processing and storage system. The sEMG signal was amplified (15x), band pass filtered between 30 and 250 Hz, sampled at 512 Hz, digitized (22 bits ADC) and smooth rectified with removal of the low frequency components. Embedded software provided the detection and calculation of muscle rest, expressed as the sEMG parameter Relative Rest Time (RRT). RRT was defined as the percentage of time of complete muscle rest (Root Mean Square (RMS) < 10 µV for at least 0.25 seconds) during a 10 seconds interval. Sensory feedback by means of vibration and a soft sound was provided after each 10 seconds interval when the relative duration of muscle relaxation in that particular interval was below 20% (i.e. when RMS was below 10 µV during less than 2 seconds for that interval)[8 31].

Immediately after B subjects assigned to the Mfb group received the myofeedback system and they were explained the principles of feedback. Subjects were instructed that relaxation could be reached by slightly depressing the shoulders, or by sitting down quietly with the eyes closed, the hands in the lap while breathing deeply. Another relaxation strategy was to maximally elevate the shoulders for three seconds to build up muscle tension and then to let loose this tension.

Subjects used the system for four weeks, for at least eight hours a week (distributed over two hours a day and two days a week as a minimum) during occupational activities. During the weekly visits the sEMG data from the previous week were scrutinized and discussed. This procedure was facilitated by means of the diary.

Measurements

Measurements were performed at B, T0, and T3, and comprised outcome, i.e. pain and disability, and process factors, i.e. coping strategies, fear-avoidance beliefs, and muscle activation patterns.

Outcome measures

The effect of the interventions on work-related neck-shoulder complaints was assessed with outcome measures pain intensity and disability.

Pain intensity in the neck, shoulders, and upper back was assessed by means of Visual Analogue Scales (VAS)[32], a 10 cm horizontal line with 'no discomfort at all' at the left and 'as much discomfort as possible' at the right extremity of the line. Subjects were asked to rate their subjectively experienced level of pain intensity at that particular moment. Psychometric properties of the VAS have proven to be sufficient[33].

The level of experienced disability was assessed with the Pain Disability Index (PDI), a self-rating scale that measures the impact of pain on the abilities to participate in life activities[34]. The PDI contains 7 items, one for each domain, i.e. (1) family and home responsibilities, (2) recreation, (3) social activity, (4) occupation, (5) sexual behaviour, (6) self care, and (7) life-support activity. Answers are provided on a categorical 11-points scale with 'not disabled' and 'fully disabled' at the extremes. Psychometric properties of the PDI are sufficient[35]. In the current study for instance, Cronbachs' alpha was .89.

Process factors

Cognitive-behavioural factors included in this study were catastrophizing, control, and fear-avoidance beliefs, selected based on literature. The first factor was assessed using the subscale of the Swedish and Dutch versions of the Coping Strategies Questionnaire (CSQ)[36 37]. Observed pain control was assessed with the Dutch version of the CSQ. The Swedish CSQ consists of 7-point numerical rating scales, while for the Dutch version questions are answered by means of a mark at a VAS scale with 'never' and 'always' as extremes. The CSQ is known to have good psychometric properties and alphas for the subscales catastrophizing and observed control were sufficiently high in the current sample (.75 and .91 respectively).

Fear-avoidance beliefs were assessed using the Swedish and Dutch language versions of the Fear-Avoidance Beliefs Questionnaire (FABQ)[38 39], a 16-item 7-point measure that aims at identifying beliefs concerning the influence of work (subscale W) and physical activity (subscale PA) on bodily damage and on whether activities should be avoided. High scores represent high fear-avoidance beliefs. The FABQ has proven to be psychometrically sound[40] with alpha .82 for FABQ_W and .83 for FABQ_PA for the current data sample.

Muscle activation patterns of both upper trapezius muscles were assessed using surface Electromyography (sEMG). Electrodes were placed according to the international guidelines of SENIAM[41]. The electrodes were connected to the EMG unit by means of cables that were attached to the skin with tape to minimise noise. The sEMG signal was sampled (1024 Hz), band pass filtered (20-500 Hz), and stored on a computer for off-line analysis.

Four reference contractions of the upper trapezius muscles were performed according to the guidelines of Mathiassen et al.[42]. Subjects sat with the spine against the back of the chair and the eyes directed at a point right in front of them. The arms were held straight and horizontal in 90^0 abduction with no additional weight, with the hands relaxed and the palms pointing downwards. Each measurement lasted for 15 seconds with 30 seconds rest in between. Subsequently subjects performed three computer-related tasks: A bilateral typing task and two unilateral mouse tasks, i.e. a stress task and a precision task. For these tasks, the table and chair of the computer work station were adjusted to the anthropometric properties of the subject, with the minimal requirement that the elbow, hip, and knee were in approximately 90 degrees flexion. The order of the computer tasks was randomised at B, T0, and T3, and each task was preceded and followed by a few minutes rest for recovery. During the typing task, subjects were instructed to copy a text which was situated in a document holder at the left side of the subject, adjustable in height and distance. The stress task was a modified Stroop task that required subjects to use the mouse to click at the name of the colour of the print of each colour-word. The appearance of this word varied in time and appeared at random location at the screen. An incorrect or late answer was followed by a beep[43] which is assumed to increase the stress level. For the precision task[44], subjects were shown a graph of 7 circular targets of 7 mm diameter connected by means of lines on the right half of the computer screen. Subjects were instructed to duplicate this graph on the left half of their screen on which the circular targets were shown. Lines could be drawn by means of clicking on the targets in the correct order. As soon as a drawing was completed another drawing popped up. These three tasks were chosen as they were assumed to give a valid representation of activities performed at the (computer) workplace, encompassing both unilateral as well as bilateral movements in a static posture, including also the stress component which is often associated with increased levels of muscle activation patterns[45].

Analysis

Data reduction

VAS scores for the neck, shoulders, and upper back were summed and averaged resulting in one total VAS score for the neck-shoulder region. PDI and FABQ (subscale) scores were calculated for each subject for each measurement. CSQ scoring methodology varied between the Swedish and the Dutch questionnaire. Therefore, relative scores were calculated by expressing the score of the subscale as a percentage of the maximum subscale score.

Two sEMG parameters were calculated: Root Mean Square (RMS) and Relative Rest Time (RRT). RRT was defined as the percentage of time in which RMS was below threshold (6μV)[46] for at least 0.125 seconds. RMS and RRT values during the computer tasks were calculated for 4 epochs about 60 seconds duration each. The values were subsequently averaged per task for each subject. For the reference contraction, RMS values were calculated for the middle 10 seconds of each contraction[42], resulting in four RMS values that were averaged and used for normalisation. This means that RMS values during the typing, stress, and precision tasks were expressed as percentages of this mean reference value.

Statistical analysis

Factors that were not normally distributed were log transformed to obtain a distribution close to normal. Statistical analysis consisted of two parts. First, it was investigated whether outcome and process factors changed after the intervention. For the normally distributed factors Mixed Linear Modelling was used to identify significant changes over time. Time (B, T0, and T3), intervention type (i.e. Mfb and EC), and study group (Sweden and the Netherlands) were considered fixed factors, as well as the interaction terms intervention*time and intervention*country. The factor study group comprises variance due to possible sociodemographic differences as well as variance caused by the different therapists, organizations, and job characteristics in the two countries. The factor subject was included in the model as a random factor. When a significant effect was observed for the factor time, post hoc mixed models were run to explore whether these changes occurred during B and T0 or between B and T3. For RRT variables, bimodal in origin, log transformation does not result in closer to normal distributions, so for this factor non-parametric methods were used (Friedman tests) to identify changes over time. Wilcoxon Signed Ranks Tests were performed post hoc to identify whether the factors changed between B and T0 or between B and T3.

Secondly, the factors which significantly changed over time were subsequently entered in a Mixed Linear Model as fixed factors to study their associations with outcome (pain and disability, dependent factors) after the interventions for that specific time interval (i.e. B – T0 or B – T3). Intervention type was additionally entered as a fixed factor, including its interactions with the process factors in order to investigate whether these factors were differently relevant for the Mfb and the EC group. In other words, it was investigated whether the process factors for the intervention were indeed different between the two interventions. Again, the models were corrected for study group and its interactions. Percentages explained variance (1st level R^2) were calculated for these models by comparing variance in the model including fixed factors and the model without fixed factors, by using the following formula according to Snijders and Bosker[47]:

$$R^2 = 1 - ((\sigma^2 + \tau^2)_{II} / (\sigma^2 + \tau^2)_{I})$$

wherein σ^2 corresponds to the within-subject variance (residual) and τ^2 is the between-subject variance (intercept), I refers to the summed variance of the model without fixed factors, and II refers to the variance of the model with the fixed factors.

Traditionally, analyses aimed at identifying process factors is performed by calculating delta (Δ) scores of the process variables, for instance between B and T0, and to enter these scores into a regression model with delta scores of outcome as dependent variable. However, there is a major concern using this approach. The Δ scores of both outcome and process factors itself are dependent on the Baseline value. Thus, for a proper model baseline values should be corrected for. The problem with this approach is that the model is at risk of containing too many variables (> 1 per 10 observations)[48] which makes it instable and invalid. To overcome these problems mixed linear modelling was used to study the association between factors, and Δ scores were just used to provide insight in the direction of the correlations (Spearmans' rho) between changes in outcome and changes in process factors.

Statistical Package for Social Sciences (SPSS) 11.5 was used for statistical testing and alpha was set at .05 for statistical significance.

Results

Detailed descriptions of the subject population as well as the course of VAS and PDI over time are provided in Voerman et al.[12]. Here, these data are presented in short.

Seventy-nine subjects with work-related neck-shoulder complaints were included in this study: Forty-two subjects were assigned to the Mfb group and 37 to the EC group. Between B and T0, 5 subjects in the Mfb and 2 subjects in the EC group dropped out, and between T0 and T3 another 4 subjects in the Mfb and 2 in the EC group ended participation. Subject characteristics at baseline are presented in Table 4.1.

Table 4.1: Characteristics of subject population

		Mfb (n = 42)	**EC (n = 37)**
Sociodemographics			
Age		52.0 (5.8)	50.7 (5.5)
BMI		25.2 (3.9)	25.2 (3.7)
Side dominance	% Right-handed	95%	97%
Living situation	% Living alone	16.7	10.8
Working hours per week		32.8 (7.8)	32.8 (8.3)
Complaints			
Trouble in neck last year	Yes	92.9	91.9
Trouble shoulders last year	Yes, in both shoulders	36.6	32.4
	Yes, in the right shoulder	36.6	43.2
	Yes, in the left shoulder	12.2	13.5
Trouble in upper back last year	Yes	66.7	48.6

Outcome factors VAS and PDI significantly changed over time ($F = 50.21$, $p < .01$ and $F = 35.30$, $p < .01$ respectively). VAS was significantly reduced between B and T0 ($F = 31.06$, $p < .01$) and between B and T3 ($F = 41.4$, $p = <.01$), without additional effects for intervention type, study group, or interactions ($p > .07$). For PDI, besides significant reductions between B and T0 ($F = 27.77$, $p < .01$) and between B and T3 ($F = 26.41$, $p < .01$), values were additionally significantly higher in the Dutch compared to the Swedish subject sample ($F = 5.45$, $p = .02$). Finally, an interaction effect was found for intervention*time between B and T3 ($F = 5.54$, $p = .02$), indicating that subjects assigned to the Mfb group showed a continued decrease in disability at T3 compared to B, while subjects in the EC group did not (see also Table 4.2).

Changes in process factors

Cognitive-behavioural factors Median (inter-quartile range) values of the cognitive-behavioural factors observed at B, T0, and T3 in Mfb and EC are presented in Table 4.2.

A main effect was found for the factor time for CSQ subscale catastrophizing ($F = 7.07$, $p = .01$), with significant decreases between B and T0 ($F = 8.94$, $p < .01$) and between B and T3 (F

= 5.18, p = .03). Generally, higher scores were observed in the Dutch compared to the Swedish sample (p ≤ .02), but no other (interaction) effects were found (p > .36).

A significant effect for the factor time was also observed for FABW_W (F = 18.20, p < .01). Fear-avoidance beliefs were slightly, but significantly, increased between B and T0 (F = 6.27, p = .01) and between B and T3 (F = 13.37, p < .01), with an additional interaction effect between B and T0 for intervention*time (F = 5.98, p = .02) which indicates that the increase in FABQ_W was significantly larger in the Mfb compared to the EC group. No other main or interaction effect was found significant for FABQ_W (p > .13).

CSQ subscale Observed control and FABQ_PA did not change over time and no other (interaction) effects were found significant (p > .06).

Muscle activation patterns Normalised RMS values during typing, stress, and precision in Mfb and EC are presented in box plots in Figure 4.1 and Figure 4.2, presenting median and inter-quartile ranges without extremes. Generally, these figures show no clear pattern of change, although a significant effect was observed for the factor time during the precision task (left side) and the stress task (right side) (F = 4.12, p = .04). Post hoc analysis revealed that small, but significant, increased RMS values were found during the precision task at the left side (F = 5.74, p = 0.01) at T0 compared to B. RMS values during the stress task were significantly reduced at the right side at T3 compared to B (F = 4.05, p = .05). but no other main effects or interactions were observed (p > .08).

Table 4.2 presents the median value and inter-quartile ranges of RRT values. RRT values did not change after the intervention (T0 and T3) compared to B (0 ≥ Z ≥ -1.71 with p ≥ .09).

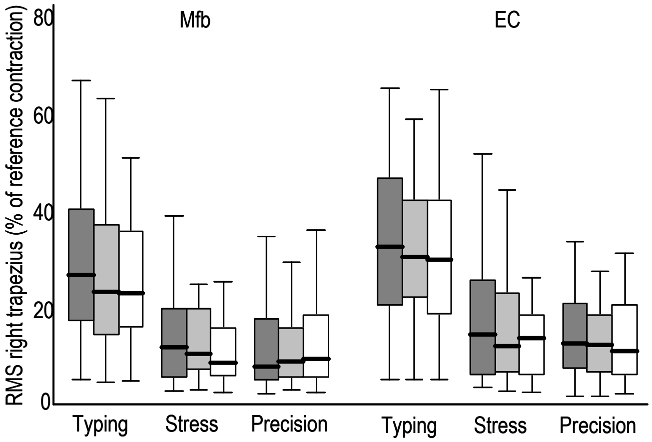

Figure 4.1: Box plots for normalised RMS values of the right upper trapezius muscle at B (■), T0 (▨), and T3 (□), during the typing, stress, and precision task in Mfb and EC

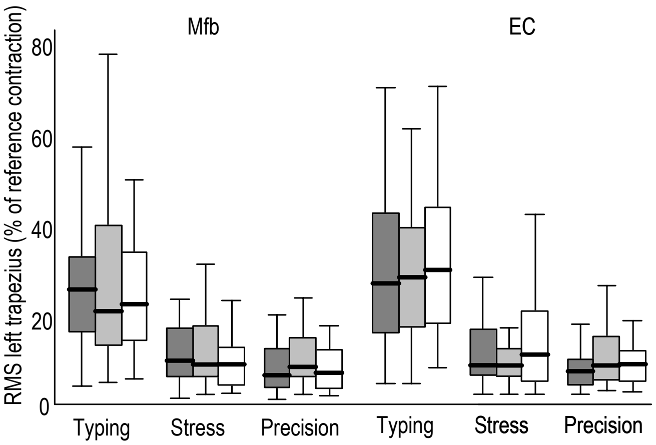

Figure 4.2: Box plots for normalised RMS values of the left upper trapezius muscle at B (■), T0 (■), and T3 (□), during the typing, stress, and precision task in Mfb and EC

Associations between process and outcome factors

Bivariate correlation coefficients between ΔVAS and ΔPDI and Δ scores of the cognitive-behavioural factors and muscle activation patterns that significantly changed between B and T0 and/or between B and T3, are presented in Table 4.3. Significant relations were only observed between reductions in catastrophizing and reductions in disability .

Mixed linear modelling indicated that changes in catastrophizing were consistently related to changes in VAS at T0 ($F = 10.93$, $p < .01$) and T3 ($F = 14.16$, $p < .01$) without other significant main or interaction effects ($p > .09$). Catastrophizing was also significantly associated with PDI at T0 ($F = 34.86$, $p < .01$) and T3 ($F = 59.67$, $p < .01$). Furthermore, FABQ_W was positively associated with PDI at T3 ($F = 6.46$, $p = .01$) but no other main or interaction effects ($p > .09$) were observed.

R^2 was relatively low for VAS (i.e. 0.09 for B – T0 and 0.14 for B – T3) and considerable for PDI (i.e. 0.30 for B – T0 and 0.40 for B – T3).

Discussion

Knowledge regarding process factors of an intervention is essential for obtaining a better understanding of the underlying working mechanism and to optimize the intervention itself. The present study aimed at identifying changes in cognitive-behavioural factors and muscle activation patterns after either ambulant myofeedback training combined with ergonomic counselling (Mfb) or ergonomic counselling alone (EC), in subjects with work-related neck-shoulder complaints. Furthermore it was explored whether these changes were

Table 4.2: Median (inter-quartile range) values for the outcome factors VAS and PDI and process factors FABQ, CSQ, and RRT

	Mfb			**EC**		
	Baseline	**T0**	**T3**	**Baseline**	**T0**	**T3**
Outcome factors						
VAS	2.1	1.2	1.1	2	1.3	.7
	(1.2 – 3.4)	(.6 – 2.1)	(.4 – 2.0)	(1.1 – 3.6)	(.7 – 2.2)	(.3 – 1.5)
PDI	14	7	4	7	4	7
	(6 – 33)	(.5 – 17.5)	(.5 -17.5)	(3 – 20.5)	(2 – 16)	(1 – 10)
Cognitive-behavioural factors						
CSQ_CA	14	5	10	8	8	4
	(0 – 28)	(0 – 20)	(1 – 21)	(2 – 18)	(0 – 17)	(0 – 16)
CSQ_OC	30	18	25	30	35	20
	(15 – 38)	(9 – 35)	(10 – 45)	(11 – 40)	(14 – 45)	(5 – 36)
FABQ_W	12	16	16	12	13	15
	(5.75 – 16)	(8.5 – 20.5)	(9 – 24)	(7 – 18)	(3 – 18)	(4 – 19)
FABQ_PA	14.5	9	10	13	8	10
	(8.25 – 18)	(3 – 13)	(1 – 14)	(8 – 15)	(4 – 12)	(2 – 12)
Muscle activation patterns (RRT)						
Right trapezius muscle						
Typing	.5	2.6	3.5	.4	1.5	.9
	(.4 – 3.4)	(0 – 37.6)	(0 – 18.0)	(0 – 9.0)	(0 – 13.2)	(0 – 11.3)
Stress	25.7	40.3	54.2	4.9	41.0	36.3
	(1.5 – 90.2)	(5.6 – 89.3)	(1.3 – 96.3)	(.2 – 87.4)	(.9 – 82.0)	(6.4 – 79.1)
Precision	60.0	67.6	45.8	28.6	32.2	32
	(0.7 - 93.0)	(.9 – 97.9)	(.51 – 98.0)	(0.6 - 68.7)	(1.9 – 81.2)	(2.6 – 87.1)
Left trapezius muscle						
Typing	5.4	7.7	5.4	.9	3.3	1.3
	(0 – 23.8)	(.4 – 52.3)	(.0 – 31.5)	(0 – 15.5)	(0 – 20.4)	(0 – 27.8)
Stress	56.2	80.0	90.7	57.7	55.9	65.6
	(20.4 – 92.8)	(23.1 – 97.8)	(25.6 – 98.3)	(8.6 – 91.5)	(12.1 – 91.3)	(8.1 – 94.0)
Precision	85.6	92.5	92.2	71.2	51.2	50.4
	(36.1 - 98.8)	(4.8 – 99.2)	(33.4 – 99.0)	(40.4 - 84.9)	(23.6 – 82.6)	(27.1 – 90.1)

related to outcome after the interventions. The results of this study indicate that rather than muscle activation patterns, cognitive-behavioural factors are likely to change and that these changes were related to changes in outcome.

Cognitive-behavioural factors

Catastrophizing appeared to be the main process factor: Baseline catastrophizing levels were low in both intervention groups but despite this, further reduction occurred after the interventions and these reductions were related to reduced pain intensity and disability

Table 4.3: Bivariate Spearmans' correlation coefficients for associations between changes in process factors and changes in outcome

	B – T0				B – T3			
	Mfb		EC		Mfb		EC	
	VAS	PDI	VAS	PDI	VAS	PDI	VAS	PDI
FABQ_W	.09	.21	.12	.31	.18	.31	.13	.001
CSQ catastrophizing	.05	.48*	.07	.41*	.18	.47*	.24	.59**
RMS precision task, left	-.04	-.21	.03	.27	-	-	-	-
RMS stress task, right	-	-	-	-	.001	.10	-.18	-.01

* significant at .05 level
** significant at .01 level

levels after the interventions. These findings correspond to literature reporting on the relevance of catastrophizing in the development and chronification of pain[49-51] as well as its relevance for outcome after treatment of (chronic) low back pain patients[24], fibromyalgia patients[23] and chronic pain patients in general[19-21]. The present findings do not justify statements with regard to causality, but it seems reasonable to hypothesize that the changes in catastrophizing were brought about by the interventions. Burns and colleagues[20 21] used a cross-lagged correlation approach to explore the effects of multidisciplinary treatment on outcome in chronic pain patients. In addition to pre- and post-treatment observations they added a midterm observation that was applied to study whether early changes in cognitive factors preceded late-term changes in outcome. They showed that an early change in cognitions indeed predicted outcome at the end of the treatment and that catastrophizing is thus likely a mediating factor for outcome. Exactly how reduced catastrophizing contributes to reduced pain intensity from a psychophysiological perspective is not clear, but Geisser et al.[52] suggested that catastrophizing is related to decreased pain thresholds in patients with fibromyalgia.

