From the DEPARTMENT OF NEUROBIOLOGY, CARE
SCIENCES AND SOCIETY, Division of Physiotherapy,
Karolinska Institutet, Stockholm, Sweden

NECK PAIN IN AIR FORCE PILOTS

On Risk Factors, Neck Motor Function and an Exercise Intervention

Björn Äng

Stockholm 2007

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Correspondence to: Bjorn.Ang@ki.se

ISBN 978-91-7357-168-5

Published and printed by

REPROPRINT AB
Stockholm 2007
www.reproprint.se
Gårdsvägen 4, 169 70 Solna

To Noah and Emma

ABSTRACT

Neck pain is a medical problem in modern military aviation. While neck exercises are recommended, clinical trials of neck motor function have been less investigated. The aims of the work presented in this thesis were to estimate potential flight-related and individual factors involved in helicopter pilots' neck pain, to explore neck motor function in fighter pilots and helicopter pilots with different progression of neck pain and to evaluate the effect of an early neck/shoulder exercise intervention for neck pain in helicopter pilots.

The subjects were volunteers recruited consecutively as the pilots reported to the Swedish Armed Forces Aeromedical Center for regular medical examinations (*papers I and II*) and from two operational air force helicopter bases in Sweden (*papers III and IV*). A survey estimated the prevalence of, and potential flight-related and individual risk indicators for, neck pain in helicopter pilots (*paper I, N = 127*). Experimental measures of neck motor function included neck extensor and flexor muscle strength, and electromyography (EMG) frequency parameters in extensors and sternocleidomastoid (SCM) muscles with the subject seated during sustained contraction against stipulated loads representing 50% of maximal strength (*paper II, N = 60*). EMG frequency parameters were also obtained for SCM in supine position against the weight of the head. Further, EMG activity in SCM during staged active craniocervical flexion when supine, as well as neck range of motion when seated, were assessed. Fear-avoidance beliefs about physical activity were rated (*paper III, N* = 72). A controlled trial evaluated a six-week, supervised, neck/shoulder exercise intervention. Intervention members and untreated controls were followed regarding the number of neck pain cases (defined as reported neck pain during the previous three months), SCM activity and rated fear-avoidance beliefs *(paper IV, N* = 68*)*.

The results showed the three-month prevalence of neck pain to be 57%. Previous neck pain and shoulder pain were associated risk factors, while use of helmet-mounted night-vision goggles indicated a risk. About half the neck pain cases reported that their pain occasionally interfered with flying duty and leisure, while only 25% had ever been on sick-leave related to neck pain. Experimental findings showed that fighter pilots with frequent pain had lower neck extensor strength than their pain-free controls, while no such differences were found for helicopter pilots. In seated position, EMG frequency shifts were less in SCM for helicopter pilots with frequent pain, while no significant effect emerged for helicopter pilots in supine. Helicopter pilots with *acute* ongoing pain as well as *subacute* pain had higher SCM activity during active craniocervical flexion than pain-free controls did, while the *acute* group, solely, had less range of motion and rated higher fear-avoidance beliefs than controls. A logistic regression entering EMG variables, range of motion and fear-avoidance suggested that SCM activity was the strongest predictor of neck pain. In the clinical trial, SCM activity at the highest contraction level of active craniocervical flexion was reduced in intervention members post-intervention while no between-group effect emerged for fear-avoidance beliefs. At a 12-month follow-up, the results indicated a reduction in number of neck pain cases among subjects allocated to the intervention.

In conclusion, neck pain is common in air force helicopter pilots, and preventive action aiming to reduce the risk of a first neck pain episode seems important. In air force pilots, screenings of neck extensor strength and surface neck flexor activity appeared to be relevant measures of neck motor function for clinical understanding of pilots' neck pain, but should be understood in the context of pilots' specific exposure. A supervised neck/shoulder exercise intervention improved neck motor function to some extent and had a positive early preventive effect over a 12-month period in reducing the occurrence of neck pain in air force pilots.

Keywords: *biomechanics, cervical pain, electromyography, military pilots, movement quality, muscle fatigue, muscle strength, neuromuscular, physiotherapy, range of motion*

ISBN 978-91-7357-168-5

SAMMANFATTNING

Nackbesvär är ett kliniskt problem i modernt militärt flyg. Emedan nackträning har rekommenderats så är kliniska studier som utreder och följer nackmuskelfunktion relativt ovanliga. Syftet med denna avhandling var att identifiera potentiella flygrelaterade såväl som individrelaterade faktorer som kan vara involverade i helikopterpiloters nackbesvär och att undersöka aspekter av nackmuskelfunktion bland strids- och helikopterpiloter i olika faser av deras nackbesvär. Syftet var även att utvärdera effekten av en tidig träningsintervention som involverar nacke/skuldra bland helikopterpiloter.

Samtliga deltagande försökspersoner var frivilliga och rekryterades dels konsekutivt i samband med regelbundna medicinska undersökningar vid Försvarsmaktents Flygmedicicentrum (*studie I och II*) samt från två Svenska militärt operativa helikopterbaser (*studie III och IV*). Ett frågeformulär gav prevalens samt underlag för potentiella flyg- och individrelaterade faktorer associerade med nackbesvär (*studie I, N = 127*). Experimentella mätningar av nackmuskelfunktion inkluderade muskelstyrka i nackextensorer och flexorer (bakåtsträckare och framåtsträckare), men även elektromyografiska (EMG) frekvensvariabler i extensorer samt i sternocleidomastoideus (SCM) i sittande position mot ett stipulerat motstånd representerande 50% av deras medelstyrka (*studie II, N = 60*). EMG frekvensvariabler insamlades även för SCM i ryggliggande position med huvudets vikt som motstånd. EMG aktivitet i SCM under stegvis aktiv craniocervical flexion i ryggliggande samt aktiv nackrörlighet i sittande registrerades. Rörelserädsla ('fear-avoidance beliefs about physical activity') skattades i frågeformulär (*studie III, N = 72*). En kontrollerad studie utvärderade en sex veckor lång handledd träningsintervention för nacke/skuldra. Interventionsgrupp såväl som obehandlad kontrollgrupp följdes prospektivt angående antal piloter som rapporterade besvär (de tre senaste månaderna), EMG aktivitet i SCM och skattad rörelserädsla (*studie IV, N = 68*).

Resultatet visade att tre månaders prevalens för nackbesvär var 57%. Tidigare nackbesvär samt skulderbesvär var associerade riskfaktorer, emedan flygning med hjälmmonterad 'night-vision-goggles' indikerade en risk. Hälften av de piloter som angav nackbesvär rapporterade att deras besvär vid något tillfälle påverkade deras flygtjänst och fritidsaktiviteter, emedan endast en fjärdedel angav att de vid något tillfälle varit sjukskrivna i samband med sina besvär. Experimentella resultat visade att stridspiloter med frekventa nackbesvär hade lägre styrka i nackextensorer jämfört med besvärsfria. Det förelåg dock inga sådana styrkeskillnader mellan helikopterpiloter med och utan frekventa nackbesvär. EMG frekvensfall var signifikant mindre bland helikopterpiloter med frekventa besvär i sittande position, emedan inga sådana signifikanta skillnader förelåg vid ryggliggande. Helikopterpiloter med akut pågående likväl som subakuta besvär hade högre ytlig SCM aktivitet vid aktiv craniocervical flexion i jämförelse med besvärsfria kontroller, emedan den akuta gruppen, ensamt, hade lägre nackrörlighet och angav högre grad av rörelserädsla. En logistisk regression där EMG variabler, nackrörlighet, rörelserädsla inkluderades visade att SCM aktivitet under craniocervical flexion var den tydligaste prediktorn för nackbesvär. En första uppföljning av interventionen visade att SCM aktiviteten vid den högsta kontraktionsnivån var reducerad för interventionsgruppen, men ingen effekt uppkom för rörelserädsla. Vid 12-månadersuppföljningen hade interventionsgruppen ett signifikant antal lägre antal piloter med nackbesvär.

Nackbesvär är vanligt bland flygvapnets helikopterpiloter. Preventiva åtgärder som syftar till att undvika initiala besvär är betonad. Screening tester av nackens extensorstyrka och ytlig nackflexor aktivitet var viktiga mätningar av nackmuskelfunktion, men resultatet bör tolkas i ljuset av piloternas särskilda flyginducerande exponeringar de facto. En handledd träningsintervention för nacke/skuldra kunde till viss del förbättra nackmuskelfunktionen och kan användas som tidig prevention för helikopterpiloter.

Nyckelord: *biomekanik, cervical smärta, elektromyografi, militära piloter, motorisk kontroll, muskelstyrka, muskeltrötthet, neuromuskulär, rörlighet, sjukgymnastik*

LIST OF PUBLICATIONS

I Äng B and Harms-Ringdahl K. **Neck Pain and Related Disability in Helicopter Pilots: A Survey of Prevalence and Risk Factors.** *Aviation, Space, and Environmental Medicine* 2006;77:713-9.

II Äng B, Linder J and Harms-Ringdahl K. **Neck Strength and Myoelectric Fatigue in Fighter and Helicopter Pilots with a History of Neck Pain.** *Aviation, Space, and Environmental Medicine* 2005;76:375-80.

III Äng B. **Impaired Neck Motor Function and Pronounced Pain-Related Fear in Helicopter Pilots with Neck Pain – A Clinical Approach.** *Journal of Electromyography and Kinesiology* 2007;doi:10.1016/j.jelekin.2007.01.002.

IV Äng B, Monnier A and Harms-Ringdahl K. **Neck/Shoulder Exercise for Neck Pain in Air Force Helicopter Pilots – A Randomized Controlled Trial.** *Submitted for publication.*

Further analyses have been added.

CONTENTS

ABBREVIATIONS

ANOVA	Analysis of variance
AP%	Attributable proportion
BMI	Body mass index
C	Cervical
CMS	Cervical measurement system
CNS	Central nervous system
EMG	Electromyography
FABQ	Fear-Avoidance Beliefs Questionnaire
G_z	Gravitational forces along z-axis (vertical)
HMD	Helmet-mounted display
ICF	International Classification of Functioning, Disability and Health
MANCOVA	Multivariate analysis of covariance
MVC	Maximum voluntary contraction
MVE	Maximum voluntary electrical activation
nRMS	Normalized root-mean-square
NVG	Night vision goggles
RMS	Root mean square
RR	Relative risk
RVC	Reference voluntary contraction
RVE	Reference voluntary electricity activation
SCM	Sternocleidomastoid muscle
SD	Standard deviation
SENIAM	Surface EMG for non-invasive assessment of muscles
T	Thoracic
VAS	Visual analogue scale

1 INTRODUCTION

Neck pain among military pilots is recognized as a challenging problem in modern air forces, with an estimated one-year prevalence approaching 50%.[3,19,107] This is a relatively high rate in comparison with the general population, where one-third on average are affected in a year.[50] Studies show pilots' cabin head-and-trunk postures to be significant for neck-muscle load[67,140] and back pain,[19] and reports indicate that pain per se may interfere with flying.[107,137] While pilots on flying duty represent a homogenous group with similar selection procedures and training, an important question is why some pilots experience episodes of neck pain related to flying while others do not. Importantly, the focus in this thesis is necessarily on the individual since cabin ergonomics in military aircraft is unfortunately not very susceptible to change, and some Swedish Air Force military jet and rotary-wing aircraft will still be operating in ten years' time or more.

Research in different populations shows neck-muscle motor dysfunction in individuals with various categories of neck pain such as whiplash[132] or chronic pain.[37] Observed deficit includes altered neck motor activity,[40,44,48,75,106,154] changed myoelectric characteristics due to fatiguing tasks,[46,54,77,99] and reduced neck range of motion.[59] However, studies show somewhat discrepant results, partly because of different study methodology or variability in the task performed and the population under investigation. In addition, results indicate that subjective ratings of fear of movement are associated with levels of muscle activity in subjects with neck pain[105] and that such belief may be involved in the development of long-term pain.[92] While clinical testing and management of neck pain is important for symptom reduction, evidence for early prevention and exercise treatment is relatively sparse.[79,93] In fighter pilots flying fast jet aircraft, neck muscular strength exercises have been suggested.[3,4,131] However, to date, none addresses the utility of exercise therapy as prevention for neck pain in helicopter pilots. Key themes in physiotherapy are preventive exercise, clinical judgment and restorative means to provide optimal function and movement of the musculoskeletal system. Such an approach may help to meet the further need for validated screening tools and evidence-based exercise interventions in air forces.