Contrary to literature (e.g.[22 53-55]), fear-avoidance beliefs about work slightly, but significantly, increased rather than decreased after the intervention, with a larger increase in subjects receiving Mfb compared to subjects receiving EC. One possible explanation for the small increase in these beliefs is enclosed in the focus of the intervention, which is related to work. The relation between work and complaints that is stipulated during the interventions may have contributed to increased fear-avoidance beliefs about work. The larger increase in the Mfb group compared to the EC group may be attributed to the experience of feedback as stressing the risks of work. In most studies usually the focus of treatment is on other aspects than work, and therefore these studies (e.g. [22 53 55]) may report decreased fear-avoidance beliefs. The level of fear-avoidance beliefs about work remained however low (< 30, which is the cut-off point for low and high scores[56]) and did not significantly contribute to explaining variance in outcome after the interventions, except for at three months follow-up: A significant, positive effect was found indicating that in the model decreased fear-avoidance beliefs were reflected in decreased disability levels.

Changing cognitions was not one of the initial targets of the two interventions in this study and this might more likely be expected in multidisciplinary treatments focusing on cognitive-behavioural changes. It has however more often been reported in literature that treatments which do not deliberately focus on cognitive factors but aim at changing behaviour are responsible for a cognitive change[57]. Generally, it is assumed that cognitions can very well be altered by changing motor behaviour[58]. From this perspective, both the Mfb and the EC interventions may have induced changed motor behaviour at the workplace and this may have reduced the negative perception towards pain (catastrophizing). Also more information on the development and background of the complaints as was provided during the meetings with the therapist may have contributed to reduced catastrophizing.

Besides the relevance of catastrophizing and fear-avoidance beliefs, several authors[16] [17] [18] [54] reported that observed control over pain or health is one of the principal process factors for outcome after myofeedback interventions. Although these studies concern traditional myofeedback approaches with other subject populations, it was hypothesized that the findings would also apply to the current study, but no effects were observed. One explanation might be that a few subjects in the Mfb group had difficulties in responding to the feedback and as a result they may not have experienced an increased control over their pain, explaining the absence of changes on a group level. It should also be considered that this CSQ subscale consisting of only two items has the lowest test-retest reliability of all subscales (r = .45)[37]. Further research, preferably combined with other methods to assess control is needed.

Muscle activation patterns

The myofeedback training in the current study aimed at increasing relaxation rather than reducing muscle activation. Accordingly, it was expected that muscle relaxation would be a key process factor in changing pain intensity and disability after myofeedback training, in line with Vollenbroek-Hutten et al.[14] and that these changes would be more prominent for Mfb than for the EC group as the latter group was not specifically trained to increase relaxation. However, no consistent change in muscle relaxation was found, neither a consistent relation between changed muscle activation and changed outcome. Rokicki et al.[17] studied the relation between tension headache and myofeedback-induced changes in muscle activation, and also found no association between change in muscle activation and change in outcome, and Sarnoch et al.[18] reported comparable findings. One explanatory concept is provided by Cram[60] who suggested that 'temporal dislocation' accounts for the discrepancy between changes in pain and changes in muscle activity. The initial changes in pain intensity are hypothesized to be more likely brought about by cognitive changes rather than muscle activation pattern changes. This might account for the absent relation. When looking at the Baseline data muscle relaxation was already quite high (>50%) and muscle activation was low at Baseline for the unilateral mouse tasks indicating a likely ceiling respectively floor effect for these parameters during these tasks. This finding might question the relevance of abnormal muscle activation patterns in persisting musculoskeletal complaints, at least in this specific subject sample. Although there is evidence for the Cinderella-hypothesis, inconsistencies have been reported as well[61-64]. Additional research needs to be done to further clarify the relation between muscle activation patterns and neck-shoulder pain, preferably specified into subgroups of subjects[65] with more severe complaints than in the present study. Another explanation for absent changes in muscle activation patterns after myofeedback training may be that the training continuously provided in the work environment may not necessarily result in changes in muscle activation patterns in the laboratory setting. It is therefore recommended to incorporate field studies in the evaluation of interventions for work-related neck-shoulder complaints, as this may provide insight in the course of changes in muscle activation patterns during the training in the work environment.

Concluding remarks and clinical implications

The results of the present study indicate that changes in cognitive-behavioural factors, especially catastrophizing and fear-avoidance beliefs about work, rather than muscle activation patterns are related to changes in pain intensity and disability after both myofeedback training combined with ergonomic counselling (Mfb) and ergonomic counselling alone (EC) in subjects with work-related neck-shoulder complaints. In clinical practice this means that both interventions additionally reduce catastrophic thoughts which may be associated with reduced pain intensity and disability levels. No difference was observed in outcome and process factors between the two interventions. As it concerns a rather specific subject population in this study, being only mildly disabled, additional research is needed to investigate whether the findings are generalisable to subjects with more severe neck-shoulder complaints, also in populations with complaints from other aetiologies as WAD training myofeedback was also effective in this population.

It is possible that other factors, related to social cognitive theories like self-efficacy in the ASE-model of de Vries and colleagues[66], are also related to changes in behaviour and perpetuation of this behaviour after the intervention. This is well reflected in the percentages explained variance of the models which left considerable contributions of other process factors for explaining changes in pain intensity and disability after the interventions. Also the number, relevance, and quality of the ergonomic changes performed during the intervention period, for instance, may have contributed to outcome and could thus be relevant process factors for outcome. Additional research needs to provide more insight into the relative contribution of different ergonomic adjustments to improvement after the intervention.

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Chapter 5

Prognostic factors for the effect of interventions for work-related neck-shoulder complaints: Myofeedback training and ergonomic counselling

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Abstract

Aim of this study was to explore prognostic factors for the effects of two interventions (Myofeedback training combined with ergonomic counselling (Mfb) and ergonomic counseling alone (EC) on pain intensity and disability in work-related neck-shoulder complaints. Thirty-eight females participated. Pain intensity and disability were assessed at baseline, immediately after four weeks intervention, and at 3 months follow-up. Sociodemographic and psychological factors were considered potential prognostic factors. Psychological factors were assessed with the Coping Strategies Questionnaire (CSQ) and the Mulitidimensional Pain Inventory (MPI). Data were analyzed using multiple regression analysis and Chow tests. Changes in pain intensity were best predicted by baseline pain intensity levels and changes in disability were predicted by baseline disability levels, a dysfunctional or interpersonally distressed patient profile, and coping strategy 'ignoring sensations'. A significant difference between the Mfb and EC group was found for coping strategy 'ignoring sensations', which appeared to be a predictor for changes in disability at three months follow-up in the EC group only.

It was concluded that subjects with high levels of initial pain intensity and disability and specific patient profiles benefit most from interventions, and that those who ignore pain sensations likely benefit more from Mfb.

Introduction

Neck-shoulder pain is common and often long-lasting. Life-time prevalence of neck pain in females was found to be approximately 43%[1]. In a subgroup of subjects complaints are related to work; for instance 15% of the working population in the Netherlands report complaints in the neck-shoulder region[2]. As it has large consequences for health care and society, there is an urgent need for adequate intervention programs for work-related complaints.

Work-related neck-shoulder complaints are multifactorial in nature[3] and as a result different intervention approaches have emerged. Interventions often focus on adjustment of the physical work environment and education of ergonomic principles[4]. There is some evidence on the effectiveness of these interventions and well-designed work stations are considered unbearable for healthy working[5] [6]. However, the prevalence of complaints among workers remains high so there is a need for developing new interventions[6].

A relatively new intervention approach is the myofeedback training based on the Cinderella-hypothesis of Hägg[7]. During this intervention[8] subjects wear a garment enabling continuous recording of upper trapezius muscle activation patterns. In contrast to classic feedback approaches during which subjects receive feedback when muscle activation is too high, Cinderella-based myofeedback provides feedback when relaxation is insufficient. The feedback can make subjects aware of this insufficient relaxation and contribute to enhance this, assumed to reduce complaints. As interventions focusing on multiple factors have shown to be related to a decreased incidence of complaints[9], four weeks of Cinderella-based myofeedback training was combined with ergonomic counselling and showed clinically relevant improvements in about 50% of the subjects[8] [10]. This suggests the presence of subgroups in which the intervention is beneficial, a common finding when evaluating the effectiveness of pain programs.

Identification of prognostic factors, factors that have predictive value regarding outcome of specific therapies, facilitates clinical decisions concerning the choice of interventions and the referral of subjects to appropriate intervention programs. The search for prognostic factors has mainly focused on low back pain programs. These factors appear to cover the whole spectrum of the biopsychosocial model of pain and disability of Waddell[11] [12] [13] [14]. Van der Hulst et al.[15] classified the factors into either sociodemographic, physical, and psychological and concluded that the prognostic value of the physical factors is superimposed by the sociodemographic and psychological factors when considering the effect of multidisciplinary treatment in chronic low back pain[15]. In only a few studies prognostic factors for neck and/or shoulder pain have been investigated. These studies showed that pain intensity, duration of symptoms, disability, age, and well-being are related to outcome[16-18]. The relation between these factors and outcome, however, appeared to be inconsistent[1] and studies predominantly focused on prognostic factors for the clinical course of neck pain rather than for outcome after interventions. This information would however be useful for optimizing clinical decisions regarding the allocation of interventions.

The present study explores prognostic factors for the effect of interventions for work-related neck-shoulder complaints. Two interventions are considered in this perspective, i.e. ambulant Cinderella-based myofeedback training combined with ergonomic counselling (Mfb) and ergonomic counselling only (EC). Outcome is defined in terms of pain intensity and disability immediately after the interventions and at 3-months follow-up, and prognostic factors for outcome were compared between the two interventions. As literature has shown that the physical factors have less predictive value, only sociodemographic and psychological factors are evaluated.

Methods

Subjects and design

This study was undertaken within the framework of a randomized clinical trial to evaluate the effectiveness of an intervention for persistent work-related neck-shoulder complaints, i.e. ambulant myofeedback training in combination with ergonomic counselling (Mfb), and the effects were compared with an Ergonomic Counselling only (EC) intervention, on pain intensity and disability. Subjects were randomly assigned to the Mfb or the EC group. Measurements were performed prior to the intervention but before randomization (Baseline), immediately after four weeks of intervention (T0), and at three months follow-up (T3).

Participants were recruited regionally in the Netherlands, using the NEW-study questionnaire (QB)[19], measuring sociodemographic characteristics, potential risk factors for the development of work-related complaints, and the extent and severity of complaints. Subjects eligible for participation were elderly female computer workers, working for at least 16 hours a week and reporting *persistent* complaints in the neck and/or shoulder region for at least 30 days during the last year. These complaints had to be subjectively assigned to computer work, and as such were labelled work-related musculoskeletal complaints. Exclusion was based on reporting pain in more than 3 body regions for more than 30 days during the past 12 months, severe arthrosis, joint disorders, diagnosis cancer/tumour(s) diagnosis, or the use of muscle relaxants. Subjects were also excluded when reporting other complaints in the upper extremity not related to work.

The study was approved by the local medical ethics committee and subjects gave their written informed consent prior to participation.

Interventions

Ergonomic Counselling

All subjects received four weeks of intervention during which they kept a diary of activities and pain intensity scores. During this four-week period they were visited weekly by a therapist. The first visit comprised an ergonomic workplace investigation by means of the risk inventory of Huppes et al.[20]. This checklist contains questions to evaluate work tasks, working hours, work load, work station, and working methods. Based on the outcome, possible improvements were discussed with the subject. The remaining visits were used to further discuss the ergonomic aspects, the consequences of possible ergonomic adjustments, etc. according to a manual to guarantee an intervention as uniform as possible.

Myofeedback training

In addition to ergonomic counselling, subjects assigned to the Mfb group used a two-channel ambulant feedback system for training of muscular relaxation during work. This system includes a garment incorporating dry sEMG electrodes to enable a stable recording of upper trapezius muscle activity[8]. The harness was connected to a sEMG processing and storage system (see Picture 1.1). Embedded software of the myofeedback system provided detection of muscle rest, expressed in sEMG parameter Relative Rest Time (RRT), which was defined as the percentage of time in which Root Mean Square (RMS) was below threshold (10 µV for at least 0.125 seconds). Feedback by means of vibration and a soft sound was provided after each 10 seconds interval[21] when RRT was below 20%. This 20% threshold was based on the results of Hägg and Åström[22].

At Baseline, subjects received the myofeedback system and they were informed about the principles of feedback. They got instructions about the working mechanism of the system and some basic information about relaxation skills. In order to fulfill the Mfb intervention, subjects had to wear the system for four weeks, for at least two days a week, two hours a day, and eight hours a week during their regular occupational activities. During the weekly visits of the therapist, the data was downloaded and discussed. This procedure was facilitated by means of the diary. For more details concerning the myofeedback training the reader is referred to Hermens et al.[8] and Voerman et al.[10 23].

Outcome measures

Pain intensity in the neck at time of the measurement was assessed by means of Visual Analogue Scales (VAS)[24]. Subjects were asked to rate their subjectively experienced level of pain intensity at that particular moment. The VAS consists of a 10 cm horizontal line with 'no discomfort at all' at the left and 'as much discomfort as possible' at the right extremity of the line. Psychometric properties of the VAS have proven to be sufficient[25].

The level of experienced disability was assessed with the Pain Disability Index (PDI), a self-rating scale that measures the impact of pain on the abilities to participate in life activities[26]. The PDI contains 7 items, one for each domain, i.e. (1) family and home responsibilities (2) recreation, (3) social activity, (4) occupation, (5) sexual behaviour, (6) self care, and (7) life-support activity. Answers are provided on a categorical 11-points scale with 'not disabled' and 'fully disabled' at the extremes. Psychometric properties of the PDI are sufficient[27], and Cronbachs' alpha was .89 in the current population.

Assessment of potential prognostic factors

At Baseline subjects were asked to complete several questionnaires assessing sociodemographic and psychological factors that were assumed to be potential prognostic factors for the effect of intervention on pain and disability. The selection of these factors was mainly based on the reviews of Borghouts et al.[1] and van der Hulst et al.[15].

Sociodemographic factors

1. Age, job satisfaction, and pain duration in the neck and shoulder region in the last year were assessed using QB[19].
2. Pain intensity and disability were assessed using Visual Analogue Scales (VAS) and the Pain Disability Index (PDI), as described above.
3. Health-related quality of life was assessed by means of the VAS dimension of the EuroQol 5D (EQ5D-VAS)[29]. The EQ5D-VAS, also called the Health Thermometer, is a global health status measure. On a 20 cm vertical line with endpoints of 0 (worst imaginable health state) at the bottom and 100 (best imaginable health state) at the top, subjects had to draw a line on the thermometer that best corresponded to their current health-related quality of life.

Psychological factors

1. Fear-avoidance beliefs play an important role in several cognitive-behavioural models explaining the perpetuation of musculoskeletal pain[30 31] and were thus considered potential prognostic factors. Fear-avoidance beliefs were assessed using the Dutch language version of the Fear-Avoidance Beliefs Questionnaire (FABQ)[32], a 16-item 7-point measure that aims at identifying beliefs concerning the influence of work and physical activity on pain and on whether activities should be avoided. High scores represent high fear-avoidance beliefs. The FABQ has two subscales; one describing fear-avoidance beliefs about work (FABQ-W, range 0 - 42) and one describing fear-avoidance beliefs about physical activity (FABQ-PA, range 0 - 24). The FABQ has proven to be psychometrically sound[33]. Internal consistency was satisfactory in the current population (Cronbachs' alpha .83 for FABQ_PA and .82 for FABQ_W).
2. Aspects related to pain experience were assessed with a Dutch language version of the Multidimensional Pain Inventory[34], a self-report instrument that measures psychosocial and behavioural aspects of pain. The MPI consists of 61 questions in three domains (psychosocial aspects of pain, the perception of responses of significant others to their pain, and activity level) and based on the outcome on this questionnaire, subjects were classified into profiles for their pain behaviour and burden of illness: 'average', 'adaptive coper', 'interpersonally

distressed', 'dysfunctional', and 'anomalous', including subjects not classifiable. The MPI has adequate psychometric properties[34].

3. Coping strategies with regard to pain were assessed using the Dutch version of the Coping Strategies Questionnaire (CSQ)[35] which has seven subscales regarding cognitive reactions: 'Catastrophizing', 'observed pain control', 'ignoring sensations', 'coping self-statements', 'reinterpreting pain sensations', 'praying or hoping', and 'diverting attention', and one subscale describing behavioural actions, 'increasing behavioural activities'. Forty-four questions are answered by means of a mark at an 11-points VAS scale with 'never' and 'always' as extremes. The CSQ is known to have good psychometric properties[35], and Cronbachs' alpha calculated with the current data for the subscales varied between .74 and .95.

4. Expectations regarding the effect of the intervention were assessed by two questions defined by the authors. These questions were: [1] I expect participation in the intervention activities to be beneficial for my musculoskeletal symptoms (Expectation_1), and [2] I do not expect participation in the intervention activities to improve my situation (Expectation_2).

Data analysis

Changes in pain intensity and disability were calculated: VAS and PDI scores obtained at T0 (immediately after the intervention) and T3 (at three months follow-up) were subtracted from B values and expressed in $\Delta VAS_{B\text{-}T0}$, $\Delta PDI_{B\text{-}T0}$, $\Delta VAS_{B\text{-}T3}$, and $\Delta PDI_{B\text{-}T3}$.

(Sub)Scores of the questionnaires assessing sociodemographic and psychological factors were calculated. Results of the MPI provided classification in patient profiles. Because of the sample size, the small number of subjects classified as 'dysfunctional' and 'interpersonally distressed', and the characteristics of these profiles, profiles were clustered in the following way: 'Dysfunctional' and 'interpersonally distressed' (MPI_1), and 'average' and 'adaptive coper' (MPI_2). Subjects with a dysfunctional or interpersonally distressed profile usually report higher pain intensity, higher levels of affective distress, lower activity levels, and less pain-related interference in their lives compared to the average and adaptive copers.

In Table 5.1 an overview is provided of the potential sociodemographic and psychological prognostic factors selected for this study.

Statistical analysis

Data from the current study are part of a large randomised trial evaluating the effectiveness of the Mfb and the EC interventions. Results for this complete group with respect to pain intensity and disability are described in detail elsewhere[10]. Here the findings of the current subgroup are provided with regard to the effects of the intervention on pain and disability.

Bivariate Pearsons' correlation coefficients were calculated to examine the relationship between the dependent outcome measures ($\Delta VAS_{B\text{-}T0}$, $\Delta PDI_{B\text{-}T0}$, $\Delta VAS_{B\text{-}T3}$, and $\Delta PDI_{B\text{-}T3}$) and the independent potential prognostic factors, measured at Baseline including VAS and PDI (see also Table 5.1). In literature, the inclusion of baseline scores in analysis of prognostic factors is subject to discussion. However, as the level of change is dependent on the initial

Table 5.1: (Subscales of) Questionnaires used to assess potential prognostic factors

Sociodemographic prognostic factors		**Psychological prognostic factors**	
Quest.	*Factor*	*Quest.*	*Factor*
QB	Age	**FABQ**	Fear avoidance beliefs work (*FABQ_W*)
	Job satisfaction		Fear avoidance beliefs physical activity (*FABQ_PA*)
	Duration complaints neck	**MPI**	Dysfunctional/Interpersonally distressed (*MPI_1*)
	Duration complaints shoulders		Average/Adaptive coper (*MPI_2*)
VAS	Pain intensity	**CSQ**	'Catastrophizing'
PDI	Disability		'Observed pain control'
EQ5D	Health-related quality of life (*EQ5D-VAS*)		'Ignoring sensations'
			'Coping self statements'
			'Reinterpreting pain sensations'
			'Praying or hoping'
			'Diverting attention'
			'Increasing behavioural activities'
		Expectations	Expectation_1
			Expectation_2

QB = NEW-study Questionnaire; VAS = Visual Analogue Scale; PDI = Pain Disability Index; EQ5D = EuroQol 5 Dimensions; FABQ = Fear Avoidance Beliefs Questionnaire; MPI = Multidimensional Pain Inventory; CSQ = Coping Strategies Questionnaire

score and alternative methods are not sufficient, inclusion of baseline values should be preferred over exclusion, similar to comparative studies of e.g. Bekkering et al. [37] and Bot et al.[14 36]. Inherently, inclusion also results in correction of within-group variability at baseline. Associated variables ($p \leq 0.2$) were subsequently included in the multivariate linear regression model. Dummy variables were created for the MPI profiles using profile 2 ('average' and 'adaptive coper') as reference category. Separate models were built for ΔVAS_{B-T0}, ΔPDI_{B-T0}, (immediately after the intervention) and ΔVAS_{B-T3}, and ΔPDI_{B-T3} (3-months follow-up) using manual backward elimination. Only factors with a $p < 0.1$ were retained in the model. When no more factors could be removed, this was considered the final predictive model. To prevent from over-fitting and thus less stable and less generalizable models, the maximum number of variables included in the models were calculated by dividing the number of subjects in each outcome measure by 10[37], i.e. 3 in the present study. Adjusted R^2 values, unstandardised B's, standard errors, p-values, and corresponding 95% Confidence Intervals (CI) were presented.

Regression coefficients were compared between the Mfb and EC groups using Chow tests, a method of pooled regression to investigate whether a set of regression coefficients are similar over several groups compared to the pooled data[38] by comparing sums of squares of the residuals. In other words, Chow tests provide a method to investigate whether the influence of a set of prognostic factors is similar for different interventions. Statistical Package for Social Sciences (SPSS) was used for statistical analysis and alpha was set at .05 for statistical significance.

Results

Subjects

Baseline measurements were performed with 38 subjects (18 in the Mfb group and 20 in the EC group), with a mean (sd) age of 49.6 (5.3) and 48.9 (4.2) respectively. Mean height was 1.67 m (6.4) in the Mfb group and 1.67 (6.8) in the EC group, with a mean weight of 72.0 (12.0) and 70.5 (12.2) respectively.