1.1 PERSPECTIVES AND THEORETICAL FRAMEWORK

According to the World Confederation of Physical Therapy (WCPT), physiotherapy is concerned with identifying and maximizing movement potential, with regard to promotion, prevention, rehabilitation and treatment. The Chartered Society of Physiotherapy[120] has defined physiotherapy as follows:

> *"a health care profession concerned with human function and movement and maximizing potential. It uses physical approaches to promote, maintain and restore physical, psychological and social well-being, taking account of variations in health status. It is science-based, committed to extending, applying, evaluating and reviewing the evidence that underpins and informs its practice and delivery. The exercise of clinical judgment and informed interpretation is at its core."* [120]

This points to a view of functioning and recovering in relation to the environment, and emphasizes human movement potential. It also points to the essence of prevention, which is a necessary element in aerospace medicine. The Aerospace Medical Association[9] defines the specialty as a:

> *“branch of preventive medicine that deals with the clinical and preventive medical requirements of man in atmospheric flight (aviation medicine) and space (space medicine).”* [9]

The present thesis addresses aviation medicine. Here, the role of the physiotherapist as a clinical practitioner and health planner was established relatively recently in the Swedish air force base medical services. Anecdotally, pilots who report neck pain episodes – seeking care or not – sometimes develop impaired functioning, i.e. disability. This concepts is included in the World Health Organization (WHO) framework, the International Classification of Functioning, Disability and Health (ICF).[136]

The overall aim of the ICF is to provide a unified language as a frame of reference for the "consequences of health conditions". The ICF has been applied in health care practice, research education, and for addressing policy issues. Each component can be described in positive and negative terms: 1) body functions and structures/impairment in body function and structure, 2) activity/activity limitation, and 3) participation/participation restrictions. Functioning is an overall term covering all body functions, activities and participation, while disability serves as an overall term for impairments, activity limitations and participation restrictions. The ICF also addresses interacting contextual factors (environmental and personal), see Figure 1.

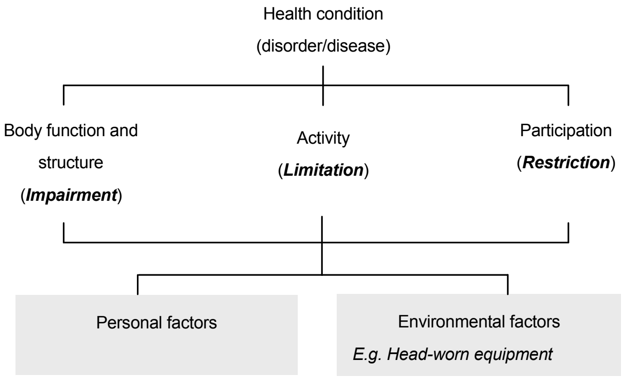


Figure 1. The International Classification of Functioning, Disability and Health (ICF (WHO))[136] including personal and environmental factors.

Body functions are physiological functions of body systems (including psychological functions). **Body structures** are anatomical parts of the body such as organs, limbs and their components. **Impairments** are problems in body function or structure such as a significant deviation or loss.

Activity is the execution of a task or action by an individual. Activity **limitations** are difficulties an individual may have in executing activities.

Participation is involvement in a life situation. Participation **restrictions** are problems an individual may experience in involvement in life situations.

Environmental factors make up the physical, social and attitudinal environment in which people live and conduct their lives.

Since the ICF is based on integration between components including body structures, psychological functions and social attitudes, it applies a “biopsychosocial” approach[124] and so confine the different dimensions of disability. The WHO explains that the ICF as a classification can be used to *map* the means of data collection in domains, or dimensions, rather than modeling the individual's "development" of functioning and disability. In this thesis the ICF model is used to *map* dimensions of assessments. It is applied under Methods, and the dimension so captured is later discussed.

1.2 DEFINITIONS OF NECK PAIN

The International Association for the Study of Pain (IASP)[1] has defined pain sensation as follows:

> *"An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage".* [1]

Pain is conceptually a complicated subjective and physiological phenomenon and may not easily be categorized for general acceptance. Several classifications and models exist for neck pain in the general population.[79,104] For non-specific neck pain the terms mechanical neck disorders, whiplash, neck sprain or strain have been included.[71] Sub-classifications using time or care-seeking are commonly applied, e.g. acute neck pain for 0 – 3 weeks of pain and/or disability from onset, subacute neck pain for 4 – 12 weeks of pain and/or disability, and chronic neck pain for more than 12 weeks' duration of pain and/or disability.[104] Here, in the latter reference, recurrent neck problems were defined as those of patients seeking care after at least one month from the last time of seeking care, or being on sick leave from work for at least one month. While neck pain is commonly recurrent,[96] the above definition of recurrent neck pain may be challenged since it may also reflect a behavior. Neck pain may not lead to sick leave or care-seeking and – in our experience – this is particularly so among military pilots.

A few authors have presented grading systems for acute neck injuries resulting from jet pilots' maneuvering under high vertical gravitational forces (G_z).[84,144] Although serious neck incidents have been reported in jet fighter pilots, also in the Swedish Air Force, experience is that most neck incidents in fighter and helicopter pilots are described as *recurrent* and distinct muscle pain or unspecific pain caused or *triggered* by flying, and lasting for a day or more. This seems to concur with experience from other air force reports of neck or back pain.[3,18,107,137] The present operational definition of neck pain was based on self-report of symptom in questionnaires. Neck pain was defined as reported neck pain, neck ache or neck discomfort during the previous three months. Its further operationalization depended on the study aim as specified under Methods.

2 BACKGROUND

2.1 NECK PAIN IN THE GENERAL POPULATION

Neck pain constitutes a significant public health problem in western countries[50] and causes personal and financial costs.[17] Along with back pain, neck pain is one of the most common musculoskeletal disorders; on average, about half the working population will suffer from neck pain at least once in their lifetime.[50] Neck pain is commonly multi-factorial and complex in nature and its etiology is often poorly understood. As the neck and shoulder region is by and large a functional unit, it cannot always be distinguished accurately when assessing neck pain. This is reflected in the literature. Epidemiological literature claims that mechanical exposure at work including awkward postures, repetitive work and previous pain episodes, pain in other regions and psychosocial condition, is related to neck-and-shoulder complaints.[8,32,57,85,100,113,129] People concurrently exposed to two or more factors may be subjected to increased risk.[57] However, explanations of the large variation in suggested risk indicators may refer to variation in methodologies, where important associated factors could differ for different populations and different definitions of pain.

Studies suggest a relationship between neck-and-shoulder pain and certain occupational exposures[58] where physical exposure seems to have an important effect on neck pain[57,113] including neck posture.[7] Harms-Ringdahl and Ekholm[64] showed that prolonged sitting with the head and neck in extreme positions may cause neck pain. However, sitting as a potential risk indicator may also depend on workplace flexibility and work task.[141] Many intervention modalities for neck pain lack evidence. However, the fact that an intervention/treatment has not been scientifically assessed does not necessarily imply that it is ineffective, simply that its value is uncertain. Mechanical or non-specific neck-pain conditions are often of multidimensional origin, and the relationship between occurrence, recurrence and long-term conditions is not always clear. It is nevertheless important to identify subjects with specific conditions for the consideration of what intervention may be appropriate.[133]

Regarding physical exercise for the management of neck pain, different forms of exercise can be recommended for populations at risk.[71] A systematic review of randomized controlled trials published in 2005 by the Cochrane Collaboration[79] indicated that specific neck exercises may be effective for the treatment of mechanical neck disorders. The authors concluded that exercise modalities should concentrate on the musculature of the neck and shoulder-thoracic area. More recently published clinical trials support the claim that exercise therapy may be effective for neck pain[23,26,27,43,82,110,125,152,153] although not always in the long term.[27] Some studies lack sufficient follow-up periods.[23,26,43] Also, there is much methodological variation among the different studies. In addition, some reports lack data concerning exercise compliance and dosage.

2.2 NECK PAIN IN AIR FORCE PILOTS

Today's helicopter and fighter jet-aircraft missions in modern air forces place high physical stress on the pilot's musculoskeletal system.[29,62,67] In this context neck pain is recognized as an epidemiologically and clinically challenging aeromedical problem.[3,19,107] However, the literature on neck pain in air-force or armed-forces pilots is limited, particularly for helicopter pilots. The first report on neck pain in military pilots appeared in the open literature in 1988, a case-report[6] of a cervical spine injury that occurred during an abrupt maneuver in a jet fighter aircraft. The back seat occupant was exposed to unexpected G_Z-loads after handing over the controls to the instructor flying from the front seat. He experienced a ligament injury and low-cervical spondylolisthesis. Later the same year two surveys were published on the occurrence of G_Z-induced neck pain in the U.S.A. Knudson and colleagues[84] reported an average lifetime cumulative incidence of 60%. Pilots flying the highest G_Z-capability aircraft rated the highest incidence (74%). In a relative large sample ($N = 437$), Vanderbeek[144] reported a three-month period prevalence of 51% for in-flight neck pain U.S. air force fighter pilots. Again, the higher prevalence of neck pain was related to higher G_z capability aircraft. Both these authors reported twisted head-and-neck positions related to the time of injury. Hämäläinen and colleagues[63] followed a cohort of 66 Finnish trainee fighter pilots from one to three years and showed an incidence rate of acute in-flight neck pain of 38%. Further, in 1997, Newman[107] reported a neck-pain prevalence rate of 85% among pilots in the Australian Air Force. Forty percent reported that their pain significantly interfered with their ability to carry out the assigned mission. Albano and Stanford reported in 1998[3] a one-year prevalence of neck injury of 57% in U.S. Air Force F-16 pilots, and for a pilot's whole flying career it was 85%. Fewer neck injuries were associated with neck-strengthening exercises and supporting the head against the seat prior to G_z loading.

Concerning helicopter pilots, there is less published knowledge in the open literature on neck pain. A literature review showed only two survey studies reporting data on neck pain prevalence. An Australian study from 1998[137] reported a neck pain prevalence of 29% over an undefined period, here revealing that the number of hours flown was linked to neck pain. A U.K. study published in 2002[19] showed a one-year prevalence rate of 48%. In addition, a Turkish study[10] using radiograph screening of the cervical and lumbar vertebrae of 732 pilots and 202 non-flying controls showed a greater prevalence of cervical changes, especially osteoarthritis, in helicopter pilots than in controls. Helicopter pilots had a higher prevalence of degenerative changes in the cervical region relative to the lumbar area, and their cervical changes were also greater than those in other pilot groups including jet fighter pilots. However, the scant attention given to helicopter pilots' neck pain problems does not reflect our experience with the Swedish Air Force, which reveals neck pain as a significant problem in rotary-wing pilots.

Although the authors who initially reported neck pain problem in 1988 concluded that preventive exercise strategies were needed,[6,144] as did several authors during the following years,[3,67,83] to date, there are no evidence-based guidelines for the clinical or preventive management of neck (or back) pain in the Swedish Air Force. Nor, it seems, are there such guidelines in many other air force nations. This may partly be explained by limited conclusive evidence.

2.3 EXPOSURE DURING FLIGHT

In the past decade, two Swedish air force jet types can be identified as high-G_z performance aircraft (human exposure > 6 G_z for longer than 15 s). They are the JA 37 Viggen and the JAS 39 Gripen, both having similar mission profiles. The JAS 39 Gripen has now replaced the JA Viggen which was withdrawn in 2005. As with many other operational high-performance jet aircraft, high G_z capabilities have exceeded human physiological tolerance for several organ systems,[81,151] and numerous countermeasures, including an anti-gravity suit and positive-pressure breathing[2] are in use during flight. Experience from centrifuge experiments (G_z-load simulation) shows that at approximately 4 G_z an untrained average person will suffer from decreases in the relative hydrostatic column between heart and brain and an initial reduction in retinal perfusion may result in impaired or loss of vision. Exposure to about 5 G_z may result in unconsciousness from loss of cerebral perfusion.[109] However, G_z-endurance is trainable;[11,31] and there is substantial variation in G_z endurance capacity between individuals.

During real flight, however, the pilot occasionally moves his head and neck with great freedom of motion, particularly during certain air exercises.[55] Part of this depends on the fixed trunk posture in the seat. It has been reported that the neck might be the most vulnerable part of the musculoskeletal system to high G_z-force injuries,[25] and in-flight electromyography recordings from abdomen, back and neck have shown muscular activity to be the highest for the neck.[111] Reports are that pilots that are regularly exposed to high G_z forces develop neck-protective strategies.[108] Harms-Ringdahl and colleagues[67] calculated that while flying at 9 G_z, the fighter pilot's head and headgear can exert loads of up to 65 kg on the neck (some fighter aircraft can subject the crew to an increase from $1G_z$ to more than $9G_z$ in less than a second). This loading frequently imposes isometric types of muscular stress on the head-stabilizing muscles. When the pilot's head deviates from the neutral position, as in a twisted or 'check-six' position, internal forces may be higher due to biomechanical alterations.[62,67] However, fatigue effects caused by repeated exposure to G_z-loading have been suggested as a risk factor for neck pain at lower G_z levels[60,61] as have the sudden and unexpected high G_z maneuvers reported in case studies.[6,84,126] During helicopter flight, however, pilots' peak muscle activity may generally be lower than that of pilots flying high-G_z aircraft, but more sustained.

Several helicopter types are used in the Swedish air force, the MBB BO 105 CB-3 (HKP 9) and the Agusta A 109-E (HKP 15) being two of the most common. Typically, the helicopter pilot sits bent forward with the neck flexed and with the trunk and shoulder slightly rotated to the left so as to control the cyclic flight stick with the right arm. The trunk and left shoulder are slightly dropped to grasp the collective stick, while the feet continuously control the rudder pedals. Control of the helicopter, which is inherently an unstable aircraft platform during flight, thus requires continuous open-chain precision work in all four extremities in a relatively poor and fixed trunk and neck position in all phases of flight (Figure 2).

Research in helicopter pilots show that the pilot's head-and-trunk postures are of significance for neck muscle load.[140] This seems also so for the lower back,[95] possible inducing back pain;[19,52] although data for the lower back also show insignificant effects of flying on electromyography activity.[34,35] However, the commonly non-linearity relation between induced load and muscle activity at lower load may result in an underestimate.[139]

Figure 2. Helicopter pilot seated in the cabin with right hand on cyclic flight stick and left hand on collective stick. Feet continuously control the rudder pedals, thus no fixed support under the feet, i.e. sitting in an open-chain situation.

2.3.1 Head-worn equipment

In the Swedish air force, the fighter pilots' helmet, including mask, weighs approximately 2 kg, depending on the protection required and the electronic equipment attached. The helmets used by helicopter pilots weigh 1.4 - 1.7 kg. While pilots' helmets were originally designed for head protection, they now also provide a base for mounting a display. The trend for helicopter pilots, in particular, over the past ten years has been to increasingly use helmet-mounted displays (HMD), predominantly vision enhancement technology – night-vision goggles (NVG) – during night or dark missions (Figure 3). The equipment is certainly useful during sea missions in rough weather or in the dark, particularly in northern Sweden during winter with nearly 24 hours of darkness. Such head-worn equipment (weighing along with the helmet approximately 3 kg including counterweight on the back of the helmet), adds to the pilot's neck workload[67,139] and may contribute to

[redacted]

Figure 3. Helicopter pilot wearing helmet with helmet-mounted display (night-vision goggles). Note: to reduce the flexing moment induced by the displays, pilots often use a counterweight (back of helmet).

early neck muscle fatigue.[119] HMD have until recently been considered inappropriate for fighter pilots operating in high-G_z environments. However, advanced HMD have now been developed for jet aircraft application, providing the new generation of jet aircrew pilots with information and sensor videos including night vision capability.

When the pilot wears a flight-protective helmet *and* HMD, the position of the centre of mass is altered forward-upward of the head/head complex.[67] The counterweight adds to the weight, but reduces the moment of force in upright head-and-neck positions.[65,139] The bulky head-worn equipment may however cause unexpected torque in altered head positions. The counterweight has been used (and debated) for some years in several air forces including the Swedish. Its further utility in jet aircraft has yet to be seen.

2.4 ANATOMY AND KINEMATICS OF THE CERVICAL NECK

The human neck is a dynamic body structure that orients the head in space in relation to the goal of a particular movement. Its musculoskeletal architecture is complex with several layers crossing one or several joints with multiple attachments and functions on the cervical spine.[78,145] The neck is designed for great motion freedom:[36] the greatest degree of flexion-extension and axial rotation occurring in the upper cervical joints while lateral flexion occurs in all cervical vertebrae.[115] Neck muscles and ligaments provide the head and neck with movement and stability. With the head in an upright neutral position, the ligaments are relatively relaxed, revealing muscle activity as the main stabilizing element. However, ligaments are important for stability in end-of-range-of-motion postures.[66] Panjabi and colleagues[114] estimated that cervical ligaments contribute about 20% to the mechanical stability of the cervical spine, while the rest is largely handled by the neck musculature. If additional loads are applied to the head, the contribution of the muscles may become more important.[114]

Neck muscles are organized in grouped layers. Surface layers consist of large and long layers such as the sternocleidomastoid and trapezius. They cover several cervical joints, have relative long levers, and produce movement and force. Surface layers are also important for counteracting externally induced forces and interaction with the shoulder girdle. The sternocleidomastoid is the main flexor of the *lower* cervical spine[80,101] but acts as an extensor in the *upper* cervical joints. With the occiput-C2 segment in neutral position, the cleido-occipital part passes dorsally of the bilateral movement axis of craniocervical joints, i.e. induces an extending loading moment in the upper cervical spine, and cleido-mastoid passes through the craniocervical movement axis.[145] Splenius capitis, a posterior semisurface muscle, is activated during neck extension along with semispinalis capitis, but also during ipsilateral rotation and lateral bending.[80,101] The trapezius seems to have little or no effect on head movement,[80,145] although it covers a large part of the posterior neck surface. As opposed to surface layers, the deep prevertebral layer, which acts ventrally on the cervical spine (i.e. longus colli and longus capitis), has relatively short levers. These act along with the intrinsic posterior muscles largely with deep kinematics including intersegmental stability. Longus colli, located deep on the anterior surface between the atlas and the third thoracic vertebra, also counteracts the lordotic increment induced by the usually stronger dorsal muscles and the weight of the head.[102]

To control the neck complex, the central nervous system (CNS) must select relevant muscles that operate over relevant joints to meet the task and the threat to stability that may be involved in a particular voluntary movement. Here, the task for the CNS is both to meet the demand for intersegmental kinetic stability and the demand for multi-segmental flexibility to achieve the movement called for. This somewhat daunting task is accomplished by the CNS by using, or organizing, functional muscle synergies to generate both the movement and cervical stability.[20,122] In 1989, Bergmark suggested[14] a model describing functional division between surface and deep muscles. The role of the superficial large muscles was mainly to counteract external gross forces and handle movements, while forces transmitted to the spinal column kinetics were claimed to be controlled by the deep-layer system. Several researchers have later supported this model for both the neck and the lumbar region. Studies demonstrate that neck pain patients exhibit disturbances between deep and surface muscle coordination.[42,44,73]

2.5 MEASURES

Sensitive measuring techniques and instruments are important for understanding functioning and potential functional limitations, and for the effect of intervention. Existing assessments of neck-muscles motor function include conventional physiological measures such as neck muscle strength, active range of motion and endurance. There are also more specific neurophysiologic measures such as different EMG applications that, when used, depend on the purpose of the study.

2.5.1 Electromyography

Muscle contraction can be quantified by recording muscle electrical propagating activity with surface or intramuscular electromyographic (EMG) measuring technique. When bipolar surface electrodes are used, detected muscle activity reflects a summary of active motor unit action potentials at the electrode sensor placement. The action potentials reflect a chemical-electrical process in several muscle fibers and motor units. Intramuscular recording technique rather selectively records muscle activity from certain muscle fibers, while surface electrode technique detects activity from a more widespread region.[101] The technique applied depends on the purpose of study. Using surface EMG on the posterior neck muscles, e.g. splenius capitis, it is likely that signals from nearby muscles will be registered[12] and such application should be considered as location-specific rather than muscle-specific.[138]

Basically, EMG signals can be analyzed in two domains; time domain and frequency domain.[49,121] The time domain is useful for analyzing activation or contraction levels, or sequences of certain muscles during movement.[12] Here, amplitude properties are commonly expressed as root-mean-square values (RMS). Other similar estimates are average rectified value or integrated rectified value: all show similar responses to force fluctuations.[12] To allow comparison between subjects or between muscles in a single subject, the RMS data should be normalized against an RMS obtained from a reference contraction.[130] This may be either a maximum voluntary contraction or activation (MVE) or a submaximal reference voluntary activation (RVE). While the use of submaximal reference contraction does not reflect maximal effort, or %MVE, it is commonly an appropriate normalization procedure when measuring subjects' in pain.

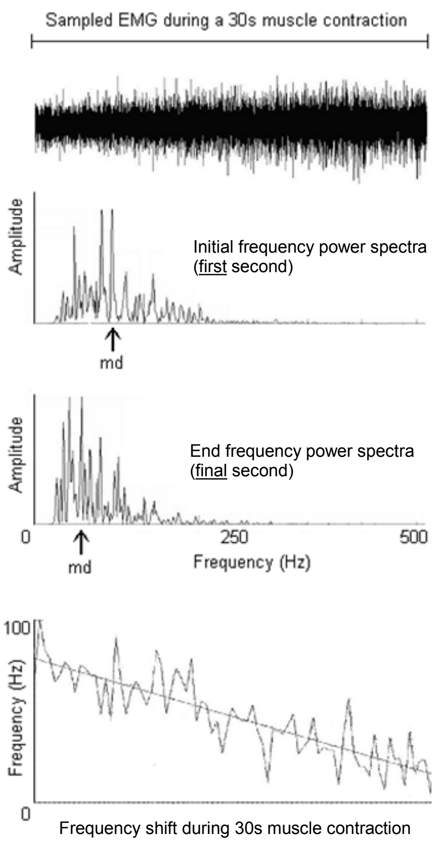


Figure 4. Change in electromyographic frequency shift during sustained muscle contraction. Note that when comparing the power spectrum from the first second to that of the final-second, the median frequency has shifted to left (lower frequency), and this may be displayed as a function of time.

Frequency domain, on the other hand, is commonly used to estimate muscle fatigue characteristics during sustained muscle contraction. Fatigue is reflected by an increase in amplitude and a decrease in power spectral average frequency in healthy subjects.[103] The wave of the electrical signal oscillation can be shown as a power spectrum and may be split up into certain frequency components using fast Fourier transformation.[12] An average measure of the power spectrum is commonly used to describe the change in frequency characteristics where the decrease in frequency is usually linear, or semilinear, and can be fitted into a linear regression for further analysis (Figure 4). *Median* frequency may be preferable to *mean* frequency since the spectrum of human myoelectric signals commonly has an asymmetric distribution. Median frequency is also considered more stable than mean value due to potential 'noise'. Signal properties nevertheless depend on the recorded configuration, including electrode properties and placement, filtering and sampling rate[12] and should be specified to allow comparison between trials.[69] Here, SENIAM (Surface EMG for the Non-Invasive Assessment of Muscles) promotes collaboration among researchers to develop recommendations useful for surface EMG sensors and signal configuration.[69]

2.5.2 Neck muscle strength

Muscle strength measured as maximal voluntary contraction (MVC) has been defined as follows:

> *"the force generated with feedback and encouragement, when the subject believes it is a maximal effort"* [150]

This indicates the voluntary nature of muscle strength effort, and should not be confused with maximal muscle force. Various measuring instruments such as portable dynamometers[5] or fixed training machines[117] are used to register neck MVC. The same device as used in the present thesis (DBC 140) seems to have very good reliability.[117] It is important to standardize test position, joint angle, instructions given and analysis procedure to allow relevant comparison. Using a portable dynamometer with a sling around the pilot's head, Alricsson and colleagues[5] showed that Swedish fighter pilots had on average about 10% greater extensor, and 30% greater flexor, neck muscle strength than young conscripts had. A Singapore study[128] could not support such results, using a Biodex isokinetic dynamometer, possible due to variation in test configuration.