Immediately after Baseline, two subjects in the EC group dropped out so T0 measurements were performed with 36 subjects (18 in the Mfb group and 18 in the EC group). Baseline and T0 were separated by 34 (± 8) and 32 (± 6) days for both groups respectively. At T3, three subjects dropped out in the Mfb group, each due to long-lasting illness, so T3 measurements were available of 15 subjects in the Mfb group and 18 subjects in the EC group. Mean number of days between T0 and T3 was 83 (± 12) for the Mfb and 84 (± 18) for the EC group. Prior to the intervention 7% of the subjects reported neck-shoulder complaints for less than one year, and 51% of the subjects reported complaints for between 2 and 5 years. Fourteen percent of the population reported to have complaints between 6 and 15 years, and the remainder (i.e. 28%) suffered from neck-shoulder pain for more than 15 years.

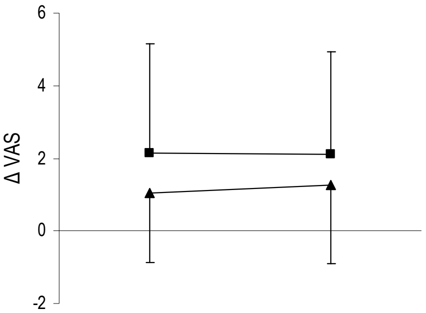

Figure 5.2: Mean ΔVAS for the Mfb (■) and the EC group (▲)

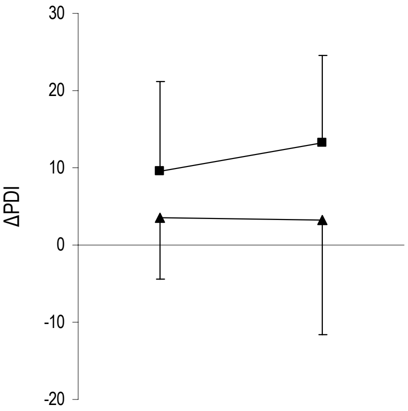

Figure 5.3: Mean ΔPDI for the Mfb (■) and the EC group (▲)

Prognostic factors for the effect of intervention

Immediately after the intervention (T0) and at 3-months follow-up (T3), both groups reported a significant decrease in pain intensity and disability compared to B (F = 11.58, p = .00; F = 9.99, p = .00). No difference was found between the Mfb and EC groups regarding changes in pain intensity (F = .69, p = .50) (see also Figure 5.2), but subjects in the Mfb group showed a trend towards a larger change in disability compared to subjects in the EC group (F = 3.27; p = .05) (see also Figure 5.3).

Initial values of the potential prognostic factors are presented in Table 5.2 for both the Mfb and EC groups. There were no significant differences in initial values between the two groups ($p > .05$).

Effects immediately after the intervention

Potential prognostic factors that were associated ($p < .2$) with the dependent factors ΔVAS_{B-T0} and ΔPDI_{B-T0} are presented in Table 5.3. In addition, this table provides the R^2_{adj} value of the multivariate regression model comprising all these factors. The strongest relation was found between ΔVAS_{B-T0} and VAS, and between ΔPDI_{B-T0} and PDI. Three CSQ subscales were related to ΔPDI_{B-T0}, but no such relations were found for ΔVAS_{B-T0}.

The final model for prognostic factors affecting changes in pain intensity immediately after the intervention is shown in Table 5.4. ΔVAS_{B-T0} is best predicted by pain intensity in the neck region at Baseline only: Subjects reporting high levels of pain intensity were most likely to benefit from the interventions. ΔPDI_{B-T0} was best predicted by the level of disability prior to intervention, the score at the CSQ subscale 'ignoring sensations', and MPI-patient profile 'dysfunctional' and 'interpersonally distressed' relative to subjects with 'average' and 'adaptive coper' profiles. Subjects characterised by a 'dysfunctional' or 'interpersonally distressed' profile benefit more from the interventions than the 'average' and 'adaptive coper'. Furthermore, subjects with high initial levels of disability and those who ignore pain sensations are most likely to benefit from the interventions (see Table 5.4). R^2_{adj} is somewhat lower for the prognostic model for changes in disability than changes in pain intensity, but both are high (.60 and .54 respectively).

Table 5.2: Baseline values for potential prognostic socio-demographic and psychological factors for Mfb and EC

		Mfb **n = 18**	**EC** **n = 20**
Socio-demographic factors	**Age**	49.6 (sd 5.3)	48.9 (sd 4.2)
	Job satisfaction		
	Highly unsatisfied	12%	0%
	Unsatisfied	0%	5%
	Satisfied	70%	79%
	Very satisfied	18%	16%
	Pain intensity		
	VAS_B	4.1 (sd 2.6)	3.0 (sd 2.2)
	Duration complaints neck last 12 months		
	1-7 days	5.6%	0%
	8-30 days	16.7%	11.1%
	More than 30 days	38.9%	61.1%
	Every day	27.8%	27.8%
	Duration complaints shoulders last 12 months		
	1-7 days	5.6%	0%
	8-30 days	5.6%	10.5%
	More than 30 days	55.6%	47.4%
	Every day	27.8%	42.1%
	Disability (PDI)		
	PDI_B	21.4 (sd 16.0)	13.4 (sd 10.5)
	Health-related quality of life (EQ5D)		
	EQ5D-VAS	72.8 (sd 16.6)	80.6 (sd 14.2)
Psychological factors	**Fear-avoidance beliefs (FABQ)**		
	Work (FABQ_W)	10.6 (sd 6.3)	9.6 (sd 5.8)
	Physical Activity (FABQ_PA)	15.7 (sd 9.2)	14.4 (sd 7.8)
	Patient profile (MPI)		
	Dysfunctional' and 'Interpersonally distressed	23%	5%
	Average' and 'Adaptive coper	50%	74%
	Anomalous and Not classified	27%	21%
	Coping with pain (CSQ)		
	Catastrophizing	2.3 (1 – 7)[a]	1.8 (1 – 4)[a]
	Observed pain control	5.0 (1 – 9)[a]	5.8 (1 – 10)[a]
	Ignoring sensations	5.2 (1 – 10)[a]	5.3 (1 – 10)[a]
	Coping self-statements	4.6 (1 – 10)[a]	4.1 (1 – 9)[a]
	Reinterpreting pain sensations	3.4 (1 – 8)[a]	3.3 (1 – 10)[a]
	Praying or hoping	3.2 (1 – 8)[a]	2.6 (1 – 10)[a]
	Diverting attention	2.8 (1 – 6)[a]	4.1 (1 – 10)[a]
	Increasing behavioural activities	2.9 (1 – 8)[a]	3.9 (1 – 10)[a]
	Expectations		
	Expectation_1	4.5 (2 – 6)[b, c]	4.5 (2 – 6)[b, c]
	Expectation_2	3 (1 – 6)[b, c]	2 (1 – 6)[b, c]

a	mean and range
b	median and range
c	1 = completely disagree; 6 = completely agree

Table 5.3: Bivariate correlation coefficients (r) and p values for factors related ($p < .20$) to changes in outcome immediately after the intervention

ΔVAS_{B-T0}			**ΔPDI_{B-T0}**		
Variable	**r**	***p***	**Variable**	**r**	***p***
VAS	.75	.00	PDI_B	.73	<.01
EQ5D-VAS	-.40	.03	MPI_1	.53	<.01
MPI_1	.37	.03	CSQ'catastrophizing'	.42	.01
PDI_B	.30	.08	VAS_B	.40	.02
Expectation_1	.25	.15	CSQ 'ignoring sensations'	-.33	.05
			Job satisfaction	-.28	.12
			CSQ 'praying or hoping'	.26	.13
			Expectation_1	.26	.12
			EQ5D-VAS	-.27	.14
R^2_{adj} .60			**R^2_{adj} .55**		

Table 5.4: Final prognostic models for ΔVAS_{B-T0} and ΔPDI_{B-T0}

	Beta (SE)	**95% CI**	***p***	**R^2_{adj}** *when removed*
ΔVAS_{B-T0} $R^2_{adj} = 0.54$				
Constant	-1.14 (.51)	-2.17 (-.11)	.03	
VAS	.79 (.12)	.54 (1.04)	<.01	-
ΔPDI_{B-T0} $R^2_{adj} = 0.60$				
Constant	1.58 (3.06)	-4.65 – 7.82	.61	
PDI	.42 (.09)	.23 – .61	<.01	.36
MPI_1	8.77 (3.56)	1.51 – 16.03	.02	.53
CSQ 'ignoring sensations'	-.70 (.40)	-1.50 – .11	.09	.57

Effects at 3-months follow-up

The results of bivariate correlation analysis for identifying potential prognostic factors for the effect of intervention after three months, and the R^2_{adj} value of the multivariate regression model comprising all factors, are presented in Table 5.5. Baseline pain intensity appeared to be the only relevant predictor for ΔVAS_{B-T3} ($F = 30.8$, $p = .00$) (Table 5.6). ΔPDI_{B-T0} was best predicted by the level of disability at Baseline, age, and scores at the CSQ subscale 'ignoring sensation' ($F = 17.60$, $p = .00$). Subjects with a higher Baseline disability score, a higher age, and lower scores on the subscale 'ignoring sensations' appeared most likely to benefit from the interventions at three months follow-up (Table 5.6).

Table 5.5: Bivariate correlation coefficients (r) and p values for factors related ($p < .20$) to changes in outcome at 3-months follow-up

ΔVAS_{B-T3}			**ΔPDI_{B-T3}**		
	r	**p**		**r**	**p**
VAS_B	.72	.00	PDI_B	.65	<.01
EQ5D-VAS	-.44	.02	Age	.42	.02
Expectation_1	.31	.09	CSQ 'ignoring sensation'	-.37	.05
Age	-.29	.12	CSQ 'diverting attention'	-.36	.05
MPI_1	.27	.14	CSQ 'increasing behavioural activities'	-.32	.08
R^2_{adj} .48			**R^2_{adj} .64**		

Table 5.6: Final prognostic models for ΔVAS_{B-T3} and ΔPDI_{B-T3}

	Beta (SE)	**95% IC**	***p***	**R^2_{adj}** ***when removed***
ΔVAS_{B-T3} $R^2_{adj} = 0.50$				
Constant	-.90 (.56)	-2.04 - .25		
VAS_B	.72 (.13)	.46 - .99	<.01	-
ΔPDI_{B-T3} $R^2_{adj} = 0.63$				
Constant	-48.08 (13.99)	-76.84 – 19.31	<.01	
PDI_B	.59 (.11)	.36 – .82	<.01	.27
Age	1.05 (.27)	.49 – 1.62	<.01	.45
CSQ 'ignoring sensations'	-1.34 (.58)	-2.54 – - .15	.03	.56

R^2_{adj} when predicting changes at 3-months follow-up was higher for disability compared to pain intensity (.63 and .50 respectively).

Comparison of regression coefficients between Mfb and EC

Chow tests indicated that the regression coefficients for the prognostic factors were comparable between the two interventions in this study with regard to ΔVAS_{B-T0}, ΔPDI_{B-T0} and ΔVAS_{B-T3} ($p > .05$). The regression coefficients for ΔPDI_{B-T3}, however, were different between the two groups for CSQ subscale 'ignoring sensations' ($p = 0.03$): The effect of CSQ subscale 'ignoring sensations' is significantly larger in the EC group (R^2_{adj} for final model .70) compared to the Mfb group (R^2_{adj} for final model .67). This means that when assigned to the EC group, lower levels of ignoring sensations are related to improved outcome, while in the Mfb group the level of ignoring pain sensations is not that relevant.

Discussion

This study explored prognostic factors for the effect of interventions for work-related neck-shoulder complaints in terms of pain intensity and disability immediately after the intervention and at 3-months follow-up. In addition, a comparison was made between prognostic factors for two interventions; myofeedback training in combination with ergonomic counselling (Mfb) and ergonomic counselling alone (EC).
The results show that:

1) The baseline level of pain intensity is the only relevant prognostic factor for changes in pain intensity immediately after the intervention and at 3-months follow-up, explaining 50 and 54% of the change in pain intensity respectively;
2) The initial level of disability and coping strategy 'ignoring sensations' are relevant predictors for changes in disability immediately after the intervention and at 3-months follow-up. Patient profile ('dysfunctional'/'interpersonally distressed') is additionally important immediately after the intervention, while age is additionally relevant at 3-months follow-up. The percentages explained variance are relatively high; 60% and 70% respectively; and
3) Prognostic factors for outcome are largely comparable between the Mfb and EC groups, except for disability at 3-months follow-up: Ignoring pain sensations is a relevant factor for disability at follow-up in the EC group only.

Changes in pain intensity both immediately after the intervention as well as at three months follow-up were best predicted by the level of pain intensity prior to the interventions: Subjects reporting higher levels of pain intensity appeared to be most likely to benefit. To some extent this finding can be explained by the fact that the dependent variable (ΔVAS) was directly related to the independent variable (VAS at Baseline). The relation between initial pain intensity and outcome has been addressed more often in literature[1 14 18 36]. Although some studies show that high initial pain intensity levels are predictors for poor prognosis[1 15 18] others report better outcome in subjects with high pain intensity as they may have more to gain from interventions compared to those with low pain intensity[14]. One explanation for this inconsistency in literature may be related to the definition of effective outcome. For instance, although those with high initial pain intensity levels are more likely to show a reduction in pain intensity, and thus benefit more from an intervention compared to subjects with low initial pain intensity levels, it is equally likely that they still have relatively high levels of pain intensity after the intervention and thus can be considered as not recovered (i.e. a poorer prognosis). It should be noted however that the observation of larger improvements in subjects reporting high baseline pain intensity may also have been affected by the 'regression to the mean' phenomenon.

The same reasoning counts for the finding of larger beneficial effects in terms of disability in subjects with high baseline disability levels, a finding that has more often been reported in literature (e.g.[15 39]). But in contrast to pain intensity, changes in disability were predicted by other factors than baseline values only.

A consistent factor for predicting disability was that subjects ignoring pain sensations, a coping strategy, were less likely to benefit from interventions. The relevance of coping strategies in pain and disability perpetuation is commonly accepted. Burton et al. [40] concluded that coping strategies were seven times more important than the clinical or historical variables for predicting outcome in disability scores in back pain patients. Subjects with low scores at 'ignoring pain sensations', which are subjects who do not deny their pain, were most likely to benefit from the interventions. One could hypothesize that subjects who do not deny or ignore their pain sensations may more easily perceive changes in their complaints and thus benefit more from intervention compared to subjects who do ignore pain sensations. The initial level of ignoring pain sensations is especially important when considering disability three months after ending the intervention: While in the EC group there is a negative, significant association between disability and ignoring sensations at baseline, this association is not significant in the Mfb group. Thus, in the Mfb group, outcome after the intervention is not affected by whether or not subjects ignore their pain sensations. Subjects showing high levels probably have poorer outcome in the EC group but not in the Mfb group. An explanation for this finding is that the myofeedback continuously confronts subjects with their sensations which makes that they more easily detect changes and benefit more compared to the subjects in the EC group. Therefore in the EC group acknowledgement of complaints and pain sensations before the start of the intervention is desirable for optimal benefit from the intervention while this is not required in the Mfb group.

There is rather strong evidence for subjects with 'interpersonally distressed' and 'dysfunctional' profiles to benefit more from interventions in terms of disability reduction compared to 'average' and 'adaptive copers' (e.g.[28 41]) and the present findings support this. Subjects with a 'dysfunctional profile' usually report higher pain intensity, higher affective distress, lower activity levels, and more interference of pain in daily living. In addition, 'interpersonally distressed' subjects report that significant others are not supportive. Van der Hulst et al.[15] hypothesized that treatment in 'interpersonally distressed' and 'dysfunctional' subjects reduces distress and improves adequate coping skills, which is not an obstruction in average or adaptive copers. Therefore, this subgroup may benefit more from interventions. In agreement, interventions based on self-management principles appeared to be beneficial in these chronic pain patients[42]. At 3-months follow-up however, patient profile at baseline is not a significant predictor for outcome anymore, while age is. The role of age in predicting outcome is often discussed in literature. Hoving et al.[18] reported a poorer prognosis in women over 40 years of age and Anonymous (1966) (see review of [1]) showed that worse outcome was found in females over the age of 50 compared to male and younger subjects. Other studies showed no relation[39 43]. A possible explanation for older subjects showing the largest improvements, as found in the present study, might be that with older age complaints are better accepted, as inherent to ageing. As a result, intervention-induced improvements may have more impact on perceived disability.

In line with literature, different predictors were found for the outcome measures pain intensity and disability[43]. This finding is not unexpected as assessment of disability reflects a broad spectrum of phenomena, and concerns an interaction between social and personal factors[17]. This study also supported the finding that different predictors are relevant at follow-up compared to at immediately after intervention[18 42 44]. The percentages of explained variance were substantial; 50 – 70% of the change in outcome after intervention could be explained by the included variables in this study, which is mainly the resultant of including baseline values in the analysis. Bot et al.[14] found rather comparable levels of explained variances for pain and disability; 43 – 54% but other studies reported lower values[18]. The sample size of the present study was not large enough to divide it into a sample from which the prognostic factors were derived and a test sample for independent validation of the models. This is important because the discriminating power of prognostic models is always higher in data from which the model has been derived compared to new data.

For clinical practice, it can be concluded that subjects with work-related neck-shoulder complaints with high initial levels of pain intensity and disability will benefit from the interventions. This benefit is more evident for patients with an 'interpersonally distressed' and 'dysfunctional profile' and those who do not ignore their pain sensations.
No difference was found between the prognostic factors for the Mfb and EC intervention, except for changes in disability at 3-months follow-up where subjects who ignore pain sensations seemed to be less responding to ergonomic counselling alone compared to subjects taking part in myofeedback combined with ergonomic counselling. This lasting improvement indicates that myofeedback contributes a specific quality to those subjects who ignore their pain sensations.

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Chapter 6

Upper trapezius muscle activation patterns in neck-shoulder pain patients and healthy controls

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Abstract

This study aimed at investigating whether patients with neck-shoulder complaints from different aetiologies (work-related musculo-skeletal disorders, WMSD; whiplash associated disorders, WAD) show comparable trapezius muscle activation patterns compared to healthy controls. Twenty healthy controls, 21 WMSD and 20 WAD patients with non-acute neck-shoulder pain were recruited for this cross-sectional study. Surface Electromyography (sEMG) recordings were performed at the upper trapezius muscles during reference contractions, standardised computer tasks (typing and unilateral stress task), and rest measurements. sEMG was continuously recorded during these measurements. Outcome measures were Root Mean Square (RMS) to study muscle activity, and Relative Rest Time (RRT) to study muscle relaxation. Statistical analysis comprised the bootstrap technique and Kruskall-Wallis tests. Results showed no clear evidence for abnormal muscle activation patterns in WMSD and WAD patients compared to healthy controls. However, a tendency was observed for higher RMS levels during the reference contractions and computer tasks in both patient groups compared to healthy controls, and lower RRT levels at the non-dominant side during stress. Both patient groups also showed larger variability in RMS and RRT values. This variability has more often been reported in literature and may suggest the existence of subgroups of pain patients with corresponding different muscle activation patterns not related to aetiology. Future research may focus on identifying these subgroups of patients with neck-shoulder pain.

Introduction

Musculoskeletal pain in the neck-shoulder region is very common and can be classified based on aetiology. Among others, pain due to repetitive work or trauma have attained increasing attention during the last decade. Work-related MusculoSkeletal Disorders (WMSD) in the neck-shoulder region are a major problem in Western industrialised countries, especially among computer workers[1]. It is characterized by a disturbance in the balance between load and physical capacity, often preceded by activities that involve repeated movements or prolonged periods spent with one or more relevant body-parts in a fixed position[2]. A large study performed in 1998 indicated that 32% out of 1400 Dutch employees had experienced neck-shoulder complaints during the last year[3]. Eight percent had been absent from work due to WMSD during that year, and about 3% of the Disability Insurance Act claims was due to WMSD[3]. In the United States, for instance, about one third of the worker compensation costs in private industry is caused by WMSD[4].
A second group of neck-shoulder pain patients concerns subjects with the Whiplash Associated Disorder (WAD). A whiplash can be defined as an 'acceleration-deceleration trauma and is particularly caused by collisions from the rear, head-on, or side of the car, or other accidents. This leads to injuries of the soft tissues (whiplash injury) ending in a diversity of clinical symptoms'[5], like neck and shoulder pain. In the Netherlands, annual incidence rates are estimated at about 40 per 100.000 inhabitants[6] of which many of them are at risk of developing chronic symptoms[7].

Although the aetiology is clearly different between WMSD and WAD, there are several similarities between the groups. There is, for instance, overlap in subjectively reported complaints such as pain and tension in the neck-shoulder region, headaches, and radiating tingling sensations in the arm and hands. In addition, in both groups there is evidence for abnormal motor control expressed in abnormal muscle activation patterns. In WMSD patients it has been hypothesised that lack of short periods of muscle rest (so-called gaps) of the trapezius muscles may be related to the development and persistence of trapezius myalgia (e.g.[8-10]) as it might result in damaged low-threshold motor units according to the Cinderella-hypothesis of Hägg[11]. In WAD patients, attention has mainly focussed on investigating muscle activity instead of muscle relaxation. Falla et al.[12] showed that in WAD patients activity levels of the neck flexors were increased compared to asymptomatic subjects. In addition, Elert et al.[13] found that chronic WAD patients have higher levels of unnecessary muscle activity of the shoulder flexors compared to healthy controls. These findings are in line with the pain-spasm-pain model[14], describing muscle stiffness expressed in higher activity levels of (surrounding) muscles. However not all studies report such clear differences between activity levels in pain patients and healthy controls[15].

Recent studies support the assumption that similar pathophysiological mechanisms are responsible for disturbances in motor control in neck pain patients of different aetiology[16 17]. For example, Nederhand et al.[18] showed that trapezius muscle activation during and after a physical task was statistically not different between WAD patients and a group of a-specific (i.e. no history of traumatic incidents or accidents) neck pain patients. Elert et al.[19] found that difficulties in relaxing the trapezius muscle were common among subjects with WMSD as well as subjects with fibromyalgia. From this reasoning, one could deduce that muscle activation patterns in WMSD and WAD patients are probably comparable, and show the same abnormalities.

This study was designed to verify the reasoning that WMSD and WAD patients would show comparable muscle activation patterns, characterised by lower levels of muscle relaxation (as described by the Cinderella-hypothesis) and higher levels of activation of the upper trapezius muscle (according to the pain-spasm-pain model) compared to a healthy control group during rest and physical or mental tasks.

Materials and Methods

Design and subjects

For this cross-sectional patient-control study three groups of subjects were recruited: One healthy control group, one group of WMSD patients, and one group of WAD patients.

The healthy subjects and WMSD patients were recruited from the employee population of a large local company in which computer-related activities prevailed, using the Dutch Musculoskeletal Questionnaire (DMQ)[20]. The DMQ is designed to obtain insight into musculoskeletal workload, working conditions, and musculoskeletal disorders in the working population, and as such provides a valuable tool for screening of suitable participants. Healthy subjects were suitable for participation if they did not report any complaints in the upper extremity for at least one year prior to measurement. WMSD patients were selected based on their self-reported existence of pain in the neck-shoulder region for at least 30 days during the last year, including the last seven days, and additionally subjects had to assign their complaints to their computer work. Subjects on sick leave were not approached for participation.

WAD patients were selected on their first visit (> 3 months post trauma) to an outpatient department for rehabilitation in a general hospital, based on the diagnosis WAD grade II according to the classification of the Quebec Task Force. In this subgroup the syndrome is manifested by neck problems and musculoskeletal signs, but patients are not restricted in their mobility[5] and complaints are not too severe to interfere with participation. Because of protocol demands, WAD patients had to be familiar with working on a computer.

In each group, subjects were excluded if they reported colour blindness, latex allergy, severe cervical arthrosis, joint disorders, or the use of muscle relaxants. Patients were also excluded when reporting other complaints of the upper extremity not related to WMSD or WAD.

The study was approved by the Medical Ethics Committee and subjects gave their written informed consent prior to participation.

Surface Electromyography recordings

Surface electromyography (sEMG) was recorded bilaterally from the upper trapezius muscle. Besides a postural and supporting function, this muscle contributes to scapula adjustment during elevation and movement of the upper arm[21] and is therefore relevant in computer related activities. The upper trapezius muscle is suitable for sEMG detection due to its size and superficial location. Additionally, the upper trapezius muscle is highly sensitive to emotional stimuli like stress[22 23]**.**

The skin overlying the upper trapezius muscle was shaved, if necessary, and cleaned with 70% alcohol to decrease impedance of the skin. Adhesive surface electrodes (Ag-AgCl Neuroline ® Disposable Neurology Electrode, type 720 00-S, interelectrode distance 2.5 cm) were placed at the skin over the trapezius muscles with the centre located 2cm laterally from the midpoint between the anatomical landmarks of the processus spinosus of C7 and the lateral end of the acromion[24]. The reference electrode was placed at the processus spinosus of C7. Electrodes were connected to an EMG unit by means of cables that were taped to the skin to reduce movement artefacts. The signal was sampled (1024 Hz), filtered (20 – 500 Hz), and stored on a computer for off line analysis.

Protocol

Subjects were positioned in a chair with arm support behind a desk with a computer and they were asked to establish their ideal workplace. Surface EMG recordings were performed during four reference contractions of 15s each and two different computer tasks of 10min each which were preceded and followed by rest measurements.

The reference task was performed according to the guidelines of Mathiassen et al.[25]. Subjects held the arms straight and horizontal in 90^0 abduction with no additional weight and the hands were relaxed with the palms pointing downwards.

The first computer task was a typing task during which subjects had to copy a text. The text, designed such that the left and right hand were equally used, was placed in a document holder that was adjustable in height and distance at the left side of the subject. The second computer task was a stress task addressing the dominant side. This task, a modified Stroop task, was a colour-word task that required subjects to use the mouse to click at the name of the colour of the print of each colour-word. The appearance of this word varied in time and appeared at random location at the screen. An incorrect or late answer was followed by a beep[26]. These beeps implicitly reinforce the pressure to complete a task in a short time which has been shown to increase the stress level. Stress, in turn may increase muscle tension in the upper trapezius muscles[22].

Both computer tasks were preceded and followed by rest measurements during which subjects were instructed to sit quietly with their arms in their lap and their spine against the back of the chair. The eyes had to be open and directed at a point right in front of the subject. Rest measurements before the typing task (Rest 1) and the stress task (Rest 3) were performed for 2min to study baseline. The rest measurements after the tasks (Rest 2 and Rest 4 respectively) were performed for 5min during which subjects watched a neutral video.

Data analysis

sEMG was continuously recorded during the reference contractions, the typing task, the stress task, and the four rest measurements. Muscle activation of the upper trapezius muscle was expressed in sEMG outcome parameter Root Mean Square (RMS, in μV). Muscle relaxation was expressed in sEMG outcome parameter Relative muscular Rest Time (RRT, in %). RRT was defined as the percentage of time in which RMS was below 6μV for at least 0.125 seconds and as such describes the relative duration of the gaps[27]. A fixed threshold was chosen instead of an individually normalized threshold as this was shown to result in a similar intra-subject variability.

RMS and RRT values were obtained for several epochs, which are periods over which RMS or RRT values were calculated. RMS values during the reference task were calculated for the middle ten seconds for each of the contractions resulting in RMS values for four epochs. For the typing and stress tasks RMS values were calculated for five and four epochs respectively with a duration of one minute each, which was considered to give a representative indication of the average RMS values during the tasks and also provided the opportunity to exclude (possible movement) artefacts from analysis by carefully selecting the epochs. For Rest 1 and Rest 3 RMS values were calculated for two epochs of about one minute each. For Rest 2 and Rest 4 RMS values were calculated for 4 epochs of about one minute each.

RRT values were calculated for each recorded minute resulting in two values for Rest 1 and Rest 3, ten values for each computer task, and five values for Rest 2 and Rest 4.

Statistical analysis

For each task (reference contraction, rest, typing and stress tasks) and each outcome parameter (RMS and RRT), epochs were averaged per subject. Data showed predominantly non-normal distributions at the group level and as transforming data did not result in normal distributions, statistical analysis consisted of non-parametric tests.

Both RMS and RRT data were visualized using Box plots. Subsequently bootstraps[28] were calculated for the differences between the three groups. A bootstrap is the non-parametric equivalent of a confidence interval and is calculated by taking a certain number of random samples from the values belonging to a population. The number of random samples should be more than 1000 when calculating confidence intervals. In this study, 2000 random samples were taken in pairs, with replacement: for example one from the WMSD and one from the WAD group. The difference between each of the pairs was stored and from the resulting database Bias Corrected and Accelerated (BCA) upper and lower limits of the 95%-confidence interval (CI) were determined. Three confidence intervals were calculated per sEMG parameter for each task: One for the difference between healthy controls and WMSD, one for healthy controls and WAD, and one for WMSD and WAD. An estimation of the difference in values was provided by the 95% CI with the assumption that a CI crossing 0 implies similarity between two groups. In addition, the differences between the groups were tested for significance by means of a non-parametric test for K Independent samples (Kruskal-Wallis test). As several studies reported high variability in muscle activation patterns of neck-shoulder pain patients[29] [30], Levene's tests were used to study potential differences in variance levels between the groups. Statistical analyses were performed using S-Plus and the statistical packages SPSS 11.5. α was set at .05 for statistical significance.

Results

Subjects

Sixty-one subjects were recruited: 20 healthy controls, 21 WMSD patients, and 20 WAD patients. In Table 6.1 an overview of subgroup characteristics is provided. The subgroups were very similar with regard to their demographic characteristics ($p > 0.05$) except for weight: WMSD patients had a significantly lower weight compared to the WAD patients included in this study ($t = -2.67$; $p = 0.01$).

Table 6.1: Mean general demographic characteristics (sd)

Characteristics	HC	WMSD	WAD
n	20	21	20
Gender (female / male)	12 / 8	17 / 4	12 / 8
Age (in years)	33.6 (5.5)	31.0 (7.6)	31.8 (8.6)
Height (in meters)	1.77 (0.10)	1.71 (0.10)	1.76 (0.12)*
Weight (in kilograms)	72.6 (8.8)	66.8 (11.9)	76.2 (18.5)*
Body Mass Index	22.88 (2.41)	22.89 (3.00)	25.34 (3.96)
% right-handed subjects	75%	95%	95%

* Characteristics are missing for one subject

HC = Healthy control; WMSD = Work-related Musculoskeletal Disorder; WAD = Whiplash Associated Disorder

Muscle activation

Figure 6.1 represents Box plots for the RMS values during the reference contraction in each group. Median values were higher in both patient groups in the upper trapezius muscles compared to the healthy control group and the largest range with the highest values were found for the WMSD group. The 95% CI indicated that RMS values during the reference contractions were comparable between the three groups (see Table 6.2), but testing for homogeneity of variances revealed that WMSD patients had increased variance levels (Levene statistic 4.19, p = .02).

Figure 6.2 shows RMS values clustered per task for each group of both trapezius muscles. Differences between healthy controls and WMSD and WAD patients were especially evident during the computer tasks. Except for the stress task at the dominant trapezius muscle, WMSD and also WAD patients tended to have higher median RMS values with higher variability compared to healthy controls during the computer tasks. For the stress task at the dominant, active side, WMSD patients showed lower RMS values compared to WAD patients and healthy controls. During the measurements, RMS values during rest were low and comparable between the groups for both the left and right trapezius muscles. Table 6.2 represents the upper and lower limits of the 95% CI for RMS values of the dominant and non-dominant upper trapezius muscles and the results of the Kruskal-Wallis test. From this table it can be derived that WMSD and WAD patients present comparable activation levels, which are not significantly different from a healthy control group as for each task the confidence interval crossed 0.

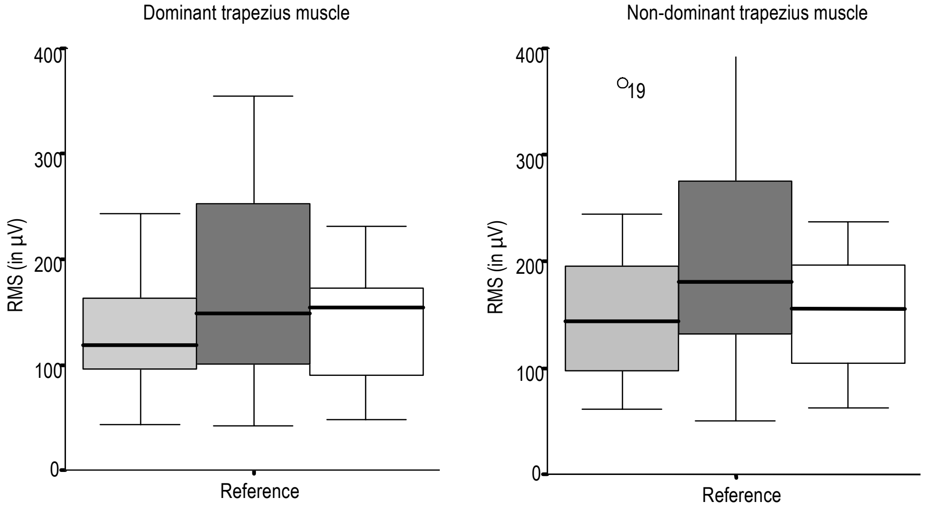

Figure 6.1: Box plots representing RMS values of the dominant and non-dominant upper trapezius muscles in healthy controls (1st box), WMSD (2nd box), and WAD patients (3rd box) during the reference task [*The box indicates the lower and upper quartiles and the central line is the median.]*

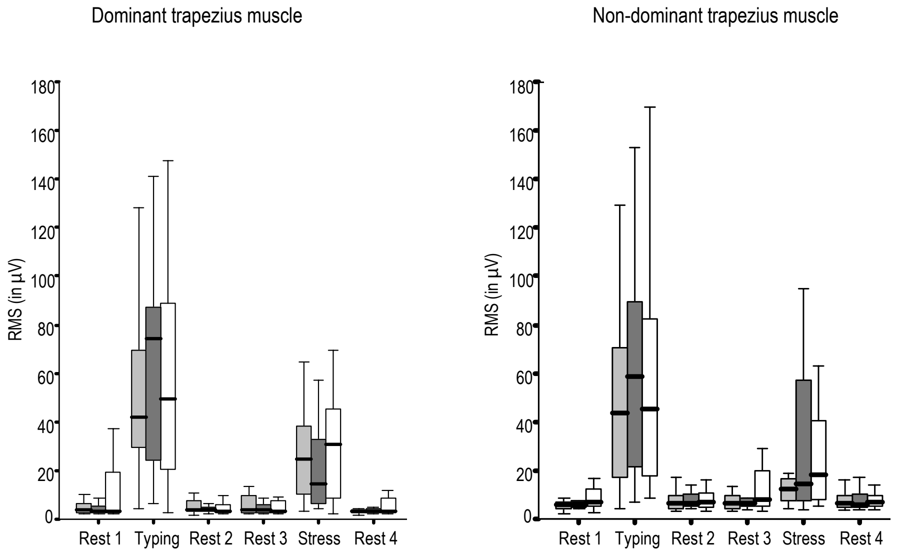

Figure 6.2: Box plots representing RMS values of the dominant and non-dominant upper trapezius muscles in healthy controls (1st box), WMSD (2nd box), and WAD patients (3rd box) during rest, typing, and stress tasks [*The box indicates the lower and upper quartiles and the central line is the median]*

Testing for homogeneity of variances indicated higher variance levels in the patient groups compared to the healthy controls during the stress task at the non-dominant side (Levene statistic 11.20, p = .01).

Muscle relaxation

Figure 6.3 represents Box-and-Whisker plots clustered per task for RRT values of both trapezius muscles for each group. In general, median RRT values were high (>90%) during the rest measurements and low (<20%) during the computer tasks.

Median values during typing were low and comparable between the three groups for both dominant and non-dominant trapezius muscles, although the ranges of values were somewhat different between the three groups. During the stress task, healthy controls had higher median levels of relaxation at the non-dominant side, compared to both patient groups. At the dominant side, WMSD patients showed higher relaxation levels. During the rest measurements median relaxation levels were high and differences between healthy controls and WMSD and WAD patients were most obvious at the non-dominant side showing lower levels of relaxation (Rest 1 and Rest 2) and larger ranges of values in the patient groups compared to healthy controls.

Table 6.3 represents the upper and lower confidence limits of the 95% CI as well as the p-value of the Kruskal-Wallis test. These data show similar RRT levels for the three groups during the measurements, expressed in occasionally very wide confidence intervals. No

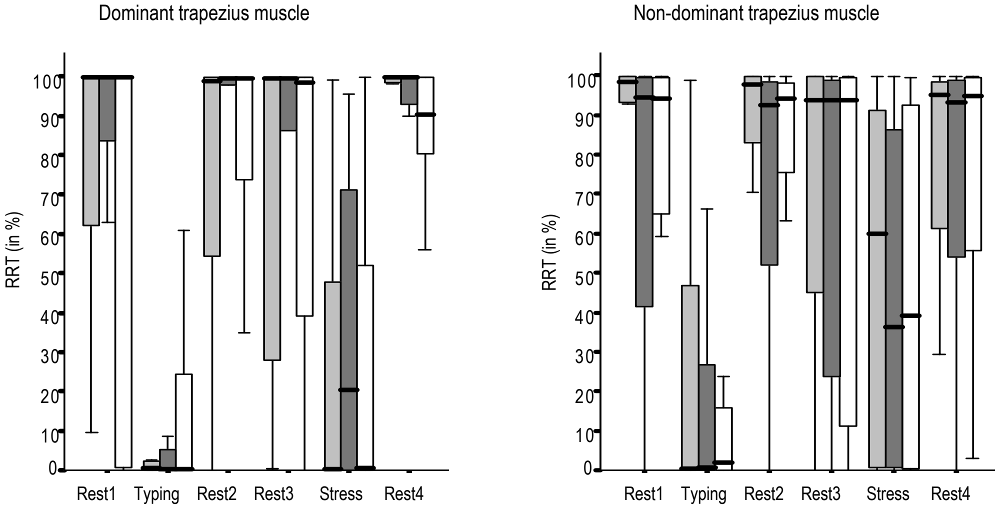

Figure 6.3: Boxplots representing RRT values of the dominant and non-dominant upper trapezius muscles in healthy controls (1st bar), WMSD (2nd bar), and WAD patients (3rd bar) during each task
The box indicates the lower and upper quartiles and the central line is the median.

evidence was found for increased variance levels in patients compared to healthy controls (p ≥ .08).

Discussion

This study aimed at investigating whether WMSD and WAD patients show comparable muscle activation patterns, hypothetically characterised by lower levels of muscle relaxation and higher levels of activation of the upper trapezius muscle in the active muscle compared to a healthy control group during rest, physical, and mental tasks.

The results showed similarities between muscle activation patterns of WMSD and WAD patients, but no significant differences compared to healthy controls. In several occasions, however, slightly higher activity levels and lower relaxation levels were found for both patient groups compared to the healthy controls. Especially with respect to muscle activation, a large range of values within the patient groups was found compared to the healthy control group.

Table 6.2: Bias Corrected and Accelerated (bca) Upper and Lower Confidence Limits (UCL and LCL) and p-values for RMS values of the dominant and non-dominant upper trapezius muscles

		RMS dominant trapezius muscle				**RMS non-dominant trapezius muscle**			
		bcaLCL (2.5%)	**Median**	**bcaUCL (97.5%)**	**p**	**bcaLCL (2.5%)**	**Median**	**bcaUCL (97.5%)**	**p**
Ref	HC - WMSD	-95.57	-21.62	16.66	0.36	-128,76	-40,33	23,26	0.20
	HC – WAD	-53,74	-32,59	18,30		-62,02	-9,64	48,02	
	WMSD - WAD	-37,49	-6,97	90,94		-32,78	30,27	123,30	
Rest 1	HC - WMSD	-0.89	0.25	1.95	0.99	-2.71	-0.18	1.48	0.36
	HC – WAD	-6.29	0.27	2.96		-5.57	-1.08	1.01	
	WMSD - WAD	-8.79	0.14	2.38		-3.82	-0.93	1.56	
Typing	HC - WMSD	-51.72	-27.99	9.34	0.62	-61.49	-9.99	25.13	0.62
	HC – WAD	-39.19	-10.13	23.35		-47.23	-1.70	42.78	
	WMSD - WAD	-13.72	17.20	62.60		-34.39	7.83	67.78	
Rest 2	HC - WMSD	-0.92	0.30	3.12	0.55	-2.44	-0.11	4.31	0.67
	HC – WAD	-0.97	0.68	3.79		-3.02	-0.62	2.77	
	WMSD - WAD	-0.43	0.43	1.68		-3.33	-0.59	2.66	
Rest 3	HC - WMSD	-1.62	0.19	4.64	0.80	-2.36	-0.12	3.20	0.32
	HC – WAD	-3.25	0.58	5.36		-14.31	-1.31	1.77	
	WMSD - WAD	-3.08	0.46	1.71		-13.54	-1.29	1.61	
Stress	HC - WMSD	-10.34	10.89	25.60	0.53	-20.67	-3.49	6.47	0.33
	HC – WAD	-25.86	-3.40	13.96		-22.66	-5.51	5.55	
	WMSD - WAD	-36.59	-15.35	5.20		-22.94	-1.23	22.02	
Rest 4	HC - WMSD	-1.00	-0.36	0.54	0.23	-2.06	0.09	5.09	0.79
	HC – WAD	-3.77	-0.60	0.49		-3.32	-0.40	1.83	
	WMSD - WAD	-4.74	-0.24	0.98		-4.90	-0.47	1.45	

Ref = reference contraction; HC = Healthy Controls; WMSD = patients with Work-related Musculoskeletal Disorder; WAD = patients with Whiplash Associated disorder

Muscle activity showed similarities between healthy controls on one hand, and WMSD and WAD patients on the other hand with a tendency for higher activity levels during computer tasks in patients. Although these differences were small and not consistent for all measurements, the direction of these differences was generally in line with the expectations based on the pain-spasm-pain model of Johansson and Sojka[14]. This model describes a reflexive increase in muscle tone due to pain by means of positive feedback loops of the gamma-motor system. An increased level of activity may result from damage of the cell membrane, the release of irritating substances and increased nociceptive activity resulting in pain perception, increased gamma-muscle spindle activity and subsequent increased muscle tone[14].