2.5.3 Neck active range of motion

Clinically, tests of active range of motion are widely accepted and used. Active range of motion is commonly measured with simple goniometers and inclinometers. Total range of motion in each anatomical plane appears to have higher reliability than split cycles.[87] An important advantage of goniometers is that they are easy to apply to the individual's head and require no electronic equipment. Hagen and colleagues[59] showed in male forest machine operators a correlation between neck active range of motion and pain intensity using the Standardized Nordic Musculoskeletal Questionnaire on Musculoskeletal Problems.[86] It was suggested that measures of active range of motion may give information important for understanding the extent of the particular neck disorder.[36,59]

2.5.4 Active craniocervical flexion

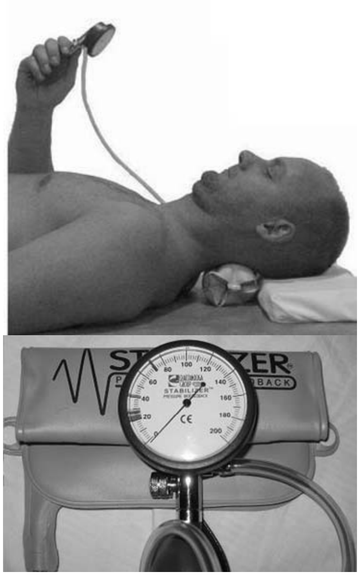


Figure 5. Upper picture: active craniocervical flexion aims to activate deep neck flexors with concomitant flattening of cervical spine lordosis. It results in an increase in pressure (mmHg) on the biofeedback unit. Lower picture: pressure biofeedback unit (Pressure Biofeedback Unit, Chattanooga Group, Hixon, TN).

Isolated craniocervical movement occurs between the occiput and the upper cervical joints. However, isolated *active* craniocervical flexion occurs when deep prevertebral neck flexors contract, as shown by EMG[45,147] and functional X-ray measurement.[30,102] Here, active craniocervical flexion will, due to its anatomical action, result in flattening of the cervical spine.[102] Since surface sternocleidomastoid is not functionally suited to assisting isolated active craniocervical flexion,[145] as earlier described, the sternocleidomastoid are not to be activated, and amplitude levels during recordings of surface EMG from sternocleidomastoid should be low. Minor activity may be expected, however, as the central nervous system uses complex activation strategies,[146] perhaps to avoid violating intersegmental instability.

A specific low-load craniocervical flexion test (Figure 5) has been developed by an Australian research group[72-74] to investigate the functional action of the deep prevertebral cervical muscles, particularly longus colli and longus capitis muscles. The test was designed for clinical use to evaluate the ability to perform and control upper craniocervical flexion with concomitant flattening of the cervical spine. The test has been validated in laboratory studies (using invasive EMG measuring technique) by showing a strong linear relationship between deep prevertebral flexor activity and increment stages of craniocervical flexion as registered by a pressure sensor.[45,48] A relationship was also shown between such increments and range of active craniocervical flexion motion.[47] The pressure sensor with associated biofeedback unit is applied to guide and give information to the patient/client concerning levels of contraction, usually five increment stages. With the subject supine, the pressure sensor is placed behind the cervical neck and inflated to fill the space between the neck and the underlying surface. Flattening of the cervical spine results in an increase in pressure (mmHg) shown on the biofeedback monitor placed in front of the subject.[72,73] Clinical experience suggests that a healthy individual should be able to control the performance of the deep neck muscles to an increment pressure of 30 mmHg and hold this pressure stable for 10s.[73,74] Such an endurance test protocol seems reliable in non-patient subjects.[28,73] While the test is fairly new and, to our knowledge has never been reported with pilots, it has been relatively widely used to study neck flexor function in subjects with neck pain,[48,75] whiplash-associated disorders,[132] migraine[154] and cervicogenic headache.[51,73,76]

2.5.5 Fear-avoidance beliefs about physical activity

Fear-avoidance beliefs refers to the avoidance of movements and activities based on fear of pain.[33,148] An individual may no longer perform certain movements or activities because he or she *anticipates* that such activities could initiate or increase pain and suffering. Authors have also termed the condition “fear of movement”[148] or “kinesiophobia”, the latter usually in more pronounced situations of fear.[98] In the present thesis, the term ‘fear-avoidance’ is used and reflects subjective rated fear-avoidance beliefs about physical activity.

The irrational state of fear-avoidance has been described in the cognitive-behavioral fear-of-movement/(re)injury model.[148] This model describes the mechanism by which fear of movement possibly contributes to the maintenance of musculoskeletal pain or disability. The painful experience intensified during movement may elicit catastrophizing cognitions in some individuals and more adaptive cognitions in others. It is suggested that catastrophizing following a painful experience may lead to a vicious circle including avoidance/fear of movement (“avoiders”), disuse and disability, possibly leading to irrational fear of physical movement and activity; a feeling of vulnerability to injury or re-injury that causes pain. Alternatively, non-catastrophizing, and confronting adapters (or “confronters”) would promote health behavior and early recovery.[148] Prospective studies referring to the model suggest that maladaptive cognitions may be involved in the development from acute to long-term spinal pain.[92,105] While fear-avoidance may indeed be justified in the acute stage of injury so as to avoid aggravating injury or aggravating perceived pain,[148] avoidance of movement may induce changes in physical activity and modulate muscle activity as previously shown with EMG.[105,149] Nederhand and colleagues[105] suggested that a decrease in upper trapezius muscle activity in subjects with posttraumatic neck pain disability is aimed at "avoiding" the use of painful muscles.

Questionnaires exist on beliefs about fear-avoidance.[98,142] The Fear Avoidance Beliefs Questionnaire (FABQ)[142] and the Tampa Scale for Kinesiophobia (TSK) were developed for use in musculoskeletal pain. Crombez and colleagues[33] suggested that fear-avoidance measured with FABQ and TSK were better for predicting self-reported disability and poor behavioral performance than pain itself. Nevertheless, screening for fear-avoidance might help the clinician to identify potential subgroups of neck- or back-pain avoiders for whom exercise intervention may be adjusted accordingly.[91] Evaluation of the effect of physical exercise on fear-avoidance seem however relatively sparse.

2.6 PREVENTIVE EXERCISE FOR NECK PAIN

The purpose of preventive exercise is to prevent or reverse pain and related dysfunction and disability, achieving muscle control and improved physical function, and to prevent recurrent episodes of pain.[68] During the past decade, approaches to musculoskeletal pain prevention in general have changed from “hands-on” modalities such as manipulation and massage to more “hands-off” modalities such as self-management exercise and tailor-made functional training. Further, the commonly held statement “Listen to your pain” may be counterproductive in some neck and back pain conditions. Here, too, there seems to be a shift from “following pain” towards individual capability and awareness of functioning.[94] The Swedish Association of Registered Physiotherapists[123] has defined physiotherapy *intervention* and its field of practice as follows:

> *“Interventions with the aim to prevent or rehabilitate are based on an evaluation and analysis of physical capacity and problems of the patient/client with regard to psychological and social factors including relevant environmental aspects. With the patient/client as an active partner, interventions, treatments and learning strategies aim at making the individual aware of his/her physical resources and thereby improve the potential of the individual to cope with the demands of daily living.”* [123]

While neck-and-shoulder exercise focusing on movement quality and control seems helpful in subjects with neck dysfunctions,[27,76,143] evidence that neck/shoulder exercise may mediate adaptational neck-muscle responses, or affect fear-avoidance is sparser; particularly in early intervention, i.e. primary and secondary prevention. In terms of avoiding neck pain or injury in high G_Z environments, exercise intervention aiming to reduce neck pain problems seems promising.[3] The few clinical trials with fighter pilots suggest that neck-muscle strengthening[4,60] and trampoline exercise[131] may improve neck-muscle performance. However, none have tackled the utility of exercise intervention in helicopter pilots.

2.7 RATIONALE FOR THE THESIS

Pilots flying either helicopters or jet aircraft represent a largely homogenous group with similar early selection procedures and training, and similar work-related exposures within each pilot group. The cabin ergonomic environment is not very flexible in several military aircraft, of which some will serve the Swedish Air Force for many years to come. This seems also to be the case in many other nations' air forces. However, from clinical experiences and anecdotal reports, an important question is why some pilots experience episodes of neck pain commonly related to flight, while others do not. What characterizes pilots with and without neck pain? - is it possible to train and hence prevent further episodes and so cope better in the pilot's environment? These questions constitute an important starting point in the work reported in this thesis.

Research on pilots' neck pain and further knowledge about their personal capabilities to interact with the environmental of flying military helicopters or jet aircraft may give new insight on this particular aeromedical problem. Such knowledge, here studied in a physiotherapy perspective, could be directed to both pilots and medical personnel.

3 OVERALL AIM

The main goals of the work presented in this thesis were to estimate potential flight-related and individual factors associated with helicopter pilots' neck pain, to explore clinically convenient measures of neck motor function in fighter and helicopter pilots with different progressions of neck pain, and to evaluate an early neck/shoulder exercise intervention for neck pain in helicopter pilots.

3.1 SPECIFIC AIMS

Specific aims were

- to estimate the prevalence of neck pain, related disability and potential risk and health factors for helicopter pilots' neck pain, *(paper I)*

- to investigate neck extensor and flexor muscle strength and EMG frequency spectral variables in neck extensors and sternocleidomastoid muscles under sustained agonist contraction in seated fighter and helicopter pilots with *frequent* neck pain, *(paper II)*

- to investigate EMG frequency spectral variables during sustained agonist neck flexor contraction in supine and EMG activity in sternocleidomastoid muscles during the performance of active craniocervical flexion in helicopter pilots with *acute* ongoing neck pain and *subacute* neck pain; also to investigate active range of motion and rated fear-avoidance beliefs about physical activity, *(paper III)*

- to evaluate whether a supervised neck/shoulder exercise intervention over six weeks may mediate adaptational EMG activity in sternocleidomastoid muscles during the performance of active craniocervical flexion and whether such a regimen may alter fear-avoidance in helicopter pilots with or without neck pain, *(paper IV)*

- to evaluate the effect of the exercise intervention in reducing the number of neck-pain cases over 12 months in air force helicopter pilots. *(paper IV)*

4 METHOD

4.1 DESIGN AND ETHICAL CONSIDERATIONS

This thesis is based on one cross-sectional survey (*paper I*), two experimental studies (*paper II and III*) and one clinical controlled trial (*paper IV*). In study IV, measurements were obtained before randomization, after the six-week intervention period, and at a follow-up after 12 months. For practical (and financial) reasons, it was not possible to collect EMG data at month 12.

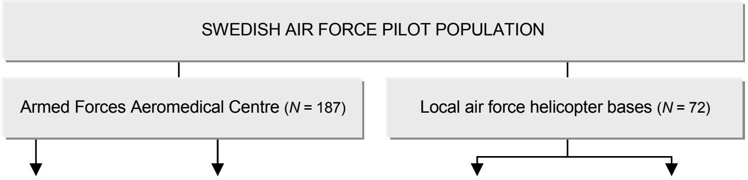
For all the studies, the participants received written and oral information about the study and gave their informed consent before inclusion. Confidentiality and the voluntary nature of a questionnaires and physical measurements were stressed. The participants were informed that they could withdraw at any time without giving any reason, and that participation or non-participation would not affect their future care or any judgment based on their regular medical examinations at the Swedish Armed Forces Aeromedical Centre. They were informed that no data could be linked to any individual pilot. The studies were approved by the Regional Medical Research Ethics Committee, Karolinska Institutet, Stockholm. Authorities at the Aeromedical Centre and at the two local air force bases gave their consent for the investigations.

4.2 STUDY SAMPLES

Recruited subjects were Swedish air force pilots on active flying duty. The sample size ranged from 60 pilots to 127 pilots in the different studies. Table 1 shows the recruiting pathway and pilots' characteristics in the studies. For helicopter pilots and for fighter pilots, there were no apparent differences in demographics or hours flown between the subgroups.

In studies I and II the recruiting and testing were done consecutively as the pilots reported to the Swedish Armed Forces Aeromedical Centre for regular medical examinations. No women reported during the consecutive recruiting procedure at the Aeromedical Centre or during the recruiting process at the local bases. In study I, 127 helicopter pilots completed the questionnaire. In study II, 30 fighter pilots and 30 helicopter pilots were recruited. Exclusion criteria were indicated neurological symptoms from the neck. For the purpose of studies III and IV, a sample consisting of 72 helicopter pilots was recruited and tested at two selected air force helicopter bases in Sweden (multi-centre study); one operating in a coastal region and one mainly inland. Exclusion criteria were indicated neurological symptoms from the neck, specific spinal disorders or undergoing neck/shoulder treatment at the time of testing. In study IV, three subjects with planned duty abroad during their intervention period were also excluded while one pilot decline to participate in the intervention. Thus, 68 helicopter pilots were grouped at random after baseline evaluation in study IV. Subjects' recruitment and retention in study IV are summarized in Figure 6.

Table 1. Recruitment pathway, demographic data, exercise habits and flying experience characteristics of the subjects participating in studies I-IV respectively. Data are mean (SD).