Table 6.3: Bias Corrected and Accelerated (bca) Upper and Lower Confidence Limits (UCL and LCL) and p-values for RRT values of the dominant and non-dominant upper trapezius muscles

		RRT dominant trapezius muscle				**RRT non-dominant trapezius muscle**			
		bcaLCL (2.5%)	**Median**	**bcaUCL (97.5%)**	**p**	**bcaLCL (2.5%)**	**Median**	**bcaUCL (97.5%)**	**p**
Rest 1	HC - WMSD	-14.01	-0.05	7.87	0.80	-4.67	4.38	33.49	0.26
	HC – WAD	-6.92	0.04	98.83		-2.39	3.50	28.25	
	WMSD - WAD	-1.15	0.12	98.92		-27.98	-0.29	19.32	
Typing	HC - WMSD	-2.83	-0.17	2.25	0.86	-26.43	-0.13	19.60	0.92
	HC – WAD	-1.61	0.09	2.33		-15.69	-0.86	10.38	
	WMSD - WAD	-19.42	0.14	3.67		-7.57	-0.78	3.50	
Rest 2	HC - WMSD	-20.63	-0.77	1.42	0.52	-5.23	5.29	36.91	0.30
	HC – WAD	-25.07	-0.60	1.75		-4.96	3.27	10.42	
	WMSD - WAD	-1.54	0.06	1.75		-33.77	-1.79	4.95	
Rest 3	HC - WMSD	-68.23	-0.13	1.04	0.77	-29.73	0.38	7.80	0.87
	HC – WAD	-49.78	0.00	66.64		-26.23	0.04	72.81	
	WMSD - WAD	-1.04	1.21	54.05		-7.92	0.04	72.44	
Stress	HC - WMSD	-69.68	-19.86	1.41	0.52	-33.59	5.97	74.75	0.97
	HC – WAD	-49.32	-0.31	8.80		-44.22	20.21	72.58	
	WMSD - WAD	-27.44	14.09	69.61		-63.84	18.06	66.90	
Rest 4	HC - WMSD	-0.61	0.03	2.90	0.72	-6.88	1.83	13.24	0.92
	HC – WAD	-0.47	9.42	16.14		-7.51	0.41	17.29	
	WMSD - WAD	-2.66	9.38	16.14		-37.33	-1.36	15.54	

HC = Healthy Controls; WMSD = patients with Work-related Musculoskeletal Disorder; WAD = patients with Whiplash Associated disorder Associated disorder

The absence of clear differences between healthy subjects and patients with neck-shoulder complaints is not unique in literature. Comparable results were also reported by Westgaard et al.[31] who did not find significantly increased EMG activity of the trapezius muscles in subjects with neck-shoulder pain, and Larsson et al.[15] only found a tendency towards an increase in RMS values in chronic WAD patients. In addition Holte and Westgaard[32] found that WMSD patients were not necessarily characterised by increased muscle activity levels.

An important finding in the present study is the larger range of RMS values found during the stress task in the non-dominant side in both patient groups compared to healthy controls (i.e. appr. 100 µV and appr. 20 µV respectively). As the stress task was a unilateral task in which only the dominant trapezius was used, activation of the non-dominant, contralateral muscle is not functional. An explanation for this finding might be overflow from afferents from the ipsilateral muscles to contralateral motoneurons that may be affected in pain patients[14]. This finding was also reported by Roe et al.[33] in patients with unilateral rotator tendinosus. Visual inspection of the data seemed to support this finding, but further research is required. The WMSD patients showed lower RMS values during stress at the active side compared to both the WAD and healthy control groups which was in contrast to the expectations. A possible explanation is that WMSD patients may have had instructions on safely using the mouse at the working place, as WMSD in the neck-shoulder region is often related to working with the mouse[34] and prevention is often primarily focussed on this topic. As WAD patients were no computer-workers it is likely that they have not had these instructions and as a result displayed higher RMS values. As such, the validity of this computerised stress task might be questioned, and more general tasks may be preferred in future research when comparing different patient groups.

Findings on muscular rest showed no clear differences between healthy subjects and WMSD or WAD patients during typing, stress and rest measurements. This is contrary to the majority of studies with WMSD patients measuring periods of total muscle rest during work (e.g. [8 10 29]). A possible explanation for this difference in results might be related to the large variability of the RRT parameter. This may be caused by a mixture of factors, like the relatively small sample size combined with the existence of subgroups with a different behaviour. The existence of such a mixture in the patients groups is indicated by the large differences in variability compared to the healthy control group. Variability within the WMSD population may be related to the recruitment procedure using self-reports on the presence of work-related neck-shoulder pain which may result in heterogeneity with regard to aetiology. However, this self-report reflects the information that is obtained and used in clinical practice and was used for this study as well because proper diagnostic tools are not available. Elert et al.[13] found that, although muscle activity is increased in patients with chronic pain, there is large heterogeneity between patients with the same disorder. In addition, Veiersted et al.[29] found large inter-subject variability in muscle activation patterns, even during a stereotype kind of activity. Variability in muscle relaxation was reported by Nordander et al.[30], who observed trapezius EMG in cleaners and office workers. More generally, Sjölander[35] concluded that disturbances in motor control in chronic neck pain patients rely very much upon the individual instead of being specific for a group of pain patients with similar diagnosis. This conclusion might fit in the avoidance-endurance model, a psychosocial approach for the persistence of pain, of Hasenbring[36]. This model describes different groups of pain patients, either characterised by fear-avoidance or endurance copers with corresponding different muscle activation patterns. Assuming that both the WMSD and WAD group comprised a mixture of these types of patients this will result in a large range of muscle activity and relaxation values. Further research on this topic is needed to verify this.

Variability in EMG values within and between populations may also be caused by variability of characteristics of the subjects such as in fat layer between electrodes and muscle and the geometric properties of the muscle. In the current study, WAD patients reported significantly higher weight compared to the WMSD patients, as the groups contained a few subjects with BMI > 30. It is quite common to use normalisation techniques to decrease variability between subjects by expressing the RMS values in an RMS value obtained during a standardised condition, like the reference contraction[25]. However, the reference contraction in itself may also be affected by abnormal motor control. Nederhand et al.[37] showed that WAD patients who were severely disabled had lower activation levels during the reference contraction compared to WAD patients who were only moderately disabled. In the current study, muscle activation during the reference contraction was higher in WMSD patients compared to the other two groups. Normalisation may thus result an over- or underestimation of the true activation level and has as such methodological implications. Furthermore, results of Hermens and Vollenbroek-Hutten[27] indicated that the intra-subject variability of RMS after normalisation is still considerable (33%) and only minimally decreased compared to non-normalised RMS values. Until more knowledge is gathered concerning the effect of normalization on data and the subsequent interpretation of results, reporting absolute RMS values instead of normalized RMS values has to be preferred. Additional data inspection showed that exclusion of the subjects with BMI > 30 resulted in comparable groups with respect to weight but did not change the interpretation of results.

Summarizing, in this study no convincing evidence was found for comparable muscle activation patterns between WMSD and WAD patients, hypothesised to be characterised by higher muscle activation and lower muscle relaxation levels compared to healthy controls. A tendency was identified for a larger variance in muscle activation patterns in both patient groups compared to the healthy controls. This might suggest that patient populations consist of several subgroups with corresponding different muscle activation patterns. Future research may focus on identifying these subgroups of patients.

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Chapter 7

Changes in pain, disability, and muscle activation patterns in chronic Whiplash patients after ambulant myofeedback training

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Abstract

Aim of this study was to investigate changes in pain, disability, and muscle activation patterns in patients with chronic Whiplash Associated Disorder (WAD) after four weeks of myofeedback training. Eleven WAD patients used an ambulatory myofeedback device, which continuously recorded and processed upper trapezius muscle activation patterns. Feedback was provided when muscle relaxation was insufficient. Pain in neck, shoulders, and upper back (Visual Analogue Scale), disability (Neck Disability Index), and muscle activation patterns during rest, typing, and stress tasks (surface Electromyography, sEMG) was assessed before and after the four weeks of training. Pain intensity decreased after four weeks of training. Clinically relevant changes in pain were found in 64% (right shoulder), 55% (neck and upper back), and 18% (left shoulder) of the subjects. A trend for decreased disability was found which was clinically relevant in 36% of the subjects. A remarkable reduction was found at the items concerning headache and lifting weights of the NDI. Overall, muscle activation was lower and muscle relaxation was higher after the training period with the largest differences during the rest measurements. Clinically relevant changes on these sEMG parameters were only found in a minority of patients. Four weeks of ambulant myofeedback training may be beneficial in reducing pain and disability levels and normalizing muscle activation patterns in chronic WAD patients. A randomized controlled study is recommended to further explore the effects of myofeedback training.

Introduction

Musculoskeletal pain in the neck-shoulder region is a rather common disorder encountered in rehabilitation medicine. Its aetiology is diverse and can be related to a high prevalence of repetitive movements, static posture, or trauma. When the disorder is caused by a trauma, e.g. a rear-end motor collision, subjects may suffer from the Whiplash Associated Disorder (WAD) resulting in a diversity of symptoms like neck pain, decreased mobility of the neck, pain in shoulders and arms, and headaches[1]. In the Netherlands, whiplash trauma affects about 188-235 per 100.000 individuals each year, in a population of 16 million[2] and about 2% - 58% of these individuals develop chronic symptoms[3]. Chronic WAD may affect individual functioning[4], but also results in substantial costs for health care and society[5 6].
The chronification process of pain in WAD patients is not clear, but there is growing evidence that altered motor strategies play a role in this process[7]. Compared to healthy control subjects, upper trapezius muscle activation patterns in WAD patients are characterised by increased activation during mental[8] and physical tasks[7 9 10], and a decreased ability to relax muscles after a task[9 11].
The Cinderella-hypothesis provides a possible explanation for the relation between abnormal muscle activation patterns and myalgia[12]. This hypothesis was originally developed to explain trapezius myalgia in computer workers and comprises the idea of a defined sequence of motor unit (MU) recruitment order in muscle activation, also called Hennemans' size principle[13]. Low threshold motor units ("Cinderella motor unit") are recruited first and remain active until the muscle is completely relaxed[12]. As a result these motor units suffer from too little rest, which may result in pain. The relevance of the Cinderella hypothesis has extensively been investigated in patients with Work-related MusculoSkeletal Disorders (WMSD) in the neck-shoulder region and results indicate that absence of muscle relaxation, measured with surface Electromyography (sEMG), may be considered a substantial risk factor for myalgia[14 15 16].

Based on this reasoning, one could conclude that treatment of neck pain aiming at normalising abnormal muscle activation patterns, especially increasing muscle relaxation, could be effective. A myofeedback device has been developed to achieve increased relaxation of the muscle[17]. While traditional myofeedback usually focuses on normalising muscle activation patterns by decreasing muscle activation[18-20], Cinderella-based myofeedback aims at increasing muscle relaxation using an ambulant device that can be used during all activities of daily living without any hinder[17]. Evaluation of the changes in pain after 4-weeks of myofeedback training in a population of WMSD patients showed a substantial decrease in pain intensity in neck, shoulders, arms, and upper back in about 60% of the subjects. Besides that, muscle activation patterns of the upper trapezius muscles normalised, expressed in a decreased level of activation and an increased level of muscle relaxation[17]. Evidence was found that this increase in muscle relaxation was correlated to a decrease in pain intensity[21].

Although abnormal motor strategies have been observed in WAD patients, there is no clear evidence yet indicating that lack of relaxation in neck-shoulder muscles is related to the development and persistence of myalgia in these patients. However, several studies have shown that abnormal muscle activation patterns might be considered a more general characteristic of neck pain patients. Nederhand et al.[10] showed that trapezius muscle activation during and after a physical task is comparable between WAD patients and non-specific neck pain patients. Jull et al.[22] concluded that both, whiplash patients as well as patients with insidious neck pain, have higher levels of sternocleidomastoid muscle activation compared to a control group during a cranio-cervical flexion test. Based on this knowledge, it could be hypothesised that lack of relaxation is might be related to the persistence of myalgia in WAD patients, and that therefore Cinderella-based myofeedback training could be effective in this patient population.

The aim of the present study was to explore the changes in pain, disability, and muscle activation patterns after 4-weeks of myofeedback training in subjects with chronic neck pain due to WAD. It was hypothesised that the training would result in a decrease in pain intensity, disability, and muscle activation, and an increase in muscle relaxation.

Methods and Materials

Subject recruitment

Subjects were recruited from a pain rehabilitation program of a rehabilitation centre (setting 1) and from a rehabilitation setting in a general hospital (setting 2), where they received standard physiotherapy once a week. Subjects were diagnosed WAD grade II, indicating the presence of neck complaints and musculoskeletal sign(s), including a decreased range of motion and point tenderness (Quebec Task Force[5]). Subjects were recruited if they were between 18 and 55 years of age, at least 6 months after injury (chronic phase), had a stable medical condition reflected in an absence of large fluctuations in pain and/or disability, and were experienced with computer work. Exclusion was based on the presence of severe cervical arthrosis or joint disorder(s), complaints of the upper extremity (not related to WAD), other chronic pain conditions, latex allergy, colour-blindness, and the use of muscle relaxants.

The study was approved by the local Medical Ethics Committee and subjects signed an informed consent form prior to the start of measurement.

Myofeedback training

A two-channel ambulant feedback system combined with a harness incorporating dry sEMG electrodes to enable a stable recording of upper trapezius muscle activity was used for myofeedback training. The harness was connected to a sEMG processing and storage system (see Picture 1.1).

The sEMG signal was amplified (15x), digitized (22 bits ADC) and smooth rectified with removal of the low frequency components. Sample frequency was 512 Hz and the signal was band pass filtered between 30 and 250 Hz. Embedded software provided the detection of muscle rest, expressed in sEMG parameter Relative Rest Time (RRT) which was defined as the percentage of time in which Root Mean Square (RMS) was below threshold (10 μV for at least 0.12 seconds). This threshold was based on the noise level of the myofeedback system including mounted electrodes at the skin. Sensory feedback by means of vibration was provided after each 10 seconds interval when the relative duration of muscle relaxation in that interval was below 20%. This 10 seconds interval was chosen based on results of Voerman et al.[23], and the 20% threshold was defined based on the work of Hägg and Åström[14]. The duration of the feedback progressively increased when there was no adequate response, i.e. muscle relaxation, on the feedback.

The therapist (GEV), a health scientist with sufficient relevant clinical experience, explained the principles of feedback, the working mechanism of the system, and standard relaxation skills to the subjects. The relaxation could be achieved by slightly depressing the shoulders, or by sitting down quietly with the eyes closed, the hands in the lap while breathing deeply. Another relaxation strategy was to maximally elevate the shoulders for three seconds to build up muscle tension and then to let loose this tension.

The system had to be used for four weeks, for at least two days a week, two hours a day, and eight hours a week during occupational activities (if employed) and activities of daily living. During these four weeks, subjects visited the therapist once a week to download data and to discuss progress. To facilitate data interpretation a task diary was filled out during the period the myofeedback system was worn. This diary provided insight in relaxation patterns over the day as well as muscle relaxation during activities, and was used for discussion on possible solutions for improvement of muscle relaxation.

Measurement protocol

Measurements were performed before (T1) and immediately after four weeks of myofeedback training (T2), to evaluate the changes in pain, disability, and muscle activation patterns after 4-weeks of myofeedback training.

Assessment of pain intensity and disability

Pain intensity was assessed by means of Visual Analogue Scale (VAS)[24]: Subjects were asked to rate their experienced level of pain at that moment for neck, left shoulder, right shoulder, and upper back. The VAS consists of a 10 cm horizontal line with 'no discomfort at all' at the left and 'as much discomfort as possible' at the right extremity of the line. Psychometric properties of the VAS have been proven to be sufficient. After this, the level of experienced disability was assessed with the Neck Disability Index (NDI), a self-rating scale for the assessment of physical disability in subjects with neck pain[25]. The NDI consists of 10 questions (scored from 0 to 5) concerning pain intensity, personal care, lifting, reading, headaches, concentration, work/workability, driving a car/riding a bicycle, sleeping, and recreational activities. The questionnaire has proven to be internally consistent. It is sensitive to detect changes over a period of time, and its' test-retest reliability has also been shown to be high[25 26] even at item level[25]. A score between 0 and 4 indicates no disability, between 5 and 14 mild disability, 15-24 moderate disability, 25-34 severe disability, and a score of above 34 points disability is perceived as complete disability[27].

Assessment of muscle activation patterns

Surface Electromyography (sEMG) was used to investigate muscle activation patterns of both upper trapezius muscles. Subjects were seated in an upright position in order to permit palpation of the anatomical landmarks. The skin overlying the muscles was shaved, if necessary, and cleaned with 70% alcohol. Adhesive surface electrodes (Ag-AgCl Neuroline® Disposable Neurology Electrode, type 720 00-S, inter-electrode distance 2.5 cm) were placed bilaterally at 2 cm laterally to the midpoint between the processus spinosus of C7 and the lateral end of the acromion (Hermens et al., 1999). The reference electrode was placed over the processus spinosus of C7. The electrodes were connected with the EMG unit by means of cables that were attached to the skin with tape to minimise noise. The sEMG signal was sampled (1024 Hz), band pass filtered (20-500 Hz), and stored on a computer for off-line analysis.

Subjects were asked to establish their ideal working place. Before each measurement, subjects sat with their hands in their lap, shoulders relaxed, and spine against the back of the chair. They were instructed not to talk during measurements and had to look at a point right in front of them, unless instructed otherwise.

The first part of the sEMG measurements consisted of four reference contractions of the upper trapezius muscles performed according to the guidelines of Mathiassen et al.[28]. Subjects held the arms straight and horizontal in 90^0 abduction with no additional weight. The hands were relaxed with the palms pointing downwards. Each measurement lasted for 15 seconds with 30 seconds rest in between.

After these reference contractions, two computer-related tasks for about 5 minutes each were performed: A bilateral typing task and a unilateral stress task. Each task was preceded and followed by a rest measurement of 2 and 4 minutes respectively to study baseline and return to baseline. The typing task consisted of copying a text, designed in such way that the left and right hand would equally be used, placed in a document holder at the left side of the subject. The unilateral stress task (Stroop) was a mouse task in which one of the words *red*, *green*, *blue*, or *yellow* was shown on a computer display in random order. The letters appeared in a colour different from the colour spelled by the word. The subject's task was to report the colour of the letters as quickly and correctly as possible, by clicking the icon with the correct answer using the mouse. The colour words were presented at random intervals in a machine determined pace for an average of 1.3 s (range 0.6-2.0 s). The colour-words, which were presented at different positions on the screen, were approximately 15 mm high in Helvetica font on a grey background. An auditory alarm (beep) sounded when the subjects gave a wrong answer or did not respond within the given time.

Data analysis

Pain (VAS) and disability (NDI)

Reported VAS scores were measured and expressed in mm, and for the NDI both total as well as item scores were calculated.

Muscle activation patterns (sEMG)

sEMG was continuously recorded during the typing task, the stress task, and the four (before and after each task) rest measurements. Two sEMG parameters were calculated: RMS and RRT. RMS provides an estimation of the amplitude of the sEMG signal. RRT was defined as the percentage of time in which RMS was below threshold (6μV)[29] for at least 0.125 seconds. These settings were slightly different from the settings used for the myofeedback system because of different signal-noise ratios between the two recording devices.

For the reference contraction, RMS values were calculated for the middle 10 seconds of each contraction[28], resulting in four RMS values that were averaged and used for normalization. This means that RMS values during typing, stress, and rest measurements were expressed as percentages of this mean reference value.

RMS and RRT values during the typing and stress tasks were calculated for 4 epochs of preferably one minute duration each. In some occasions when movement artefacts were detected, epochs of between 30 to 60 seconds duration were selected.

For the rest measurements that preceded the computer tasks, RMS and RRT values were calculated for one epoch of about 1 minute. For the rest measurements that followed the computer tasks, RMS values were calculated for three epochs of about 1 minute duration each.

Statistical analysis

Each outcome variable showed a non-normal distribution requiring non-parametric tests for 2 related samples (Wilcoxon Signed Ranks tests).

The changes after 4-weeks of myofeedback training were analyzed at a group level for pain (VAS score), disability (NDI), and muscle activation patterns (RMS and RRT). Data are presented using median values without providing confidence intervals as data were not normally distributed. The bootstrapping technique could provide the alternative non-parametric equivalent of confidence intervals, but due to highly abnormal distributions this technique could not reliably be used.

An additional individual evaluation was performed, based on improvement or deterioration between T1 and T2 for each parameter. Cut-off points were used for defining clinically relevant differences in outcome. These cut-off points were derived from existing literature that best corresponded to the present study with regard to characteristics of the patient population in which the cut-off points were determined. In this study a relevant change in pain (VAS) was defined as being 13 mm or more, which corresponds to the upper limit of the confidence interval of clinically relevant changes in VAS scores in traumatic and non-traumatic pain patients as provided by Kelly[30]. Differences in VAS scores between T1 and T2 (ΔVAS) were classified into four classes for each individual separately: A clinically relevant decrease in pain ($\Delta VAS \geq 13$ mm), a decrease in pain ($0 \text{ mm} < \Delta VAS < 13$ mm), an increase in pain ($-13 \text{ mm} < \Delta VAS < 0$ mm), and a clinically relevant increase in pain ($\Delta VAS \leq -13$ mm). For the NDI, a clinically relevant difference was defined as a minimal change of 5 points[27]. Differences in NDI scores between T1 and T2 (ΔNDI) for each individual separately were then classified into four groups: A clinically relevant decrease in disability ($\Delta NDI \geq 5$), a decrease in disability ($0 < \Delta NDI < 5$), an increase in disability ($-5 < \Delta NDI < 0$), and a clinically relevant increase in the subjectively reported level of disability ($\Delta NDI \leq -5$).

For RMS and RRT, cut-off points were based on the study of Hermens and Hutten (2002) who defined a difference in RMS (ΔRMS) and RRT (ΔRRT) during the typing and stress tasks as at least 5%. For each RMS epoch, a clinically relevant improvement was defined as $\Delta RMS > 5$, and clinically relevant deterioration was defined as $\Delta RMS < 5$. ΔRMS scores between -5 and 5 were defined as equal. ΔRRT epochs were classified into $\Delta RRT < 5$ (clinically relevant improvement), $\Delta RRT > 5$ (clinically relevant deterioration), and $-5 \leq \Delta RRT \leq 5$ (equal). Because no cut-off points have been described in literature for changes in RMS and RRT during rest, no classification of subjects into improved, equal, or deteriorated was made for those measurements. Alpha was set at 0.05 for statistical significance.

Results

Subjects

Fourteen subjects were recruited: Six subjects from setting 1 (rehabilitation centre) and eight subjects from setting 2 (rehabilitation department of a general hospital). The total population consisted of five female and nine male subjects with a mean age of 34.9 years (standard deviation 10.0). Mean height was 1.72 m (0.11) with a mean weight of 78.6 kg (19.0). The Body Mass Index (Weight/Height^2) was 26.4 on average (4.3). Only one subject was left-handed but the mouse was handled with the right hand. The occupational groups were office workers (n = 4), teachers (n = 2), self-employed persons (n = 3), and subjects who were unemployed or at long-term sick leave (n = 5). There were no differences in demographic variables of subjects between the two settings.