	Paper I	*Paper II*				*Paper III*			*Paper IV*	
	N = 127	*N* = 60				*N* = 72			*N* = 68	
	Helicopter	Fighter pilots		Helicopter		Helicopter			Helicopter	
		NP	Ctrl	NP	Ctrl	*Acute* NP	*Sub* NP	Ctrl	Exercise	Ctrl
N	127	16	14	15	15	20	27	25	34	34
Age (yrs)	37 (7)	37 (8)	35 (9)	39 (6)	40 (8)	39 (5)	35 (5)	38 (7)	37 (6)	38 (5)
Height (cm)	181 (5)	180 (3)	181 (6)	180 (5)	182 (4)	180 (5)	181 (5)	182 (5)	181 (4)	182 (6)
Weight (kg)	81 (8)	80 (7)	82 (8)	80 (7)	81 (6)	83 (9)	81 (8)	83 (9)	81 (6)	83 (10)
Exercise Habits (h x wk^{-1})										
Fitness training	3.7 (2)	3.9 (2)	4.1 (2)	3.8 (2)	3.8 (1)	2.9 (1)	3.1 (2)	3.6 (1)	3.3 (2)	3.1 (1)
Strength training	1.2 (1)	1.1 (1)	1.3 (1)	1.4 (1)	1.1 (1)	0.9 (1)	1.2 (1)	1.3 (1)	1.0 (1)	0.9 (1)
Flying hours (h)	2523 (1524)	2050 (1198)	1736 (905)	3363 (1878)	2969 (1695)	2364 (1318)	1922 (784)	2132 (916)	1989 (916)	2209 (1180)

NP, neck pain (reported neck pain episode the previous three months); *Acute*, pilots reporting ongoing neck pain at the time of testing (VAS > 10 mm); *Sub*, subacute; Exercise, pilots allocated to exercise intervention; Fitness training, aerobic training such as running and bicycling; Strength training, general muscle strength training for any body part.

4.3 OPERATIONAL DEFINITION OF NECK PAIN

Neck pain was defined as self-rated neck pain experience, neck ache or neck discomfort during the previous three months (area as in Figure 7). In experimental studies II – III, neck pain was further operationalized as follows: *Frequent* neck pain was defined as at least one episode a month during the previous three months (*paper II*). *Acute* neck pain was defined as the presence of pain at the time of testing (VAS > 10 mm) (*paper III*): median (range) in pain intensity on the VAS scale (0-100 mm) was 20 (11-71). *Subacute* neck pain was defined as neck pain during the previous three months but no pain at the time of testing (*paper III*).

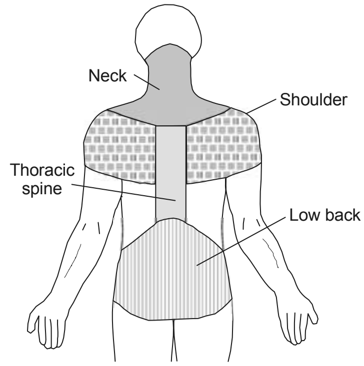


Figure 7. Operationally defined body regions.

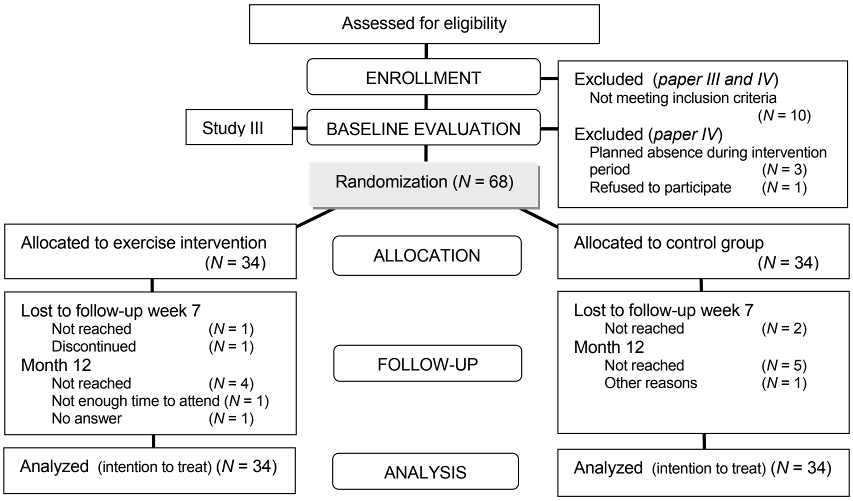


Figure 6. Participants' flow through study IV.

4.4 INSTRUMENTS

4.4.1 ICF classification

Table 2 displays an overview of the instruments used according to the ICF classification.[136]

Table 2. The International Classification of Functioning, Disability and Health (ICF) domains and the instruments used in the present work.

ICF components	Instruments and domains	*Paper*
Impairments		
Neck muscle strength (MVC)	David Back Clinic machine 140[117]	II
Neck muscle fatigue function	Electromyographic initial *and* frequency shift[12,103]	II and III
Neck muscle activity	Electromyographic activity[12] (amplitudes) + PBU [a]	III and IV
Neck active range of motion	Cervical measurement system[116]	III
Pain	VAS (0 – 100 mm)[15,70]	III
Fear-avoidance beliefs	Fear-avoidance beliefs questionnaire [b]	III and IV
Activity limitation/participation restriction		
Interfering with flying duty, leisure	Pilot questionnaire [c]	I
Sick leave		I
Personal factors		
Compliance with exercise intervention	Diary	IV
Exercise habits (fitness and strength training)	Pilot questionnaire [c]	IV
Environmental factors		
Aircraft type and use of NVG	Pilot questionnaire [c]	I

[a] Pressure Biofeedback Unit[28,73]

[b] modified Fear-avoidance beliefs questionnaire about physical activity[22,92]

[c] Represents single item/items from the questionnaire

4.4.2 Neck muscle strength

Figure 8. Test position for measuring isometric neck maximal voluntary contraction (MVC) in extension (upper picture) and flexion.

Study II: Neck extensor and flexor maximal voluntary contraction (MVC) were measured with the subject in an upright sitting position in a training and testing unit DBC-140 (David Back Clinic machine 140, DBC-140, David Fitness and Medical Ltd, Helsinki, Finland). This device was also used under sustained contraction during EMG recordings. The DBC-140 has been recommended for use in clinical practice and shows very good reliability for recorded neck MVC in upright seated position.[117] The height of the seat cushion was adjusted for each subject so that the bilateral motion axis of T1-C7 was in line with the rotation axis of the testing unit. A chest fixation bar with a pad supported the chest. The subjects performed isometric neck extension against the resistance pad with the cervical spine in a neutral upright position and flexion in a position with the neck slightly flexed (Figure 8).

4.4.3 Electromyographic setup and instrumentation

Figure 9. Electrode placement. Upper picture show electrode placement for extensors (*paper* II), lower picture for sternocleidomastoid (*papers* II – IV). The grey buttons visible on picture are ground electrodes with built-in preamplifiers.

Studies II - IV: Surface EMG activity was recorded bilaterally from the neck extensors (*paper II*) overlying splenius capitis muscles at vertebra C2 level (between the uppermost parts of the trapezius and the sternocleidomastoid).[138] Activity from the sternocleidomastoid (*papers II – IV*) was recorded with electrodes overlying the lower part of the sternal muscle belly as previously recommended[41] and measured in military pilots.[138] Applied electrode placement are shown in Figure 9.

After shaving, sandpapering and cleaning the skin with 70% alcohol, disposable, pre-gelled surface-disc, bipolar, self-adhesive electrodes with an active diameter of 10 mm (Ag/AgCl, Blue Sensor N-00-S, Medicotest A/S, Ølstykke, Denmark) were applied pairwise with an interelectrode center-to-center distance of 20 mm according to SENIAM recommendations.[69] A reference electrode was placed over bone. The signals were pre-amplified 1000 times using preamplifiers located in the cables close to the electrodes, band-pass-filtered 20-500 Hz (Butterworth filter), and passed through a 12-bit A/D converter with a sampling frequency of 1 kHz (Mespec 1000 System, Mega Win 2.0, Mega Electronics Ltd, Kuopio, Finland). The electrode placements using this equipment have been shown to be reliable for measuring spectral parameters in helicopter pilots' neck extensor and flexor muscles.[138]

4.4.4 Biofeedback unit for active craniocervical flexion

Studies III and IV: Low-load active craniocervical flexion was performed with resistance from an air-filled pressure sensor (Pressure Biofeedback Unit, Chattanooga Group, Hixon, TN). The subject lay supine on a bench. The sensor was placed between the neck and bench. Here, the sensor was pre-inflated to a baseline level of 20 mmHg.[73,74] The equipment displayed movements of the cervical spine. Flattening of the cervical lordotic curvature occurs when deep neck flexors are contracted,[47,48,102] and results in an increase in pressure (mmHg) shown on the display in front of the subject[74] (see Figure 5). Active craniocervical flexion with a pressure sensor has previously been used in EMG studies of neck flexor function in subjects with neck disorders,[48,75,132,154] and an endurance test of active craniocervical flexion has been shown to be reliable in non-patient subjects.[28,73]

4.4.5 Cervical measuring system for active range of motion

Study III: Active range of neck motion in flexion-extension, axial rotation and lateral flexion was recorded with the subject in a sitting position. A three-dimensional measuring instrument, the 'cervical measurement system' (CMS), a development of ad modum Myrin (Medema AB, Bromma, Sweden), was used. The CMS consists of two gravity-controlled inclinometers to measure flexion-extension and lateral flexion, left-right. A third meter, a magnetic compass, measured axial rotation. The CMS device has shown good reliability[59,116] and is suggested for use in clinical measurements.[116]

4.4.6 Questionnaires

Study I: A questionnaire previously developed and used to study musculoskeletal problems in Swedish Air Force pilots[4,5,65] was administered at the Aeromedical Center. Questions concerned demographic data, flying experience, physical exercise habits, potential pain frequency and pain severity on the Borg Category-Ratio scale (CR 10 scale).[16] The pain frequency questions were initially developed through items derived from the Nordic Musculoskeletal Questionnaire.[86] The instruction ran: "State any pain experience (pain, ache, discomfort) during the past three months in any body areas shown" (Figure 7). Pain frequency was reported on a four-step scale (0 – 3), where 0 no, never; 1 once/a few times over the previous three months; 2 once/a few times per month, and 3 once/a few times per week. Subjects who reported any pain frequency were asked to complete the fourth section concerning potential interference with flying duty, and/or leisure activities, and sick leave ($^{no}/_{yes}$). Preliminary results indicate that items used here have acceptable test-retest stability (unpublished data). Eleven risk and health indicators were used in the regression analyses to detect possible association with neck pain; flying-related indicators: 1) type of helicopter flown (four types), 2) use of night-vision goggles $^{no}/_{yes}$, 3) total flying time < 1500 h/1500-2612 h/> 2612 h, 4) flying hours previous year ≤ 135 $^{h}/_{yr}$, 5) flying hours per month ≤ 13 h $^{h}/_{mo}$. Individual indicators concerned: 6): body height (m) < 1.78/1.78-1.82/>1.82, 7) BMI $\leq 25.1\ ^{kg}/_{m^2}$, 8) fitness training $\leq 3.5\ ^{h}/_{v}$, 9) muscle strength training $\leq 1.0\ ^{h}/_{v}$, 10) history of neck pain $^{no}/_{yes}$, 11) recent pain in closely related regions (shoulders, thoracic, low back: $^{no}/_{yes}$).

Studies III and IV: Fear-avoidance was measured with the modified Fear-avoidance Beliefs Questionnaire (mFABQ),[21,92] which focuses on individuals' beliefs about how physical activity (4 items) and work (7 items) affect their pain. In the present work, the four items about physical activity were used. The mFABQ is derived from the original 16-item FABQ[142]. As with the original, the items were answered on a 0–6 verbal scale (score sum 0–24); 0: "strongly disagree" to 6: "strongly agree"; a higher score indicates more fear-avoidance beliefs about physical activity. Subjects were instructed to focus on their neck region when answering the questions since the original questions in the FABQ refer to back pain.[142]

Study III: Pain intensity was quantified on horizontal 100-mm visual analogue scales, VAS (0: no pain, 100: worst imaginable pain).[15,70]

4.5 NECK/SHOULDER EXERCISE INTERVENTION FOR NECK PAIN

Study IV: An experienced physiotherapist supervised a self-management neck/shoulder exercise intervention weekly with individual follow-ups including instruction and manual guidance. The exercises emphasized neck/shoulder movement control and included endurance-strength exercises. Instructed exercises were to be conducted twice daily, but once for those reporting no pain the previous three months, or on flying days. Each session lasted 10-15 min, included 2-4 exercises and allowed a pilot to perform the intervention independently of any clinic or stationary equipment (Figure 10).