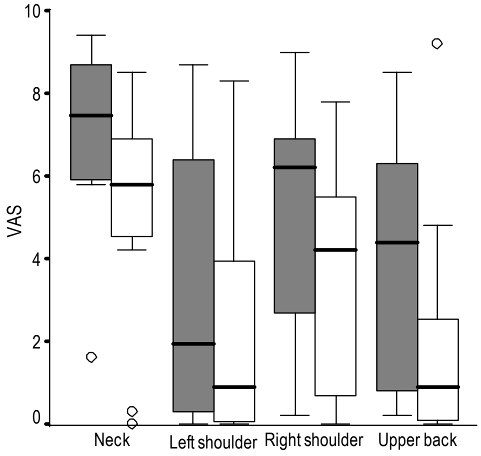

Figure 7. Box plots of VAS scores for neck, shoulders, and upper back before (grey box) and after (white box) myofeedback training *[O = outlier]*

Three subjects dropped out after inclusion, due to illness (n = 1; setting 1), motivational reasons (n = 1; setting 2), and non-compliance (n = 1; setting 1). These subjects were not different from the subjects who remained in the study with regard to age (mean 32.0; sd 2.6), height (1.74; 0.08), pain, or disability, although they had a somewhat higher weight (87.0; 38.2) and BMI (28.5; 10.3).

Pain intensity

Figure 7.1 shows box plots of the VAS scores of the neck, shoulders, and upper back at T1 and T2. At T1, the highest median VAS score was found for the neck (7.5), while the lowest median VAS score was reported for the left shoulder (2.0). Compared to T1, for each body region a remarkable decrease in the median level of pain was reported at T2: From 7.5 to 6.1 for the neck, from 2.0 to 0.9 for the left shoulder, from 6.2 to 4.7 for the right shoulder, and finally from 4.4 to 0.9 for the upper back. This decrease in pain was significant for the neck (p = 0.047) and close to significant for the upper back (p = 0.051). VAS scores for the left and

Table 7.1: Classification ΔVAS, percentage of subjects

	Neck	Left shoulder	Right shoulder	Upper back
ΔVAS ≥ 13	**55**	**18**	**64**	**55**
0 < ΔVAS < 13	36	46	9	18
-13 < ΔVAS < 0	0	9	9	9
ΔVAS ≤ -13	**9**	**27**	**18**	**18**

right shoulder did not significantly change after 4-weeks of myofeedback training ($p = 0.95$; $p = 0.17$ respectively).

Table 7.1 presents the relative number of subjects in each class of ΔVAS (T1 minus T2) for each body region. Clinically relevant effects of myofeedback training (ΔVAS > 13 mm) were found in 64% (right shoulder), 55% (neck and upper back), and 18% of the subjects (left shoulder). Between 9% and 27% of the subjects showed a clinically relevant increased level of pain intensity after four weeks of myofeedback training. Visual inspection of the data showed that subjects with an increased level of pain intensity for one body region were also likely to show an increased level of pain intensity in other body regions.

Disability

The median NDI score changed from 21 at T1 to 19 at T2. Although not significant ($p = 0.06$) this decrease can be considered an interesting trend, indicating a lower level of subjectively experienced disability after four weeks of myofeedback training. Inspection of changes in scores at individual items of the NDI showed a significant decrease in the experienced level of disability resulting from headaches ($p = 0.02$) and a trend for reduced disability when lifting weights ($p = 0.06$). Scores at other items of the NDI were not significantly altered between T1 and T2 (p between 0.16 and 0.66).

Seventy-three percent of the subjects showed a decrease in the experienced level of disability as assessed by the absolute NDI score; in 36% of the subjects this difference was clinically relevant. On the opposite, 27% of the patients reported an increase in disability but this was not clinically relevant in any subject.

Muscle activation patterns

RMS

Figure 7.2 shows the course of normalised RMS values at T1 and T2 during rest, typing, and stress tasks for the right and left trapezius muscles. After 4 weeks myofeedback training, median RMS values were lower compared to T1. This was statistically significant for the rest measurements after the typing task (Rest 2) for the right ($p < 0.01$) and left trapezius muscle ($p < 0.01$). In addition at the left trapezius muscle, the non-dominant side, RMS values were significantly reduced during the typing task ($p = 0.01$) and after the stress task (Rest 4; $p = 0.02$). No differences were found for the other tasks (p varied between 0.05 – 0.66).

Figure 7.3 classifies ΔRMS of the right and left trapezius during the typing and stress tasks. The percentage of epochs showing an improvement (i.e. ΔRMS > 5) is especially evident during the stress task for the right trapezius and the typing task for the left trapezius muscle.

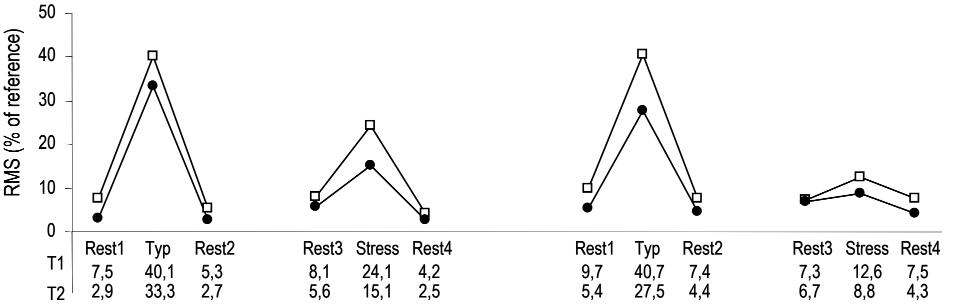

Figure 7.2: Median RMS (Root Mean Square) values of the right and left upper trapezius muscles prior to (T1; -□-) and after four weeks of myofeedback training (T2; -●-), during rest, typing and stress tasks

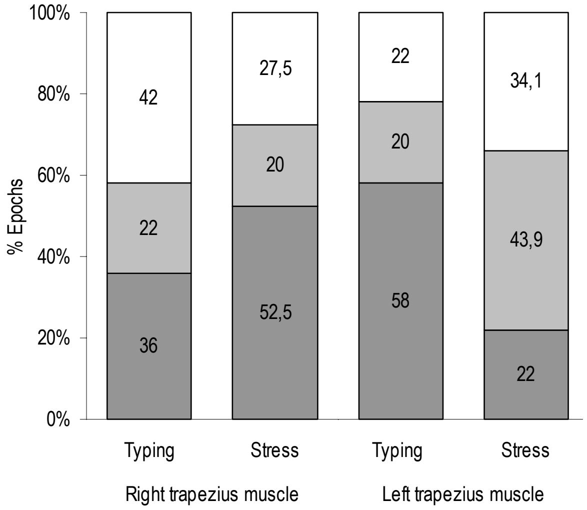

Figure 7.3: Percentage of epochs showing a clinically relevant improvement (lower part of bar), equal (middle), or clinically relevant deterioration (upper) in RMS (Root Mean Square)

RRT

The effect of myofeedback training on muscle relaxation patterns of the upper trapezius muscle was especially evident during the rest measurements. A typical pattern of RRT recorded during Rest 2 (directly after the typing task) at T1 and T2 is presented in Figure 7.4. This figure shows that at T1 a substantial part (± 40%) of the recorded epochs presented RRT values of 0 or close to 0. At T2, in contrast, no RRT values of 0 were found any more: All epochs showed RRT values ≥ 40%. For the rest measurement after the typing task (Rest 2), this difference between T1 and T2 was significant for the right trapezius and the left trapezius muscles ($p < 0.01$; $p < 0.01$). In addition, this difference was significant during the

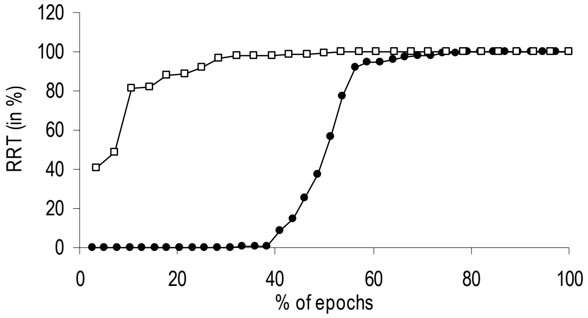

Figure 7.4: Cumulative representation of RRT (Relative Rest Time) values prior to (T1; -□-) and after four weeks of myofeedback training (T2; -●-), per % of epochs during Rest 2

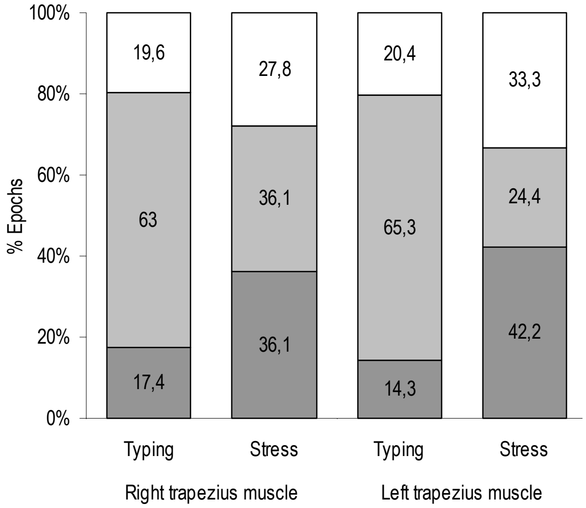

Figure 7.5: Percentage of epochs showing a clinically relevant improvement (lower part of bar), equal (middle), or a clinically relevant deterioration (upper) in RRT (Relative Rest Time)

rest measurement after the stress task (Rest 4) for the left trapezius muscle, i.e. the non-dominant side ($p < 0.01$). No differences were found for the other tasks (p varied between 0.10 – 0.99).

Classification of ΔRRT epochs during typing and stress tasks into improved, equal, or deteriorated showed that improvement ($\Delta RRT < -5$) was especially evident during the stress task for the right and left trapezius muscles (see Figure 7.5).

Discussion

The results of this explorative study on applying ambulant Cinderella-based myofeedback training in chronic WAD patients indicate a clinically relevant decrease in pain in a substantial number of the subjects. Sixty-four percent of the subjects reported a clinically relevant decrease of pain in the right shoulder, 55% in the neck and upper back, and 18% of the subjects reported clinically relevant decreases in the left shoulder. In line with these findings, 73% of the subjects reported lower levels of disability, which was clinically meaningful in 36% of the subjects. Subjects were less disabled due to headaches or when lifting weights. In general muscle activation was lower and relaxation levels were higher at T2 compared to T1 and this was especially evident during the rest measurements after tasks.

Hermens and Hutten[17] used an identical Cinderella-based myofeedback device as was used in the current study, with a comparable study design in patients with work-related neck-shoulder pain. Results showed a relevant decrease in pain intensity in the neck and shoulder region in 59% of the subjects, similar to the results of the present study for the neck and right shoulder, but considerably higher for the left shoulder compared to the present study. Although a different cut-off point was used in the study of Hermens and Hutten[17] (i.e. 10 mm) compared to the present study (i.e. 13 mm), this does not provide an explanation for this discrepancy in improvement of pain for the left shoulder. The discrepancy is more likely to be caused by the floor effect: In the present study seven subjects showed initial values below 10 mm, which suggests a low pain intensity level in this body region[31], and this makes clinically relevant improvement in these subjects impossible.

The effect of biofeedback on disability has not yet been investigated in WAD patients but in chronic low back pain patients Newton-John et al.[18] were able to demonstrate a significant decrease in self-perceived disability due to biofeedback training. In the present study, a trend was found for a decreased level of disability with a significant reduction in disability experienced related to headaches. This finding is in line with results described by King[32] in which feedback on trapezius muscle activation appeared to be effective in reducing tension headaches. A decrease of disability due to headaches is highly important since neck pain combined with headaches is the most commonly experienced complaint in chronic WAD patients[33].

Hoving et al.[34] raised the question whether the NDI represented the full spectrum of experienced disabilities relevant to the WAD population. Using a problem elicitation technique, it appeared that the NDI assesses only some items, i.e. work, driving, and sleeping, while especially social and emotional factors were not assessed, for instance depression, participation in sports, or socialize with friends were more important in the subjectively experienced level of disability in WAD patients. It would be useful to investigate changes in these items due to myofeedback training as well.

In patients with work-related neck-shoulder pain Cinderella-based myofeedback training resulted in decreased activation levels and increased relaxation levels of the trapezius muscles[17]. The results of the present study show generally comparable effects in WAD patients which implies that myofeedback training may normalize the pathological hyper-reactivity of the trapezius muscles in WAD patients as was found both during as well as after (low) biomechanical tasks[9 11 35 7]. Furthermore, an increase in muscle relaxation may contribute to a reduction in pain[14-16 21]. Normalisation of muscle activation patterns was not only found on the dominant side which is usually the most active side, but also on the non-dominant side.

An important difference between the results of the current study and the study of Hermens and Hutten[17] is that in WAD patients changes in muscle activation patterns were less evident during the typing and stress tasks compared to the WMSD patients, i.e. the largest differences in the WAD group were found during the rest measurements. This was also reflected in a difference in the percentage of subjects classified into 'improved', 'equal', or 'deteriorated' during the typing and stress tasks between the two studies. An explanation for this discrepancy may be related to the environment in which the myofeedback training was performed. In the study of Hermens and Hutten[17], the myofeedback training was mainly applied during relatively low-demanding (computer) work with regard to trapezius muscle activity, while the WAD patients in the present study were trained both during work (predominantly not computer-related, if employed) as well as activities of daily living that could require various intensities of trapezius muscle activation. It is not unlikely that WMSD patients were more capable of transferring relaxation skills acquired during the training at work to computer-related activities in the laboratory.

Results of the present study indicate that myofeedback training may be beneficial with regard to pain intensity, disability, and muscle activation patterns in the majority of WAD patients. However, a few patients adversely showed an increase in pain intensity and it appeared that these subjects also showed an increased level of pain intensity in other body regions, together with an increased level of disability. This finding was less consistent for muscle activation patterns. An explanation for this deterioration could be hypersensitivity to sensory stimulation resulting in increased responsiveness to this stimulation[36 37]. The pressure of the harness on the skin overlying the shoulder muscles is minimal, but hypersensitive subjects may negatively react on this sensory stimulation expressed in increased pain intensity. From a cognitive-behavioural perspective, some subjects may interpret this continuous myofeedback training as an endorsement of their complaints, reflected in a (emotional) focus on their pain perception. This focus may have a detrimental effect on the subjective experience of pain[38]. Future studies may aim at further exploring the relation between cognitive-behavioural characteristics and the effects of myofeedback training. This knowledge could contribute to optimalisation of the myofeedback training as well as the pain rehabilitation program of subjects with the Whiplash Associated Disorder.

The small subject population and the absence of a control group have affected the internal validity of this explorative study focused on changes induced by myofeedback training on pain, disability, and muscle activation patterns in WAD patients. With this study design, it can not be derived from the results whether the changes in pain, disability, and muscle activation patterns are due to the intervention or that these have been caused by other factors, like physiotherapy. The interference of this therapy with changes in pain and disability after myofeedback training is considered to be limited, as the patient population involved was stable with regard to medical condition and pain intensity and disability. To unravel the net effect of myofeedback it is recommended to perform a randomised controlled trial with a larger subject sample. To reach statistical significant changes in pain intensity and disability, power-analysis using the current data as starting point indicated that at least 22 subjects should be included (power 0.8, alpha 0.05). As initial VAS scores for the left shoulder were low and changes were small, the number of patients, needed to achieve statistical significant changes in this body region would need to be considerably larger.

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Chapter 8

General Discussion and Conclusions

General Discussion

Musculoskeletal neck-shoulder complaints constitute a problem of considerable proportion throughout the Western world as it affects functioning and quality of life[1]. By and large, these complaints are difficult to measure[2]. Most models explaining development and persistence of musculoskeletal neck-shoulder complaints ascribe a substantial role to abnormal activation patterns of the upper trapezius muscles. The Cinderella-hypothesis of Hägg[3] is the leading hypothesis specifically to explain trapezius myalgia in relatively low biomechanical load conditions in subjects with (computer) work-related neck-shoulder complaints. Lack of complete muscle relaxation during a long period of time is considered an important determinant of developing trapezius myalgia under these circumstances. Taking the Cinderella-hypothesis as a theoretical foundation, nourished by substantial experimental evidence, the idea originated that normalization of muscle activation patterns and especially increasing muscle relaxation would contribute to recovery and a reduction of pain intensity and disability. This idea was the starting point for the development of a new myofeedback intervention approach: ambulant Cinderella-based myofeedback training, which aims at increasing muscle relaxation. Because the training can be provided ambulant, it is applied with high intensity during activities of the subjects daily living[4].
The primary aim of this thesis was to obtain insight into the effects and mechanisms of this myofeedback intervention in subjects with persistent musculoskeletal neck-shoulder pain, especially focusing on work-related complaints but also pilot testing was performed in subjects with complaints related to WAD. For this purpose four studies were designed and performed. In this final chapter, main findings of these studies are integrated, and evaluated in the context of the existing literature.

Effects of ambulant myofeedback training: The relevance of muscle activation patterns, cognitions, and behavioural characteristics

Effects on pain intensity and disability

The self-reported levels of neck-shoulder pain intensity and disability were substantially reduced after four weeks Cinderella-based ambulant myofeedback training, whether or not combined with a conventional intervention (Chapters 3 and 7 respectively). About 50% of the subjects who received the myofeedback training reported a clinically relevant reduction in pain intensity immediately after the training, independent from whether complaints originated from work or a trauma (WAD), and at 6 months follow-up still about 40% of the subjects with work-related complaints reported a clinically relevant reduction. These numbers support the results of the first prognostic cohort study of Hermens and Hutten[4]. For disability comparable results as for pain intensity were reported, with 36% – 45% of the subjects showing clinically relevant improvements immediately after myofeedback training, with effects in an even larger proportion, i.e. 50%, at six months follow up in the subjects with work-related complaints. These changes in pain intensity and disability after myofeedback training appear somewhat larger compared to the results of other interventions or pain programs. Mes[5] for instance, evaluated the effectiveness of a multidisciplinary cognitive-behavioural program for chronic pain treatment and showed that immediately after the therapy about 37% of the subjects had clinically relevantly improved in pain intensity (assessed with the VAS of McGill Pain Questionnaire) while at three months follow-up about 41% showed improvements. It should be noted here that the duration of treatment in Mes' study was twice as long as compared to the myofeedback intervention applied in the present thesis.

The positive effects of Cinderella-based ambulant myofeedback training on pain intensity seem to be in agreement with findings of earlier studies in which a traditional myofeedback approach was applied(e.g.[6-9]). It would be of interest to compare effect sizes between these two feedback approaches because the theoretical concepts are quite different. In addition, the present myofeedback intervention is more intensive due to its ambulatory nature and applied in the normal environment of the subject which potentially increases its benefits. A direct comparison however appeared not feasible because of the use of different outcome measures. Furthermore the studies reporting on traditional myofeedback did not present results on improvement in terms of clinical relevance at the individual level but relied mainly on the statistical significance of changes in outcome scores. A statistically significant change in outcome on the group level does not necessarily relate to a change in the individual score that the patient or the clinician would mark relevant. Literature on what size of improvement reflects clinical relevance is emerging during the last years and cutoff points for relevant changes are quite well investigated for the Visual Analogue Scale and numerical rating scales (e.g.[10] [11]). There is some variation among studies concerning the cutoff points that are recommended for use, and this is largely dependent on the approach that is used to calculate these cutoff points (i.e. anchor- or distribution-based) [12]. Future research need to prioritize this topic: A consistent and reliable use is highly advisable in studies on the effectiveness of interventions because this will enhance the clinical relevance of these studies and their mutual comparability[13].

It was anticipated that combining myofeedback training with an existing intervention for work-related neck-shoulder complaints, i.e. ergonomic counselling, would be more effective than ergonomic counselling alone[14] (Chapter 3). However, mean reductions in pain intensity and disability and the proportion of subjects improving were comparable between the two intervention groups. The ergonomic counselling intervention appeared more effective than anticipated and herewith the contrast with outcome after the myofeedback intervention was small. One explanation for the unexpectedly large effect of ergonomic counselling is that the focus on muscle relaxation and regular breaks in the myofeedback group might have been transferred to the ergonomic counselling group, because the therapist was not blinded for the intervention. This focus on relaxation may have had positive effects on complaints in the group receiving ergonomic counselling only (see also van den Heuvel et al.[15]) and herewith the contrast between the two interventions was probably reduced. This contrast was furthermore affected by the effect of attention of the therapist, which was present in both groups and could have contributed to favourable outcome in both intervention groups[16]. Finally, the between-group comparison was hampered by the inequality of baseline values despite randomization. Especially the unexpectedly low level of pain intensity and disability in both the myofeedback and the ergonomic counselling groups incorporated a potential risk for floor effects that might have masked a difference in effect between the groups.

It should be noted that a small number of subjects deteriorated after the myofeedback training in terms of pain intensity, both in the WAD group (about 18%) (Chapter 7) and in the group of subjects with work-related complaints (3%, unpublished results from data reported in Chapter 3) in which myofeedback was combined with ergonomic counselling. Hypersensitivity of nociceptive pathways[17], as commonly found in chronic pain or an increased focus on pain perception[18] can be possible explanations. Hypersensitivity, or hyperalgesia, is easily measured by palpation or using a pressure algometer. Performance of this simple test before assignment of subjects to myofeedback is thus recommended to prevent from adverse outcome after myofeedback training.

The percentage of subjects in the ergonomic counselling group deteriorating in terms of pain intensity was considerably larger at 3 and 6 months follow-up compared to the subjects receiving combined myofeedback training and ergonomic counselling (i.e. 10% and 13% in the ergonomic counselling group compared to 0% and 0% in the myofeedback group) (data from Chapter 3, not explicitly reported). Thus, although the combined intervention with myofeedback and ergonomic counselling does not contribute to further improvement compared to ergonomic counselling alone, at least it seems to prevent subjects from deteriorating and as such it might be a valuable tool for tertiary prevention.

The relevance of (ab)normal muscle activation patterns

It was anticipated that muscle activation patterns of the upper trapezius muscle would be different between healthy subjects and subjects with neck-shoulder complaints, and that 'normalizing' these activation patterns would contribute to reduced pain intensity and disability levels. The findings reported in the separate chapters of the current thesis do not ully support this. Muscle activation patterns were not clearly different between subjects with neck-shoulder complaints and healthy subjects (Chapter 6), and did not consistently change (Chapters 2, 4, and 7) after the myofeedback intervention. As such, alterations in muscle activation patterns were not related to changed pain and disability levels after myofeedback training (Chapter 4, unpublished results from data reported in Chapter 7).

What, then, might be the relevance of abnormal muscle activation patterns in (treating) musculoskeletal neck-shoulder complaints? Although there is considerable evidence supporting the Cinderella-hypothesis[19], there are also studies which were unable or only partially able[20] to prove reduced trapezius relaxation in subjects with neck-shoulder complaints. Similarly, both increased (pain-spasm-pain model[21]) and reduced[22-24] (pain-adaptation model[25]) trapezius muscle activation has been reported, which seems contradicting. These inconsistent findings may have been caused by the large between-subject variability that is often observed in muscle activation patterns[26 27 28]. This variability, also reported in Chapter 6, suggests the presence of subgroups. One possible classification of subgroups is related to the duration of complaints, being acute, subacute, or chronic. There is some experimental support indicating that changes in motor control strategies occur during the transition from acute to chronic complaints[22 24 29], with the pain-adaptation model being relevant in the acute stage of complaints as a guarding mechanism to prevent from damage and more pain, while in chronic complaints reflexive increased muscle activation occurs as a response to painful movement (pain-spasm-pain model). When and how such transition occurs is not clear. But when muscle activation patterns indeed differ dependent on the duration of complaints this can cause heterogeneity in the subject population and variability in outcome. Variability in muscle activation patterns within populations may furthermore occur due to subject-specific characteristics like individual responses to stress, interacting with muscle activation. Sjölander[30] concluded that disturbances in motor control in chronic neck pain patients rely very much upon the individual instead of being specific for a group of pain patients with similar diagnosis. This also corresponds to what could be expected from the avoidance-endurance model of Hasenbring[31]. According to this model subjects can overload or avoid behaviour expressed by possibly different muscle responses. However, whether indeed overload behaviour is characterised by different muscle activation patterns compared to avoidant behaviour, needs to be verified.

To be able to study changes in motor control in response to pain and in the chronification process, a longitudinal cohort study is required including non-symptomatic subjects at baseline. This study should include besides sEMG recordings also a complete set of questionnaires to observe cognitions and behavioural characteristics that could be relevant during this process.

Muscle activation patterns did not consistently change and were also not related to outcome after the myofeedback training. Outcome measures muscle activity (RMS) and muscle relaxation (RRT), assessed during short-duration computer tasks in the laboratory might have been too generic to detect subtle differences and thus maybe other outcome measures or measurement methods quantifying muscle activation patterns should be considered. One suggested outcome measure is for instance muscular sensitivity[8]. Increased sensitivity after myofeedback means that subjects have a better perception of their muscle activation levels, and as a result they may be more capable of detecting an absence in muscle relaxation. The occurrence of dysfunctional muscle activation patterns would then become less frequent, and this might serve as a protective condition for recurrence or aggravation of complaints. An alternative method to assess the characteristics of the muscle activation patterns is sEMG recording with multi-channel array-electrodes, which enables a more detailed look at the action potentials of the muscle rather than the global RMS and RRT parameters. The study of Kallenberg and Hermens[32] indeed suggest that this method, especially the number of motor unit action potentials per second and the median frequency of these potentials are more discriminative between subjects with and without complaints. A major advantage of this method is furthermore that it provides outcome measures which are independent from individual properties like the subcutaneous fat layer[32]. These specific qualities are an impetus for future research on the relation between complaints and abnormal motor control.

The relevance of cognitions and behavioural characteristics

The hypothesis of 'temporal dislocation' of Cram[33] offers another explanation for the absent relation between muscle activation patterns and pain intensity of disability: There is an extended time lag between the onset of / change in pain and abnormal muscle activity levels, and the reduction in pain intensity that is usually immediately seen after myofeedback training is primarily resulting from changes in cognitions and behaviour. This reasoning is supported by findings of Hermens and Hutten[34] and those of the current thesis (Chapter 4): Decreased catastrophizing and fear-avoidance beliefs about work were associated with improved pain and disability levels. Several authors mentioned these factors also in relation to other intervention programs[35 36], representing a rather generic mechanism for pain and disability reduction in musculoskeletal complaints after interventions[37]. It can thus be hypothesized that the effectiveness of myofeedback training is largely explained by changes in cognitions and behavioural characteristics and that alterations in muscle activation patterns are no essential conditions for improvement. Catastrophizing and fear-avoidance beliefs are relevant in the persistence of musculoskeletal pain as described by cognitive-behavioural models, like the fear-avoidance model of Vlaeyen[38 39] and the avoidance-endurance model of Hasenbring[31] as introduced in the first chapter of this thesis. According to these models, catastrophizing is related to pain-related fear and avoidance behaviour which in turn affects disability and pain intensity. Myofeedback training may thus well seize at prominent components of these models and disrupt or at least affect the vicious circle of cognitions and behaviour. The changes in cognitions and behavioural characteristics after myofeedback (combined with ergonomic counselling) could be ascribed to the fact that the focus of the intervention was on how the subject *herself* could reduce the complaints in an active way, by improving muscle relaxation and changing work posture for instance. However, judgments with regard to causality can not be justified based on the current results as it could not be derived from the data whether the changes in pain and disability preceded or followed changes in cognitions and behavioural characteristics. For this purpose observations need to be done with short intervals during the intervention period as well.

The findings indicating the relevance of catastrophizing and fear-avoidance beliefs about work stem from the group of subjects with work-related neck-shoulder complaints. In this group, baseline values of maladaptive cognitions and coping strategies were low but still improvement was related to better outcome after the intervention. It is reasonable to assume that maladaptive cognitions and coping strategies are more common and pronounced in subjects with WAD. This suggests that intervention-induced changes in cognitions and behavioural factors in the WAD population could even be broader than just catastrophizing and fear-avoidance beliefs. For more insight into the working mechanism and potential prognostic factors, it thus needs to be investigated which cognitions, coping strategies and behavioural characteristics underlie outcome after myofeedback in WAD patients.

In the search for prognostic factors and process factors for outcome after myofeedback training a considerable amount of variance was left unexplained. This implies that except from catastrophizing and fear-avoidance beliefs, the factors investigated are not that relevant in subjects with work-related neck-shoulder complaints and that other factors influence the outcome of the intervention. Catastrophizing and fear-avoidance beliefs are key components of the fear-avoidance and avoidance endurance models, but until recently the models were predominantly validated in subjects with lower back pain[38 40] rather than neck-shoulder complaints. So what is known about the relevance of these constructs in the latter population? George et al. [41] explored fear-avoidance beliefs in subjects with non-traumatic work-related complaints and showed that these beliefs are comparable between patients with cervical and lumbar spine complaints. Fritz and colleagues[42] later confirmed these findings and demonstrated the presence of fear-avoidance beliefs in work-related musculoskeletal complaints. From this starting point Huis in't Veld and colleagues[43] made a first attempt to validate the fear-avoidance model in subjects with work-related neck-shoulder pain, in a subject sample highly comparable to those recruited for this thesis. The results confirmed the maladaptive role of pain-related fear in disability, and furthermore indicated that fear-avoidance beliefs affect disability regardless of the physical impairments (expressed as the maximum voluntary contraction) of the subject. These results indicate that occupational interventions need to focus on maladaptive coping strategies and fear rather than focusing on physical performance[43], which actually are the factors involved in myofeedback training and ergonomic counselling.

The challenge is now to find other factors that add to the explained variance of outcome after the myofeedback intervention. For effective interventions it is necessary to consider factors that promote behavioural change[44]. In this thesis, this behavioural change is required to improve muscle relaxation and to comply with the ergonomic advices during myofeedback training and ergonomic counselling. If one is not ready or willing to change, the effectiveness of the intervention is suboptimal. For understanding these behavioural determinants social-cognitive models have been developed[45]. A leading model in this field is the ASE-model[46], Attitude – Social support – self-Efficacy, that originated from the Theory of Reasoned Action[47] and the Social Cognitive Theory of Bandura[48]. The ASE components together ascertain behavioural intention, which can be staged according to the Stages of Change construct of the Transtheoretical Model[49]. Subjects are either pre-contemplating (not ready to change in the future), contemplating (intending to change but not quite soon), preparing (intending to change within the next month), performing (recent change of behaviour), or maintaining (changed behaviour for at least 6 months). The information that is provided to the subjects should be tuned to the stage they are in for optimal effect.

Translating these models to the current interventions and desired behavioural changes, it is reasonable to assume that because subjects participated voluntarily they were at least in the contemplation or preparation phase to undertake action for reducing complaints although not necessarily for myofeedback training or ergonomic counselling. The myofeedback intervention was more demanding than the ergonomic counselling only intervention. Therefore a larger readiness to change, to fulfil and continue behavioural changes induced by the intervention, was required for myofeedback training. The relevance of this statement is probably reflected in the larger number of subjects who dropped out during myofeedback (n = 5) compared to ergonomic counselling (n = 2). Assessment of the 'stage of change' subjects were in at baseline may thus be an important prognostic factor for outcome. A useful tool for this purpose is the Pain Stages of Change Questionnaire (PSOCQ) developed by Kerns in 1997[50]. Pretreatment stage and changes in stages during treatment indeed appeared to be valuable predictor and process factors for outcome after multidisciplinary treatment of chronic pain patients[51].

Methodological considerations and implications for future research

Subject population

In contrast to the WAD patients, the subjects with work-related complaints were recruited using questionnaires and self-reported complaints without a clinical diagnosis. This self-reporting may have induced heterogeneity as was commented on in the first section of this chapter. One study indicated that the agreement between self-reported neck-shoulder complaints and a clinical diagnosis in computer workers is about 60%[52]. The principal diagnoses were trapezius myalgia, tension neck syndrome, and cervicalgia and it is likely that these diagnoses were also at hand in the current subject sample. While it was initially hypothesized that myofeedback training would be especially beneficial in subjects with pain related to increased muscle tone and insufficient relaxation, the results of the present thesis indicate that an abnormal muscle activation pattern at baseline is no prerequisite for positive outcome and that changes in cognitions and behavioural characteristics are more relevant for outcome after myofeedback. Therefore, it can be hypothesized that other subject populations with musculoskeletal neck-shoulder complaints may also benefit from the myofeedback intervention as described here. Especially patients with fibromyalgia[37] and low back pain may be considered, as catastrophizing and fear-avoidance beliefs have been ascribed a main role in these populations as well, but also abnormal muscle activation patterns have been observed in these patients[41] [53] [41] [54-57]. For the low back however, an implementation of ambulant myofeedback is more complicated due to the different physiological role and activation patterns of trunk muscles, so it will require a more intelligent feedback algorithm.

Myofeedback strategies

As stated in Chapters 1 and 2, the effectiveness of myofeedback training is dependent on the reinforcement schedule. Here, this schedule was defined by the interval chosen for feedback and the definition of insufficient relaxation dependent on the definition of complete muscle rest (in terms of duration and threshold). Based on the results of Chapter 2, an intermittent interval with a duration of about 10 seconds was selected. Continuous feedback, although it may result in a large initial physiological response[58], is less favourable for learning skills that need to proceed after the training period[59 60]. Besides that, continuous feedback could be too disturbing for subjects and might end in loss of productivity, loss of motivation, and negative effects of the feedback training. Even with the 10 seconds schedule, some subjects described the system as disturbing their work due to the feedback modality (vibration and sound) in combination with a high feedback frequency. Some subjects informally reported this to be the main reason to quit the study and drop out. It is also possible that the intriguing sound of the myofeedback system increased the arousal level during the training. As reported by Nideffer[61] and Wofford[62], an increased level of arousal can result in increased muscle tension and lack of concentration. These findings were further confirmed by van Dijk et al.[63], who showed that a high self-reported energy level, hypothesised to be translated in a high arousal level, prior to the myofeedback training was related to a smaller physiological change at the end of the learning phase, especially when negative reinforcement was used. Negative reinforcement implies that something undesired (e.g. the sound) is omitted when the desired behaviour (e.g. relaxation) is portrayed. It is often associated with delayed learning and smaller learning effects when compared to positive feedback (see e.g. [63]). The bottleneck with positive feedback in this current application is that when the subject is improving, i.e. shows more relaxation, the feedback would become too frequent which might be disturbing and intriguing as well. A profound search to optimal feedback strategies for this application is recommended.

The threshold used for muscle rest concerns an absolute threshold, which is somewhat deviating from existing literature (e.g.[20 26 27 64 65]), where percentages of the submaximal or maximal voluntary contraction were used for normalisation. This normalization is usually performed as it is assumed to contribute to reduced intersubject variability. There are a few disadvantages of using a normalized threshold. First of all, when considering complete muscle rest it is illogical to express this as a percentage of the maximum contraction level. Secondly, Hermens and Vollenbroek-Hutten[66] reported that this normalization does not significantly contribute to reduced variability. A practical disadvantage of a relative gap threshold is that it requires sEMG measurements being done prior to the start of the intervention, which is time consuming and costly as sEMG analysis software should be available in the clinical setting. Automated processes for this normalisation procedure are then required but difficult to develop and implement. Finally, and more generally, when abnormal motor control underlies musculoskeletal complaints the reference contraction[67] which is often used for normalisation is likely to be abnormal as well (see Chapter 6). Normalisation thus may decrease intersubject variability but it may also decrease the contrast between subjects with and without complaints considerably, and has as such methodological implications.

Applications in (occupational) research and clinical practice

One methodological problem in intervention research concerns compliance with for instance recommendations on proper work posture. The actual changes in working posture are hard to measure, and when directly observed it may be affected by subjects knowing themselves to be observed. To a certain extent ambulant myofeedback training may contribute to overcome this problem. Continuous, long-term sEMG storage during myofeedback allows in-detail discussion with the individual about performance of specific activities and adaptation of working posture. This could inherently reinforce compliance of the subjects to the intervention and learned behaviour. More generally, continuous monitoring it is highly informative and may constitute a good research tool evaluating the effectiveness of interventions on a muscular and behavioural level and also makes usually unobservable behaviour visible by showing the muscle activation patterns in relation to activities, either at work or in leisure time. This can give the therapist an indispensable supportive tool for deciding optimal performance of activities. Hägg and colleagues[68], while suggesting different analysis methods for sEMG in the occupational setting, note that sEMG assessment is a unique method to obtain insight in internal exposure. This is especially interesting to study the fit between individual and (work)task and its interaction with physiology.

Cost-effectiveness and remotely-supported myofeedback training

Musculoskeletal complaints are associated with loss of productivity, absenteeism and inactivity, and study results of a Swedish sample in long-term sick listed subjects in the public sector have shown that this is especially the case for neck, shoulders, and back complaints[69]. Hansson and Hansson[70] showed that costs associated with neck and back complaints corresponded to 1% of GNP, and that especially the indirect costs offer the largest opportunities for savings. About 60% of the subjects who returned to work after a 2 to 6 weeks period of sick leave due to musculoskeletal complaints reported loss of productivity of about 1.6 hours a day, both immediately after return to work and also at 1 year follow-up[71]. These costs can be classified as indirect costs, which is one of the three sources for total costs associated with complaints[72]. The other two categories are the direct medical costs (e.g. General Practitioner (GP) visits, prescribed medication and physiotherapy) and direct non-medical costs (costs that are not refunded by health insurance like out of pocket expenses, assistance from partner of relevant others, but also the use of alternative health care). Next to the clinical evaluation of the myofeedback training as reported in this thesis, it could be highly interesting to explore its cost-effectiveness relative to other interventions for neck-shoulder complaints. Both subjects and therapists reported that the myofeedback training gave them valuable insight in the pattern of complaints and activities. This may make that subjects feel less need to consult their GP or their company doctor in the near future for information on their complaints who as a consequence can prescribe less frequently medication. Reduced catastrophic thoughts appeared to be associated with reduced health care consumption in patients with temporomandibular disorder[73]. Relatively few cost-effectiveness evaluations have been performed so far for neck-shoulder interventions, but this way of evaluating interventions is receiving more attention recently[74] and results are more often used for developing and supporting health care policy.

The cost-effectiveness of myofeedback training may further be improved when the training is provided remotely supervised. Myofeedback data are then automatically sent to an external, secured server that can be accessed by the therapist and the patient. The weekly visits are replaced by an e-consult which reduces the travel time (direct non-medical cost). Due to the high costs for health care, remote monitoring methods are emerging for more and more interventions. The main question is not anymore whether it is technically feasible, but whether patients and therapists are receptive to it. A first explorative study has shown that especially patients see the benefits of the remote myofeedback training. Therapists are more reluctant but still about half of them has a positive attitude towards the remote alternative of the myofeedback intervention. An essential aspect that needs attention is the potential lack of non-verbal communication and physical interaction (in vivo contact) between patient and professional. Non-verbal communication is important in shaping, defining relationships between patients and professionals, and compliance, and future research thus needs to determine optimal remote communication modes allowing sufficient non-verbal communication[75].

Conclusions

Ambulant Cinderella-based myofeedback training is beneficial in reducing neck-shoulder pain and disability in subjects with complaints related to work or WAD, and potentially other subject populations may benefit from this intervention as well. Improvements, lasting up to six months after the training, are especially large in those subjects with work-related complaints who ignore their pain sensations. Although the combination of myofeedback with a traditional ergonomic counselling intervention for work-related complaints did not contribute to further improvement, it might add a specific quality to the tertiary prevention of neck-shoulder complaints and might also be more cost-effective when applied remotely. The working mechanism of myofeedback is not fully unravelled yet, but cognitive-behavioural factors are likely to be more important than muscle activation patterns. Additional research is recommended to further identify factors, like social-cognitive factors, related to positive outcome of myofeedback training.

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Summary

Persisting musculoskeletal complaints in the neck-shoulder region are highly prevalent and associated with high health care and community costs in industrialized countries. The mechanisms underlying the development and perpetuation of these complaints have not fully been identified yet, but explanatory models and hypotheses generally acknowledge a role for abnormal muscle activation patterns. The pain-spasm-pain and the pain-adaptation models ascribe an important role to abnormal muscle activation levels. However, the leading hypothesis from a physiological perspective is the Cinderella-hypothesis, which suggests that lack of complete muscle relaxation, rather than abnormal muscle activation levels, is relevant for developing and perpetuating complaints. The hypothesis has especially been investigated for (computer) work-related neck-shoulder complaints, in which contraction levels are relatively low but continuous over a long time frame. A purely physiological approach of musculoskeletal neck-shoulder complaints related to abnormal muscle activation patterns is according to the commonly adopted biopsychosocial approach not tenable. Within this approach the fear-avoidance and the avoidance-endurance models are relevant, describing the role of cognitions and behaviour in perpetuating pain and disability, and also indirectly addressing the reflected effects on muscle activation patterns. As such, normalisation of muscle activation patterns has been a starting point for developing an intervention strategy for treating musculoskeletal neck-shoulder pain. An appropriate method for this purpose may be ambulant myofeedback training based on the Cinderella-hypothesis, which provides feedback to the subject when muscle relaxation is insufficient. This feedback is anticipated to increase muscle relaxation levels contributing to recovery in terms of pain and disability, but likely other factors like cognitions and behavioural characteristics are important for outcome after myofeedback training as well. The ambulant Cinderella-based myofeedback approach is deviating from traditional feedback studies in that feedback is provided when the muscle is *insufficiently relaxed* rather than when muscle activation *exceeds a certain threshold*, and that it enables continuous monitoring. This makes it potentially more effective than traditional feedback approaches. This thesis aimed at evaluating the effects and mechanisms of ambulant Cinderella-based myofeedback training in subjects with persistent musculoskeletal neck-shoulder pain, focusing on subjects with neck-shoulder complaints related to work or Whiplash Associated Disorder (WAD).

Chapter 2 describes a multiple cross-over trial designed to optimise feedback strategies for learning relaxation of the upper trapezius muscles during Cinderella-based ambulant myofeedback. The effectiveness of three different feedback intervals (feedback provided after 5, 10, or 20 seconds) were evaluated during unilateral gross-motor task performance. sEMG of the dominant upper trapezius muscle was recorded from eighteen healthy subjects when the task was performed with and without the different feedback interval schedules to study baseline, learning relaxation, and extinction. The 10 seconds schedule showed slightly however non-significant favourable outcome values compared to the 5 and 20 seconds schedules as muscle relaxation reached the highest values during the learning phase.

Furthermore the 10 seconds schedule was unique in its ability to elevate muscular rest above the 20% level which may be considered relevant in the prevention and treatment of myalgia. The 10 seconds feedback interval was favoured and used in subsequent studies described in this thesis.

The chapters 3, 4, and 5 elaborate the evaluation of ambulant Cinderella-based myofeedback training in subjects with persisting work-related neck-shoulder complaints, in a randomised trial with two intervention groups: A conventional intervention for work-related complaints, i.e. ergonomic counselling (EC), and a combination of this ergonomic counselling with ambulant Cinderella-based myofeedback (Mfb). Both interventions are provided for 4 weeks with weekly visits from the therapist at the workplace.