Subjects received written instructions with pictures illustrating the exercises. Exercises were individually adjusted and progressed by the supervising physiotherapist. In subjects reporting ongoing pain at baseline, the exercises basically followed the procedure described by Jull and colleagues.[74] Progression went from isolated low-load to synergy exercises to endurance-strength exercises. Progression was based on the pilot's observed progress towards neck/shoulder movement quality rather than certain amount of sets and repetitions.

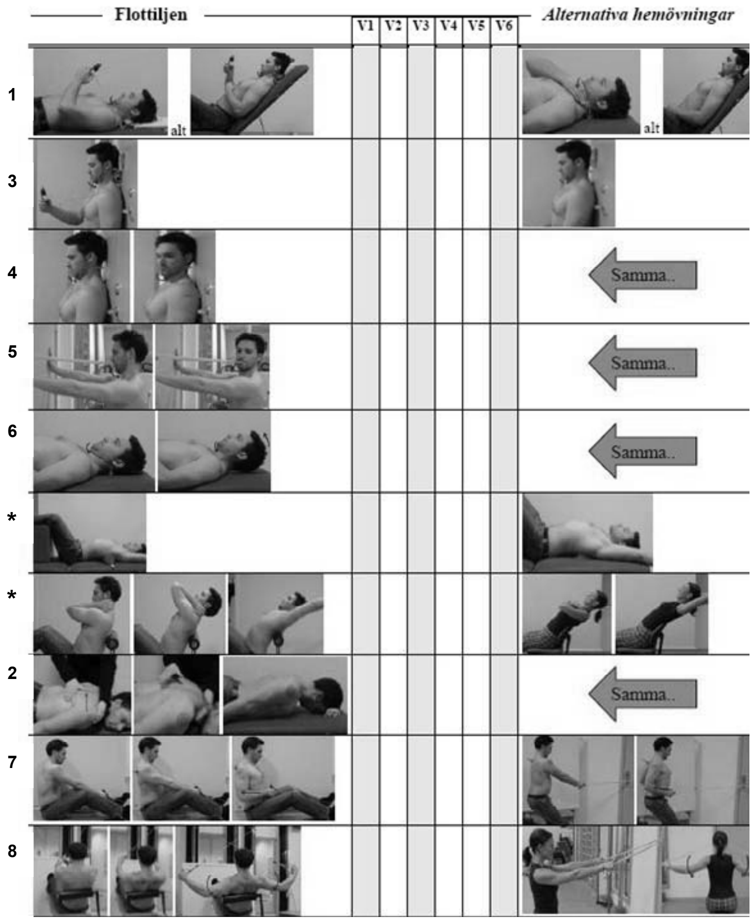


Figure 10. Overview of exercises used in the exercise group. Exercises in left column were intended to be conducted at the helicopter base, while exercises in the right column were alternatives to do at home etc. Arrows indicate that the same exercise could be conducted at either. Middle column (V1 – V6) shows week 1 to week 6 and was ticked by the supervising physiotherapist to show each pilot which exercises to do each week (the exercise group received the overview and each exercise in detail with written instruction and figure illustrated).

Isolated low-load exercises. 1) The participants were instructed and guided to perform active craniocervical flexion while trying to focus on maintaining surface neck flexors relaxed. Then they trained with low-load increment levels of active craniocervical flexion with feedback from the pressure sensor.[74] 2) Exercises for shoulder retraction aimed to target scapular muscles. Initially these muscles were guided/instructed by emphasizing movement control at a retracted- and mid-motion range in prone position.

Synergy exercises. 3) Seated subjects performed active craniocervical flexion and controlled shoulder retraction separately. 4) Synergy exercises were conducted with simultaneous scapular retraction, active craniocervical flexion and neck rotation. Subjects with current pain performed isometric low-load neck rotator exercise.

Endurance-strength exercises. 5) Seated subjects performed dynamic neck rotation exercises against moderate resistance using elastic bands (Theraband, Hygiene Corp, Akron, Ohio) which aimed to train flexor-extensor co-contraction. The subjects first slightly nodded the head, extended the head slightly and then rotated the head. 6) Neck flexor endurance was trained supine by first nodding the head and then lifting a little bit and hold it against gravity (for 30s or until perceived exertion was 5 “strong” on the Borg CR-10 scale.[16] 7-8) Scapular retraction was performed in ‘rowing’ exercises, emphasizing shoulder retraction in the initial concentric phase and upright trunk postures in the inner range. No maximal-load neck exercises were included.

*Thoracic stretching could also be instructed to those with thoracic symptoms.

4.6 EXPERIMENTAL PROCEDURES

4.6.1 Neck muscle strength

Study II: The subjects were familiarized with the DBC-140 equipment by performing a few submaximal isometric cervical contractions at a low torque level. Muscle strength (torque [Nm]) of neck extensors and flexors, respectively, was measured by encouraging the subject to press his head against the resistance pad with increasing force up to MVC. That was to avoid injury and artifacts such as sudden high values. Three trials were done with two minutes of rest in between. MVC was analyzed as the mean of the two highest neck-muscle torque values of three trials.

4.6.2 Electromyographic sampling during sustained neck muscle contractions

Study II: Neck muscle EMG recordings were made in sitting position (DBC 140). The median frequency of the myoelectric signal from the cervical extensors and flexors, respectively, was established during a 40s isometric fatiguing contraction. During these contractions the subject maintained a constant force (torque): 28 Nm for extension and 16 Nm for flexion (calculated as 50% of pilots' average strength, shown previously.[65])

Study III: Sustained isometric neck-flexor contraction was performed supine against the weight of the head, a resistance representing 35% of helicopter pilots' average neck flexor strength (calculated with available values[65,139]). A folded towel was placed under the head and the position of the head was standardized so that the craniocervical joint and the cervical spine were slightly flexed. After removing the towel, the subject was requested to hold the head in position for 30s while EMG signals were recorded.

4.6.3 Electromyographic sampling during active craniocervical flexion

Studies III and IV: With the subjects supine on a plank bed with the knees bent (crook lying), the craniocervical flexion pressure sensor was applied and the subjects were instructed and guided to perform active craniocervical flexion. They first practiced controlling the five pressure levels aided by the display. The instruction was: "slowly nod your head as if you were saying yes". Correction was made if necessary. Tendency to extend the head to substitute for the increments was prevented. Subjects then performed the active craniocervical flexion at five pressure increments (22-24-26-28-30 mmHg) and maintained the contraction for 10s while myoelectric activity was sampled. A mark was set in the recorded EMG sequence when the subject reached the target pressure level.

4.6.4 Neck active range of motion

The subject sat on a chair, and the CMS was applied. Then subjects performed each movement with a minimum of coupled movements: flexion, extension, lateral flexion left-right, and rotation left-right, and the active range of motion between neutral position and maximum angular displacement was recorded. Tendency to elevate/rotate shoulders/upper thorax to substitute for range of motion was discouraged.

4.6.5 Electromyographic data analysis

Studies II and III: EMG spectral characteristics (frequency domain) during the sustained neck extensor (*paper II*) and flexor (*papers II and III*) contraction were computed as the median frequency of the power spectrum[103] for consecutive 1-s intervals of the recorded signal. Hanning windowing was used prior to fast-Fourier transformation. The median frequency shift was analyzed with linear regression in the recorded sequence, and was normalized as the change in percent per second:

Normalized frequency shift (nf_{shift}) = $\Delta\text{Hz} \times f_{\text{initial}}^{-1} \times s^{-1} \times 100$

where f_{initial} = initial median frequency, defined as the intercept at $t = 0$ of the regression line. Mean values of the left and right are presented since there were no side differences.

Studies III and IV: Neck EMG activity (time domain) in sternocleidomastoid sampled during active craniocervical flexion was quantified as root-mean-square (RMS [µV]) values at rest (20 mmHg) and for each contraction level (22 – 30 mmHg) over a 1-s interval. This was windowed one second ahead of the point when the subject reached the target pressure level. It was then normalized as the percentage RMS of the reference contraction:

Normalized RMS (nRMS [%µV]) = $\text{RMS} \times \text{RVE}^{-1} \times 100$

where RVE = reference voluntary electricity, calculated as the initial RMS ($t = 0$ to $t = 1$ s) of the neck flexor contraction against the weight of the head when supine.

4.7 STATISTICS

The statistics methods used in this thesis (*papers I – IV*) are presented in Table 3.

Table 3. Statistical methods applied in the different studies. For further details, see *papers* I – IV.

Statistics applied	*Paper I*	*Paper II*	*Paper III*	*Paper IV*
Regression				
Cox regression (relative risk, RR)	**X**			
Logistic regression			**X** [a]	**X**
Simple correlation (*r*)		**X**	**X**	
Analyses of (co)variance				
Repeated-measures mixed model MANCOVA				**X**
Repeated-measures general linear model MANCOVA			**X**	
ANCOVA / ANOVA		**X**	**X**	
Non-parametric				
Non-parametric rank invariant method [134]				**X**
McNemar (Chi^2)				**X**
Mann-Whitney U test	**X**			**X**
Kruskal-Wallis test			**X**	
Effect size				
Attributable proportion (AP%)	**X**			
Cohen's f^2			**X**	

[a] Best subset using Akaike Information Criterion (AIC) autoregression

AP = $P(RR - 1) \times (1 + P(RR-1))^{-1}$, where P is prevalence

Cohen's $f^2 = R^2 \times (1(- R^2)^{-1}$

Ratio and interval data were pre-inspected with histograms and residuals, and tested for assumption of homogeneity of group covariance matrices. EMG data obtained during active craniocervical flexion (*papers III and IV*) were typically positively skewed and were log transformation before analysis. In addition, to estimate how well a polynomial trend captured within-subject change over the $nRMS_{22\text{-}30}$ course, a random coefficient model was fitted for this thesis (using the SAS PROC MIXED procedure). Here, the linear estimate was significant ($P < 0.001$). Thus, each subject received a linear $nRMS_{22\text{-}30}$ coefficient for further analyses in the logistic regression analysis (*paper III*). In study IV, an intention-to-treat procedure was followed (last-observation-carried-forward). A *P*-value equal or lower than 0.05 indicated significance.

5 RESULTS

5.1 PAPER I

5.1.1 Prevalence

The three-month prevalence of neck pain was 57% (72/127 respondents). The three-month prevalences of shoulder pain, thoracic pain and low-back pain were 35%, 16% and 46%, respectively. Of the 72 neck pain cases, 58% reported that their pain occasionally interfered with their flying duty, while 55% reported interference with leisure activity. However, of the 72 cases, 25% reported that they had never been on sick leave related to neck pain.

5.1.2 Risk indicators

Concerning flight-related indicators, use of NVG was the only flight-related risk indicator considered for further analysis ($P< 0.25$), RR = 1.8. Concerning individual indicators, history of neck pain, RR = 2.4, pain in closely-related regions, that is, shoulder pain, RR = 1.9, thoracic pain, RR = 1.6, and low-back pain, RR = 1.8, and in addition muscle strength training, RR = 0.7, were all below *P* 0.25 level and were thus considered for further analysis.

Six indicators were included in the initial regression model (Table 4). After reduction, history of neck pain (AP% = 21%) and shoulder pain (AP% = 17%) appeared as significant risk factors in the final model ($P < 0.05$). Albeit not significant use of NVG revealed a fairly large attributable proportion (AP% = 22%), while muscle strength training (AP% = 7%) showed a non-significant trend towards having a preventive effect. Thoracic pain (AP% = 5%) showed a weak association.

Table 4. Initial and final multivariate regression models. Adjusted relative risks (RR) for neck pain associated with risk indicators (univariate $P \leq 0.25$). Corresponding 95% confidence intervals (CI) and *P* values *(N* = 127).

	Initial model			Final model		
Indicators	RR*	95% CI	*P*	RR*	95% CI	*P*
Use of NVG (yes)	1.6	0.8 – 3.1	0.20	1.7	0.9 – 3.3	0.14
Muscle strength training (>1.0 h x wk^{-1})	0.6	0.4 – 1.0	0.07	0.6	0.4 – 1.0	0.06
History of neck pain (yes)	1.8	1.1 – 2.6	0.01	1.8	1.2 – 2.7	0.01
Shoulder pain	1.5	1.0 – 2.3	0.04	1.6	1.1 – 2.4	0.03
Thoracic pain	1.4	0.8 – 2.4	0.19	1.4	0.9 – 2.3	0.19
Low-back pain	1.3	0.9 – 1.1	0.28			

[*] Adjusted for age and smoking

5.2 PAPER II

5.2.1 Neck muscle strength

Figure 11 shows the mean and 95% confidence interval of neck muscle strength (MVC) of the neck extensors and flexors for fighter pilots and helicopter pilots, respectively. Analysis yielded effect for pilots x groups. Further post-hoc testing showed that fighter pilots with *frequent* neck pain episodes had significantly ($P < 0.05$) lower neck extensor MVC by 18% than their pain-free controls. There was no such effect for flexors, nor any effect between the helicopter groups or between fighter pilots' and helicopter pilots' pain-free controls.

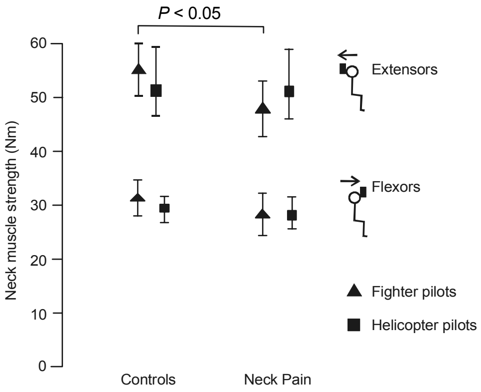


Figure 11. Isometric MVC for neck extensors representing fighter pilots (▲) and helicopter pilots (■), respectively, with *frequent* neck pain and pain-free controls. Error bars show weighted mean and 95 % confidence intervals.

5.2.2 Electromyography frequency spectral variables in sitting

Table 5 shows the mean EMG frequency shift and initial frequency for the neck extensors and flexors in fighter pilots and helicopter pilots obtained during sustained contractions in sitting position. There was no correlation between spectral parameters either for extensors and flexors, or for frequency shift and initial frequency. The ANOVA revealed no effect for fighter pilots with or without *frequent* neck pain for either frequency shift or initial frequency. In helicopter pilots, there was no effect for extensors, while an effect emerged for flexor frequency shift ($P < 0.05$), here showing that helicopter pilots with *frequent* neck pain had on average 35% less frequency shift (less negative) than their pain-free controls.

Table 5. Mean (SD) values for normalized surface EMG (sEMG) median frequency shift and initial median frequency obtained from sustained neck extensor and flexor contraction in seated position: fighter pilots and helicopter pilots with *frequent* episodes of neck pain and pain-free controls.

	Seated position		*(Paper II)*		
	Fighter pilots		Helicopter pilots		
Dependent variable	Neck pain (*N* = 16)	Controls (*N* = 14)	Neck pain (*N* = 15)	Controls (*N* = 15)	Between-group post-hoc, *P*
sEMG frequency shift					
Splenius capitis	- 0.47 (0.19)	- 0.54 (0.24)	- 0.55 (0.22)	- 0.49 (0.18)	*NS*
Sternocleidomastoid	- 0.76 (0.25)	- 0.77 (0.35)	- 0.52 (0.21) *	- 0.81 (0.24)	< 0.05
Initial frequency					
Splenius capitis	61 (15.7)	66 (14.7)	58 (12.4)	60 (15.6)	*NS*
Sternocleidomastoid	76 (11.1)	79 (13.4)	73 (13.6)	75 (12.1)	*NS*

NS, non-significant (*P* > 0.05)

5.3 PAPER III

5.3.1 Electromyographic frequency spectral variables in supine

Table 6 shows mean EMG frequency shift and initial frequency for the neck flexors in helicopter pilots obtained in supine against the weight of the head. There was no correlation between the parameters. ANOVA analyses for the three helicopter groups (*acute, subacute* and pain-free controls) revealed that there were no differences between the groups.

Table 6. Mean (SD) values for normalized surface EMG (sEMG) median frequency shift and initial median frequency obtained from sustained neck flexor contraction against the weight of the head in supine for the subject groups; *acute* (ongoing neck pain at time of testing), *subacute* (reported neck pain episode the three previous months), and pain-free controls.

	Supine position		*(Paper III)*	
	Helicopter pilots			
	Neck pain			
	Acute (*N* = 20)	*Subacute* (*N* = 27)	Controls (*N* = 25)	Post hoc, *P*
sEMG frequency shift				
Sternocleidomastoid	- 0.40 (0.21)	- 0.41 (0.25)	- 0.50 (0.19)	*NS*
Initial frequency				
Sternocleidomastoid	83 (12.7)	80 (13.0)	77 (10.6)	*NS*

NS, non-significant (*P* > 0.05)

5.3.2 Electromyographic activity during active craniocervical flexion

Figure 12 presents mean and 95% confidence intervals (CI) of the $\text{nRMS}_{22\text{-}30}$ for the three defined groups, *acute, subacute* and pain-free controls, respectively. A repeated-measures MANCOVA revealed a significant main effect for groups and stages of nRMS (score from mFABQ as covariate). There was no interaction effect for group x stages. Further post-hoc testing showed that both the *acute* group and the *subacute* group had higher sternocleidomastoid $\text{nRMS}_{22\text{-}30}$ (*acute* vs. controls: $P < 0.01$; *subacute* vs. controls: $P = 0.01$) by on average 127% and 73%, respectively, than pain-free controls. No differences were revealed between *acute* and *subacute* groups.

In addition, when stages were modeled as a linear regression variable for between-group comparison, the *acute* group indicated a significantly steeper linear nRMS coefficient than the controls did, $P < 0.05$, while there were no other between-group effects.

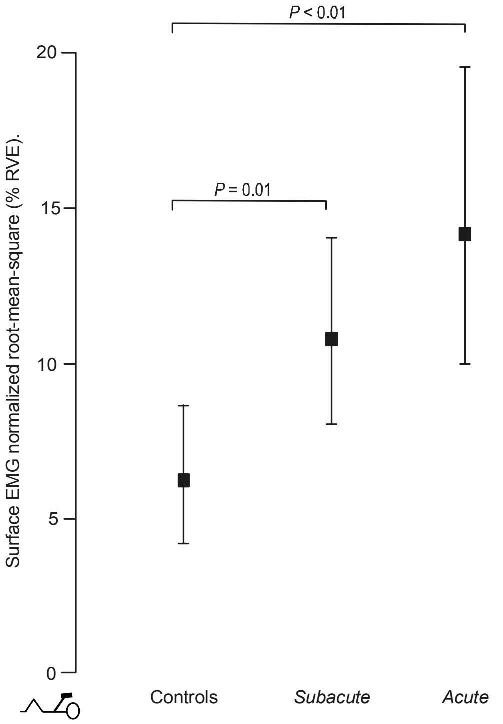


Figure 12. Mean EMG normalized root-mean-square (nRMS) values for sternocleidomastoid for the three groups (*acute*, *subacute*, controls) for the five stages of craniocervical flexion (22 – 30 mmHg induced from a pressure sensor behind the subject’s neck). Values are geometrical means after subtracting rest RMS.

5.3.3 Neck active range of motion

Table 7 shows the mean neck active range of motion measurements in flexion-extension, axial rotation and lateral flexion. The MANCOVA yielded a main significant effect (age as covariate). A univariate effect was revealed for flexion-extension and axial rotation, but not for lateral flexion. Post-hoc testing showed that the *acute* group, as compared to controls and the *subacute* group, had less flexion-extension and rotation ($P < 0.01$). There were no differences between *subacute* and controls.

Table 7. Mean (SD) values for active range of motion in sitting for subject groups; *acute* (ongoing neck pain at the time of testing), *subacute* (reported neck pain episode the three past months), and pain-free controls.

	Helicopter pilots			
	Neck pain			
	Acute (*N* = 20)	*Subacute* (*N* = 27)	Controls (*N* = 25)	Post hoc, *P*
Neck active range of motion				
Flexion-extension (°)	113 (13)	126 (15)	127 (12)	< 0.01
Axial rotation, left-right (°)	132 (20)	148 (13)	148 (12)	< 0.01
Lateral flexion (°)	64 (14)	73 (12)	72 (14)	*NS*

NS, non-significant

5.3.4 Fear-avoidance beliefs about physical activity

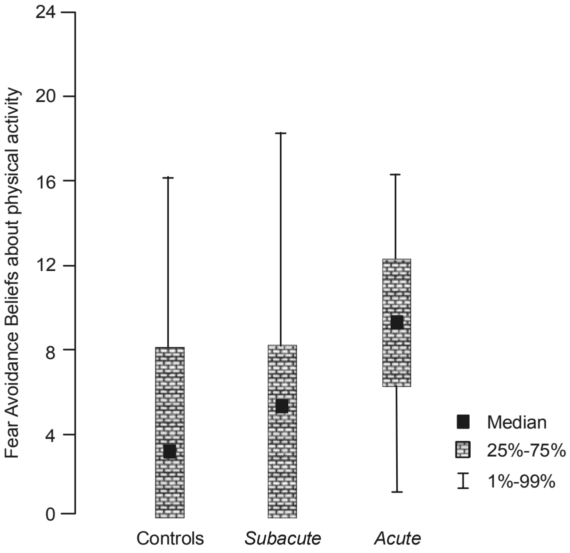


Figure 13. Median and 25% - 75% percentile range values of rated fear-avoidance beliefs about physical activity for the three groups, *acute* (*N* = 20), *subacute* (*N* = 27) and controls (*N* = 25).

Figure 13 shows median and 25% - 75% percentile range values of rated fear-avoidance about physical activity. The Kruskal-Wallis test revealed an overall effect. Post-hoc showed higher fear-avoidance in the *acute* group than in controls ($P < 0.01$), while there were no other differences significant at the confidence level chosen.

In addition, to discriminate neck pain (*acute* and *subacute* clustered), a logistic analysis was conducted using five regressors: nRMS$_{22\text{-}30}$ linear coefficient obtained from the random coefficient model (coefficient of the five stages), initial frequency, frequency shift, active range of motion in axial rotation, and score from fear-avoidance beliefs. Logistic regression revealed the best-fitting model for nRMS coefficient, frequency shift and active range of motion (sensitivity/specificity = 87%/50% [cut-off value 0.5]). nRMS coefficient combined with active range of motion revealed the highest sensitivity (96%) however, specificity was low (40%). Stepwise forward and backward elimination regression suggested that the nRMS coefficient was the most significant regressor for predicting neck pain.

5.4 **PAPER IV**

No complication associated with the intervention was reported post intervention. Overall mean compliance with the prescribed intervention was 77%.

5.4.1 Adaptational electromyographic activity

Figure 14 presents the change in $nRMS_{22-30}$ from pre- to post-intervention for the exercise and control group, respectively. A repeated-measures mixed model MANCOVA procedure (fear-avoidance score as covariate) showed an interaction effect for follow-up x group x nRMS-stages. Post-hoc analyses showed that at week seven the exercise group had significantly decreased $nRMS_{30}$ sternocleidomastoid activity compared to controls ($P = 0.01$), revealing a mean reduction of 46% $nRMS_{30}$, while controls reduced by 17%. In addition, there was a trend towards reduction in $nRMS_{28}$ ($P = 0.07$), indicating a reduction of 43% $nRMS_{28}$.; controls by 21%. There was however no effect for lower stages, i.e. $nRMS_{22-26}$.

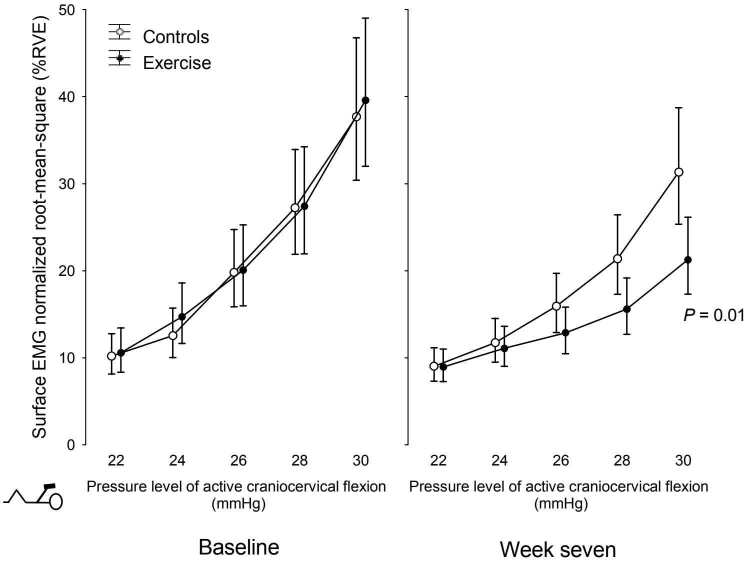


Figure 14. Mean and 95% confidence interval surface electromyographic activity (normalized root-mean-square) for sternocleidomastoid at each stage of active craniocervical flexion, 22 – 30 mmHg (pressure from an air-filled sensor placed behind the neck). Graphs illustrate the change in muscle activity from baseline to week seven; control group (controls) and intervention (exercise) group. Values are geometric means.