Chapter 3 focuses on the effects of the interventions on pain intensity (Visual Analogue Scale, VAS) and disability (Pain Disability Index, PDI), and it was hypothesised that the combined Mfb intervention would be more effective than EC as Mfb focuses on both increasing muscle relaxation as well as on ergonomic factors. Seventy-nine subjects with work-related neck-shoulder complaints participated and measurements were performed before (B), immediately after (T0), and at 3 (T3) and 6 months follow up (T6). VAS and PDI were significantly reduced at T0 and at follow-up, without a difference between the two groups. About 45% of the subjects in the Mfb group reported a reduction in VAS of ≥ 13 mm, indicating a clinically relevant improvement, and for PDI about 50% of the subjects were clinically relevantly improved (change ≥ 7). These percentages were less favourable in the EC group (i.e. about 40% and 30%) but Odds Ratios controlled for confounding factors indicated that subjects in the Mfb group had the same 'chances' for improvement as subjects in the EC group. It was concluded that both Mfb and EC were beneficial for work-related neck-shoulder pain and disability in this study group and that the effects were comparable between the two groups.

Knowledge regarding the working mechanism of an intervention is essential and can be used to optimize the intervention itself. Therefore, changes in muscle activation patterns and cognitive-behavioural factors after Mfb and EC were evaluated and it was explored whether these changes were related to changes in VAS and PDI. This study is reported in **Chapter 4.** Upper trapezius muscle activation patterns were investigated during three computer tasks. Cognitive-behavioural factors were selected primarily based on low back pain literature and traditional myofeedback studies. Catastrophizing and observed pain control (subscales of the Coping Strategies Questionnaire, CSQ), and fear-avoidance beliefs regarding work or physical activity (assessed with the Fear-Avoidance Beliefs Questionnaire, FABQ) were evaluated. Muscle activation patterns did not show a clear trend for changes. Catastrophizing decreased and fear-avoidance beliefs about work slightly, but significantly, increased during the intervention period especially in the Mfb group probably due to the focus of the intervention on work. The application of mixed modelling techniques showed that the reductions in VAS and PDI were especially associated with reduced catastrophizing and that the changed fear-avoidance beliefs about work were positively associated with changes in disability, indicating that reduced fear-avoidance beliefs about work were reflected in reduced disability. The percentages explained variance were higher for changes in disability ($R^2 \geq 0.30$) compared to pain intensity ($R^2 \leq 0.14$). Other factors related to outcome need to be investigated as well in future research.

Identification of prognostic factors, factors having a predictive value regarding outcome of specific interventions, can serve the clinician in making decisions concerning the choice of, and the referral of subjects to, appropriate intervention programs. So far, prognostic factors have predominantly been investigated for chronic low back pain interventions but not for interventions focusing on neck-shoulder complaints. In **Chapter 5** this need is dealt with by describing the search for prognostic factors for Mfb and EC at T0 and T3 in a subset of 38 subjects with work-related neck-shoulder complaints. The focus was on sociodemographic and psychological (using the Multidimensional Pain Inventory, MPI)/ cognitive-behavioural (assessed with CSQ and FABQ) factors, selected primarily from low back pain literature. Multiple linear regression analyses indicated that changes in VAS and PDI at T0 and T3 were best predicted by VAS and PDI levels at baseline. Changes in PDI were larger in subjects with MPI profile 'interpersonally distressed' or 'dysfunctional' rather than the 'average' and 'adaptive copers', as in these subjects the intervention probably contributes to optimizing coping skills and reducing distress, which is related to better outcome. Furthermore, changes in PDI were predicted by coping strategy 'ignoring sensations': Subjects ignoring pain sensations appeared to benefit more from Mfb than from EC. A likely explanation for this finding is that myofeedback probably contributes to the acknowledgement of complaints and limitations which makes it easier to detect changes in pain and disability.

There is some support in medical literature suggesting that the abnormalities in muscle activation patterns in neck-shoulder pain patients are independent from the origin (e.g. work or trauma) of the complaints. To further explore this, upper trapezius muscle activation patterns were compared between subjects with neck-shoulder complaints related to work and subjects with complaints due to trauma (WAD), and it was hypothesized that these subjects would show lower muscle relaxation levels (in agreement with the Cinderella-hypothesis) and higher levels of activation (in agreement with the pain-spasm-pain model) compared to healthy controls. This study is presented in **Chapter 6**. Twenty healthy subjects, 21 subjects with work-related neck-shoulder complaints and 20 WAD patients participated in this cross-sectional study during which bilateral sEMG recordings of the upper trapezius muscle were performed during reference contractions, standardised computer tasks (typing and unilateral stress task), and rest measurements. Bootstrapping results indicated that in this particular study sample muscle activation patterns were comparable in both subject groups with neck-shoulder complaints, but that these patterns were not clearly deviant from the healthy control group. However, subjects with complaints showed larger variability in muscle relaxation and activation compared to healthy controls, suggesting the probable existence of subgroups.

Comparable muscle activation patterns among different groups of subjects with neck-shoulder complaints as presented in Chapter 6 suggests that the effects of ambulant Cinderella-based myofeedback training observed in subjects with work-related complaints is generalisable to subjects with neck-shoulder pain related to WAD. In **Chapter 7** the effect of myofeedback training on pain (VAS), disability (Neck Disability Index, NDI), and muscle activation patterns (sEMG) in 11 WAD patients is presented. VAS was decreased, clinically relevant in 55% of the subjects for the neck-upper back region, and 64% and 18% for the right and left shoulders. A trend for decreased NDI was found which appeared clinically relevant in 36% of the subjects, especially with regard to lifting weights and headaches. Overall, muscle activation was lower and muscle relaxation was higher after the intervention with the largest differences during rest, but clinically relevant changes in muscle activation patterns were found in a minority of patients only. Ambulant myofeedback training may thus be beneficial in reducing pain and disability levels and normalizing muscle activation patterns in chronic WAD patients, but further research is needed to obtain insight into the effects and mechanisms in this specific subject population.

In the final chapter (**Chapter 8**), the findings of the different studies presented in this thesis are integrated and discussed, reflected with literature and existing models and theories. It was concluded that ambulant Cinderella-based myofeedback training is beneficial in reducing neck-shoulder pain and disability in subjects with complaints related to work or WAD, and potentially other subject populations may benefit from this intervention as well. Improvements, lasting up to six months after the training, are especially large in those subjects with work-related complaints who ignore their pain sensations. Although the combination of myofeedback with a traditional ergonomic counselling intervention for work-related complaints did not contribute to further improvement, it might add a specific quality to prevent from further deterioration of complaints at follow-up. Furthermore, it might especially be favourable in terms of cost-effectiveness when applied remotely. The working mechanism of myofeedback is not fully identified yet, but cognitions and behavioural characteristics are likely more important than muscle activation patterns. Additional research into the identification of other factors, like social-cognitive factors, that are related to outcome after myofeedback training is recommended.

Samenvatting

Aanhoudende klachten aan het houding- en bewegingsapparaat in de nek-schouderregio kennen een hoge prevalentie en worden geassocieerd met hoge kosten voor de maatschappij. Het mechanisme dat ten grondslag ligt aan het ontstaan en instandhouden van deze klachten is nog niet duidelijk, maar in de diverse modellen en hypothesen, beschreven in de literatuur, spelen abnormale spieractivatiepatronen een belangrijk rol. De meest prominente, fysiologisch georiënteerde, verklaring voor het ontstaan en in stand houden van nek-schouderklachten wordt gegeven door de Cinderellahypothese. Deze hypothese veronderstelt dat niet zozeer hoge *spieractivatie*niveaus relevant zijn, maar dat onvoldoende *spierrelaxatie* belangrijk is in de pathogenese en persistentie van nek-schouder klachten. Onderzoek naar de relatie tussen onvoldoende spierrelaxatie en het voorkomen van nek-schouderklachten bij mensen die laag-intensief, monotoon werk uitvoerden, leverde empirische steun voor deze hypothese. Een puur fysiologische benadering van nek-schouderklachten ten gevolge van abnormale spieractivatiepatronen is echter volgens het algemeen aangenomen biopsychosociale model niet houdbaar. Vanuit deze benadering zijn het fear-avoidance- en het avoidance-endurancemodel belangrijk. Deze modellen beschrijven cognitief-gedragsmatige factoren welke een belangrijke rol spelen bij de ontwikkeling en het in stand houden van klachten en dat afhankelijk van deze factoren effecten op fysiologisch niveau, inclusief spierniveau, tot uiting komen.
Op basis van het hierboven geschetste perspectief van abnormale spieractivatiepatronen bij mensen met nek-schouderklachten vormt normalisatie van deze patronen een belangrijk uitgangspunt bij de behandeling. Een mogelijk geschikte behandelstrategie hiervoor is myofeedbacktraining. Tijdens traditionele myofeedbacktrainingen, aangeboden in sessies van maximaal enkele tientallen minuten, wordt feedback gegeven wanneer spieractivatie een bepaald niveau overschrijdt. Volgens de Cinderellahypothese is echter spierrelaxatie een belangrijker determinant van klachten. Daarom is een nieuwe, ambulante myofeedbacktraining gebaseerd op deze hypothese ontwikkeld, waarbij bij onvoldoende ontspanning van één der beide m.trapezius p.descendens feedback gegeven wordt aan de drager. Omdat het systeem geheel ambulant is, kan de training met een hogere intensiteit aangeboden worden dan de traditionele trainingen en is ook daardoor potentieel effectiever.
In dit proefschrift worden enkele studies beschreven aan de hand waarvan de effecten en mechanismen van deze nieuwe ambulante myofeedbacktraining gebaseerd op de Cinderella-hypothese onderzocht worden op klachten aan het houding- en bewegingsapparaat in de nek-schouderregio. De nadruk ligt hierbij op klachten gerelateerd aan (beeldscherm)werk, hoewel ook klachten na een trauma (Whiplash Associated Disorder, WAD) bestudeerd worden.

Hoofdstuk 2 beschrijft een multipele cross-overtrial waarin onderzocht wordt wat het optimale interval is waarover feedback gegeven moet worden teneinde optimale resultaten te verkrijgen in de zin van spierrelaxatie. Hiertoe zijn drie tijdsintervallen van verschillende duur onderzocht, namelijk 5, 10 en 20 seconden. Oppervlakte electromyografie (sEMG) van de m. trapezius p.descendens aan de dominante zijde werd gemeten bij 18 gezonde proefpersonen tijdens een grof-motorische taak welke zowel met als zonder feedback werd uitgevoerd om baseline, de leercurve en extinctie van het geleerde te bestuderen. Elke proefpersoon nam deel aan metingen op drie verschillende dagen, met op elke dag een ander feedback-intervalschema waaraan zij random toegewezen waren. Hoewel de verschillen tussen de drie intervalschema's niet statistisch significant waren, resulteerde het tiensecondenschema in het hoogste ontspanningsniveau, waarbij tevens de grens van 20% overschreden werd. Spierontspanning met een relatieve duur van meer dan 20% van een interval werkt mogelijk beschermend voor het ontstaan van klachten. Om deze redenen is het tiensecondenschema dan ook toegepast in de volgende studies van dit proefschrift.

De hoofdstukken 3, 4 en 5 gaan uitgebreid in op de effectevaluatie van de ambulante myofeedbackbehandeling bij mensen met (beeldscherm)werkgerelateerde nek-schouderklachten. In een gerandomiseerde trial zijn hiertoe twee interventies vergeleken: een conventionele interventie gericht op ergonomische consultatie alleen (EC) en een combinatie van deze ergonomische consultatie met de ambulante myofeedbackbehandeling gebaseerd op de Cinderellahypothese (Mfb). Beide interventies duurden vier weken. In **Hoofdstuk 3** wordt het effect van EC en Mfb op pijnintensiteit (gemeten met de Visueel Analoge Schaal, VAS) en beperkingen (gemeten met Pain Disability Index, PDI) beschreven. Verondersteld werd dat pijn en beperkingen meer zouden afnemen na Mfb dan na EC, omdat Mfb op meerdere aspecten aangrijpt; zowel spierontspanning alsmede de ergonomische inrichting van de werkplek. Negenenzeventig mensen met werkgerelateerde nek-schouderklachten namen deel aan het onderzoek waarbij VAS en PDI op vier momenten gemeten werden: op baseline (B), meteen na 4 weken interventie (T0) en op 3 (T3) en 6 maanden (T6) follow-up. VAS en PDI scores waren aanzienlijk lager op T0, T3 en T6 dan op B, maar er waren geen verschillen tussen beide interventiegroepen. De reductie in VAS was klinisch relevant (d.w.z. een reductie van tenminste 13 mm) in ongeveer 45% en de reductie in PDI was klinisch relevant (d.w.z. een reductie van tenminste 7 punten) in ongeveer 50% van de mensen in de Mfb groep. In de EC groep lagen deze percentages iets lager (ongeveer 40% en 30% respectievelijk), maar gecorrigeerde odds ratio's toonden gelijke 'kansen' voor klinisch relevante afname van pijn en beperkingen voor Mfb en EC.

Hoewel beide interventies een vergelijkbaar effect lijken te sorteren zou het werkingsmechanisme wellicht verschillend kunnen zijn. Inzicht in deze werkingsmechanismen is essentieel voor optimalisatie van de interventies. Hiertoe zijn in **Hoofdstuk 4** veranderingen in spieractivatiepatronen en cognitief-gedragsmatige factoren na de interventies onderzocht, inclusief de associatie met veranderingen in pijn en beperkingen. Spieractivatiepatronen van de m.trapezius p.descendens werden gemeten tijdens drie verschillende computertaken. De relevante cognitief-gedragsmatige factoren die in kaart gebracht werden zijn: catastroferen, waargenomen controle (subschalen van de Coping Strategies Questionnaire, CSQ) en fear-avoidance beliefs (Fear-Avoidance Beliefs Questionnaire, FABQ). De resultaten suggereerden dat na beide interventies (op T0 en T3) spieractivatiepatronen niet veranderd waren ten opzichte van B. Catastroferen daarentegen nam significant af terwijl fear-avoidance beliefs met betrekking tot werk gering, doch significant, toenamen, met name in de Mfb- groep. De afname in VAS en PDI was geassocieerd met een afname in catastroferen, terwijl de afname in PDI op T3 additioneel samenhing met een reductie in fear-avoidance beliefs met betrekking tot werk. De percentages verklaarde variantie waren hoger voor veranderingen in PDI ($R^2 \geq .3$) dan voor VAS ($R^2 \leq .14$). Toekomstig onderzoek dient zich te richten op het verder ontrafelen van het werkingsmechanisme van beide interventies.

Inzicht in prognostische factoren, factoren gemeten bij aanvang van de behandeling welke een voorspellende waarde hebben met betrekking tot de uitkomst, stelt de behandelaar in staat een meer adequaat beleid te voeren ten aanzien van toewijzing van patiënten aan specifieke behandelprogramma's. Deze factoren zijn met name in kaart gebracht voor behandelingen voor chronisch lage rugklachten en niet voor de behandeling van nek-schouderklachten. In **Hoofdstuk 5** wordt een exploratieve studie beschreven ter identificatie van prognostische factoren voor uitkomst (VAS en PDI) na Mfb en EC in een subgroep van 38 mensen met werkgerelateerde klachten. Om sociodemografische, psychologische en cognitief-gedragsmatige factoren in kaart te brengen werden o.a. de Multidimensional Pain Inventory (MPI), CSQ en FABQ gebruikt. Veranderingen in VAS en PDI op T0 en T3 ten opzichte van B bleken het best voorspeld te worden door baseline waarden. Daarnaast waren verbeteringen in PDI met name evident bij mensen met een specifiek MPI-patiëntprofiel ('interpersonally distressed' en 'dysfunctional'). Voor deze groep draagt de interventie wellicht bij aan een reductie van distress en een subsequente vermindering van pijn en beperkingen. Daarnaast werd een verandering in PDI voorspeld door het niveau van copingstrategie 'ontkennen van pijnsensaties', met name in de EC groep; hoe meer mensen die hun pijnsensaties ontkennen, hoe minder baat zij hebben bij EC terwijl dit effect afwezig was voor Mfb. Dit veronderstelt dat myofeedback bijdraagt aan het erkennen van klachten en beperkingen waardoor veranderingen eerder kunnen optreden en eenvoudiger opgemerkt worden.

Zoals reeds beschreven wordt verondersteld dat mensen met (beeldscherm)werkgerelateerde nek-schouderklachten abnormale spieractivatiepatronen vertonen ten opzichte van mensen zonder deze klachten; namelijk onvoldoende spierontspanning (Cinderellahypothese). In de medische literatuur zijn recentelijk enkele studies gepubliceerd waaruit blijkt dat deze abnormale activatiepatronen mogelijk niet sterk samenhangen met de oorzaak van de klachten. In **Hoofdstuk 6** wordt een cross-sectioneel onderzoek beschreven welke deze hypothese toetst. De bilaterale spieractivatiepatronen van de m.trapezius p.descendens van zowel gezonden (n=20) alsmede twee groepen personen met klachten, danwel gerelateerd aan werk (n=21) dan wel gerelateerd aan een trauma (WAD, n=20) tijdens referentiecontracties, computertaken en in rust, werden vergeleken. Resultaten van bootstrap- analyses toonden geen verschillen aan tussen de drie groepen. Echter, spieractivatiepatronen bij de proefpersonen met klachten toonden een trend voor grotere variantie vergeleken met die van gezonden. Wellicht duidt dit op het bestaan van subgroepen, zoals ook verondersteld wordt in de cognitief-gedragsmatige modellen zoals hierboven kort beschreven.

Een vergelijkbaar spieractivatiepatroon tussen mensen met werkgerelateerde klachten en klachten na een trauma (WAD) zoals beschreven in hoofdstuk 6, suggereert dat ambulante myofeedbacktraining wellicht ook effectief is bij WAD (**Hoofdstuk 7**). Elf proefpersonen met chronische WAD-gerelateerde nek-schouderklachten namen deel aan de myofeedbacktraining waarbij pijn (VAS), beperkingen (Neck Disability Index, NDI) en sEMG tijdens gestandaardiseerde computertaken, voor en meteen na de training werden gemeten. VAS -scores voor de nek en hoge rug bleken klinisch relevant verminderd in 55% van de proefpersonen. Vierenzestig procent van hen toonde een klinisch relevante reductie in VAS in de rechterschouder, terwijl dit voor de linkerschouder 18% was. NDI- scores waren klinisch relevant afgenomen in 36% van de gevallen. Met name een afname in beperkingen door hoofdpijn en tijdens het tillen bleek hierbij relevant. Na de myofeedbacktraining was de spieractiviteit over het algemeen wat lager met verhoogde relaxatieniveaus, maar klinisch relevante verschillen traden slechts op in een kleine groep. De resultaten van deze pilotstudie suggereren een potentieel positief effect van myofeedback- training op pijn, beperkingen en spieractivatiepatronen bij WAD- patiënten, maar aanvullend onderzoek met een grotere populatie is noodzakelijk om meer inzicht te krijgen in de effecten en mechanismen van de training in deze specifieke populatie.

In **Hoofdstuk 8** van dit proefschrift worden de bovenstaande bevindingen geïntegreerd, bediscussieerd en gespiegeld aan de hand van bestaande modellen en theorieën. Geconcludeerd wordt dat pijn en beperkingen ten gevolge van werkgerelateerde nek-schouderklachten significant afnemen na vier weken ambulante myofeedbacktraining en dat dit effect beklijft tot tenminste zes maanden na beëindiging van de training. Hoewel Mfb niet effectiever bleek dan EC, lijkt Mfb meer bij te dragen aan tertiaire preventie van klachten op de lange duur. Het exacte werkingsmechanisme van de interventies is nog niet helder maar het is evident is dat cognities en gedragsmatige factoren als catastroferen en angst- en vermijdingsgedachten een prominentere rol spelen dan spieractivatiepatronen. Met name bij hoge initiële pijn, beperkingen en distressniveaus zijn beide interventies effectief, maar de behandelaar doet er in geval van een preoccupatie tot het ontkennen van pijnsensaties goed aan Mfb in plaats van EC aan te bieden.

Myofeedback lijkt breder toepasbaar dan uitsluitend bij werkgerelateerde klachten. Hierbij kan men denken aan klachten na trauma (WAD), maar ook fibromyalgie of rugklachten. De attractiviteit en bereidheid van behandelaars om de myofeedbacktraining zoals beschreven in dit proefschrift in te zetten in de behandeling van klachten aan het houding- en bewegingsapparaat, neemt wellicht toe indien de doelmatigheid vergroot wordt door de training op afstand aan te bieden.

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Curriculum Vitae

Gerlienke Voerman werd geboren op 14 maart 1979 te Eibergen. De middelbare school volgde zij in Enschede op het Ichthus College, waar zij in 1997 haar VWO diploma behaalde. In datzelfde jaar begon zij aan haar opleiding Gezondheidswetenschappen aan de Universiteit Maastricht, met als afstudeerrichting Arbeid en Gezondheid aangevuld met keuzevakken uit de afstudeerrichting Bewegingswetenschappen. In mei 2001 startte zij haar afstudeerstage bij Roessingh Research and Development (RRD), waarbij onderzoek werd verricht naar psychosociale kenmerken en spieractivatiepatronen bij mensen met werkgerelateerde en whiplash-klachten. Met deze stage werd de studie Gezondheidswetenschappen in februari 2002 succesvol afgerond waarna ze als junior onderzoeker bij RRD binnen het cluster NINA (Non-Invasive Neuromuscular Assessment) onder leiding van Prof.dr.ir. H.J. Hermens aangesteld werd. Naast projecten op het gebied van pijn, waaronder ook het promotieonderzoek deels uitgevoerd binnen het door de EU gesubsidieerde NEW-project (Neuromuscular Assessment in the Elderly Worker), was Gerlienke ook betrokken bij diverse projecten op het gebied van spasticiteits assessment. In december 2006 haalde zij bij het instituut voor Extramuraal Geneeskundig Onderzoek haar Master of Epidemiology toegekend door de Vrije Universiteit en beschikt ze over een goedgekeurd opleidingsplan voor registratie tot Wetenschappelijk Onderzoeker Epidemioloog (Epidemioloog B). Gerlienke is thans werkzaam als onderzoeker bij RRD.

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