5.4.2 Adaptational fear-avoidance beliefs about physical activity

Table 8 shows the median change in fear-avoidance from baseline to the month-12 follow-up. In the exercise group, a within-group reduction from baseline to week seven was apparent ($P < 0.01$), while baseline-to-month-12 was somewhat less significant ($P < 0.05$) (non-parametric rank invariant method[134]). However, in the control group, a change was indicated at week seven ($P < 0.05$); although not at month 12. The Mann-Whitney U test revealed no between-group differences at week seven, nor at month 12.

Table 8. Median (min – max), [mean (SD)], scores for fear-avoidance beliefs about physical activity (mFABQ) at baseline, week seven and month 12; intervention group (Exercise, n = 34) and control group (Controls, n = 34).

Fear-avoidance beliefs	Group	Baseline	Week seven	Month 12
mFABQ	Controls	6.5 (0 – 18) [6.7 (5.4)]	3.5 (0 – 18) [5.1 (5.3)]	5.5 (0 – 21) [6.1 (5.9)]
	Exercise	6.0 (0 – 17) [6.5 (5.6)]	1.0 (0 – 20) [4.4 (5.7)]	1.5 (0 – 17) [4.0 (4.9)]

mFABQ (score range 0 – 24): higher score indicates greater fear-avoidance beliefs about physical activity.

5.4.3 Effect of exercise intervention on number of neck pain cases

In the exercise group, the proportion of cases the previous three months decreased by 42% (26/34 to 15/34), while in controls it was unchanged (21/34 to 21/34). Logistic regression revealed that the exercise group had a significant reduction in neck pain cases as compared to controls ($P < 0.05$).

In the exercise group, analysis of predictors of reduction in neck-pain cases showed that general muscle-strength training for more than one hour per week at the time of study allocation was the only variable that approached a P level lower than 0.05 for reduction. This result indicated that those who trained more at baseline were, at the 12-month follow-up, associated with a good outcome, i.e. pain-free the previous three months. Clustering all 68 subjects (exercise and controls together), we found no significant predictor.

In addition, EMG change from baseline to week seven was traced retrospectively in the exercise group using results for cases at the month-12 follow-up. Cases that improved, i.e. pilots that rated neck pain at baseline but not at the 12-month follow-up, reduced their $\text{nRMS}_{22\text{-}30}$ by on average 41%, while other exercise members (those who become new cases remained healthy/cases) reduced it by 37%. Clustering all 68 subjects (accounting exercise and control group together), cases that improved reduced their $\text{nRMS}_{22\text{-}30}$ by on average 36 % while other subjects reduced by 25 %.

6 DISCUSSION

The research presented in this thesis focused on potential functional limitation in air force pilots who experience neck pain. The approach involved observational methodology including a survey and experimental clinical trials considered from a physiotherapy perspective. A main finding was that a neck/shoulder exercise intervention had a positive preventive effect among air force helicopter pilots and that pilots with acute ongoing neck pain and those with subacute neck pain had greater surface neck flexor activity than those without such previous pain. Figure 15 offers a simplified over-view of the research progress.

A time frame of three months was used in the definition of neck pain, but the definition was further operationalized for the purpose of studies II and III. The inclusion criteria were in addition progressively narrowed as new a hypothesis became established throughout the research progress. This points to the complexity to define neck pain; after all, it is a subjective sensation that may differ much between two individuals,[13] although both may fit in the same "well-defined" study group.

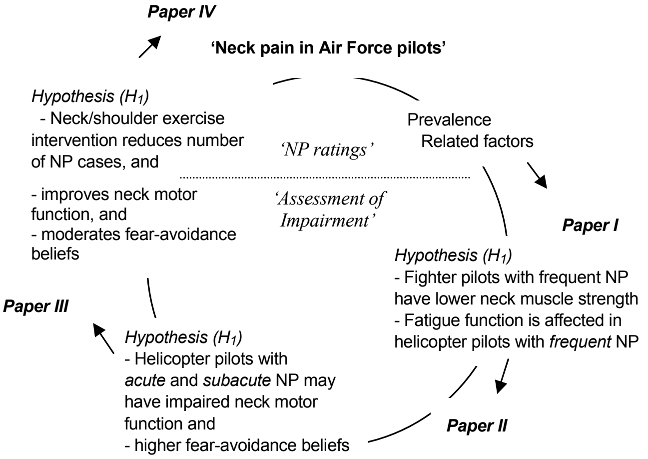


Figure 15. Overview of research progress in the present work. NP, neck pain (note: the figure reflects a state of mind regarding the present research rather than a complete conceptual model).

6.1 FINDINGS

6.1.1 *On risk factors*

The neck pain prevalence of 57% was considered high, but corresponded essentially to previous reports of relatively high neck pain rates in helicopter pilots[19] and fighter pilots.[3,107,144] It was also high compared to the one-third in the general population who on average report neck pain in the course of a year.[50] However, in the latter review-study the one-year prevalence was found to range between 17% to 75% and, surprisingly, Scandinavian countries reported somewhat higher mean estimates than did other countries in Europe and Asia. About half our neck-pain cases reported that their pain interfered with their flying duty and leisure, while only a quarter rated "never" being on sick leave related to neck pain. While we have found no such previous data for helicopter pilots' neck pain, these findings correspond to some extent with those of other studies surveying helicopter pilots' *back* pain disability and the consequence for flying.[19,137] Whereas these questions simply concerned "no/yes", anecdotal information from the respondents concerned shortened sorties, changed nature of sorties, or avoidance of flight duty for desk jobs, etc. This item may therefore be ascribed to interference with flying *duty* rather than flying missions specifically. Together these points offer a message on the importance of early prevention in this population.

The most important risk factor for neck pain was previous pain episodes. Type of helicopter flown and flying hours were not associated. An Australian survey on helicopter pilots' back pain[137] found similar results. Moreover, in the general population, several studies reveal that previous neck pain[32,57,90,100,129] and pain in closely related regions[32,100,129] is associated with neck pain. Granted, findings that previous pain predicts further pain could possibly reflect the fact that neck pain is long-term or recurrent; and this applied to our helicopter pilots as well. Concerning head-worn equipment, technical reports[56,67] and generally held hypotheses suggest NVG as a contributor to neck pain. However, use of NVG was not significantly associated here. Biomechanical calculations[139] and experimental EMG measurements done in our group[140] have shown a tendency for NVGs to add to the pilot's neck workload, but head-and-neck posture appeared more important. These two factors of course interact during flight and should therefore be investigated more closely *in vivo*. Such investigation could map EMG values from the functional movements of pilots when giving full attention to flying their helicopter. The information so gained may be useful since new equipment in use is heavier, and future demands on night-vision-aided flight are on the increase.

6.1.2 *Neck motor function*

Surface sternocleidomastoid EMG measurements during active craniocervical flexion showed greater activity in both the *acute* group and the *subacute* group, by on average 127% and 73%, respectively, than in controls. There were no significant differences between the *acute* group and the *subacute* group. This tallies with findings using comparable methodology in subjects with whiplash-associated disorders[132] and non-specific neck pain.[75] So further investigation of the direction of cause-and-effect is warranted, particularly since testing and training that trace neck-muscle activation in subjects with neck pain syndromes is relatively widespread in the clinic.

Although the sternocleidomastoid lacks the mechanical advantage to assist during craniocervical flexion,[145] minor activity may be expected since the central nervous system uses complex activation strategies.[146] Minor activity obtained in pain-free subjects is shown in Figure 12, where pain-free controls activate their sternocleidomastoid to, on average, 7% of what is required for a standard head lift in supine. However, pain may interfere with motor control.[89] In response to experimentally-induced muscle pain, reorganization of arm and shoulder muscle EMG activity during dynamic exercise has been indicated,[39] as well as during isometric tasks against moderate load.[127] This supports the hypothesis by Lund and colleagues[97] of an inhibition of motor neurons to the agonist muscles and simultaneous excitation of motor neurons to the antagonist muscles. Hypothetically, the greater sternocleidomastoid activity found in the present studies *may* indicate inaccuracy in neck-flexor motor coordination, perhaps in synergy with deep neck muscles as previously suggested.[48] This should be further investigated in other more functional tasks using multiple agonist-antagonist electrode placements.

Scores on fear-avoidance beliefs were related to sternocleidomastoid activity, albeit weakly. Such co-linearity between fear of movement (recorded with the Tampa Scale of Kinesophobia) and upper-trapezius activity has previously been found during a submaximal isometric task in civilians with neck pain after motor accidents.[105] This suggests, however, that complex psychophysiological mechanisms may be associated with perceived neck pain, possible influencing both motor control and movement behavior. Important, this: the fact that no group difference was evident between the present *acute* and *subacute* groups possibly implies that altered muscular function exists independently of a stage of *acute* ongoing neck pain. Whether this reflects an inability to resolve motor activity after pain relief should be further followed.

Analyses of EMG frequency spectral variables showed that helicopter pilots with *frequent* neck pain had about 35% lesser frequency shift than pain-free controls in sternocleidomastoid during sustained flexor contraction when sitting. There were no differences between the fighter pilot groups; nor was there any significance for helicopter pilots with *acute* and *subacute* neck pain as compared to controls when supine, although shifts were somewhat less in these pain groups. This smaller frequency shift in subjects with pain has, in contrast to others' findings,[46,54] also been observed in other populations using low-load sustained contractions[77] during dynamic tasks;[99] and in back-pain subjects.[38,88] However, the present results suggest that a less localized EMG frequency shift may reflect impaired neck muscle motor functioning in subjects with pain, while not relating significantly to neck muscle fatigue. Our EMG fatigue results for sternocleidomastoid lacked corresponding differences between the fighter pilot groups, and this may be taken to mean that flight-induced neck pain is caused or triggered by different limitations in neck muscle function, perhaps due to the different external loading. This would need further investigation.

Regarding neck muscle strength, mean extensor MVC for the fighter pilots' pain group accounted for 18% lower strength than their controls, while there were no significant differences for flexors. Nor were there any differences between the helicopter groups, whose overall strength resembled fighter pilots'. Oksa and colleagues[112] showed by measuring neck MVC between repeated high G_z flight sorties that MVC decreases. Using *in vivo* flight EMG measurements, they also showed that repeated G_z loadings cause muscle fatigue, and this was particularly pronounced in the neck region as compared to other body regions. However, the lower MVC found in fighter pilots with *frequent* neck pain could possible reflect insufficient ability to counteract and stabilize the head and neck at the high external loadings induced during flight. Compared to a study using the same measuring device but with civilian subjects,[117] our pilots appeared stronger, especially in their flexors. Such greater strength balanced to advantage for flexors as compared to those of non-flying controls was also found by Alricsson and colleagues[5]. An Australian study[24] investigated neck muscle strength response to eight months' exposure to flying jet aircraft with moderate G_z capacity. The sample of nine pilots showed an increment only in neck flexor strength. Hypothetically, while less neck extensor strength in fighter pilots may reduce functional capability during high G_z flight, effects on neck muscle strength from flying in high G_z environments may be greater on neck flexors as measured as peak isometric MVC. This is because neck flexors are *occasionally* recruited to a great level during flight,[111] that is, to counteract head-and-neck external load in certain positions. Extensors, on the other hand, fairly continuously control head movements and head center-of-mass positioning in front of the motion axis of the cervical spine. Neck flexors may thus be activated more in sequences, as usually occurs in "normal" strength training, while extensors are, rather, exposed to gradual muscle strain. It would be interesting to see how this speculation applies in future research.

The active range of motion in axial rotation and flexion-extension was 11% less in the *acute* group than in the *subacute* group and the controls. Reduced range of motion in the sagittal and horizontal planes has also been reported in other neck-pain populations.[59,132] While such reduced active range of motion in subjects with ongoing neck pain could be expected to relate somewhat to fear-avoidance, no such relationship was found. Concerning fear-avoidance, it will be interesting to further follow the importance of this variable and whether it relates to other factors involved in neck (or back) pain, especially since such beliefs may predict further pain.[92]

6.1.3 *Exercise intervention*

Results indicate that the present neck/shoulder exercise intervention can reduce the number of neck pain cases over 12 months in helicopter pilots. The results are in line with clinical investigations of the positive effects of muscle control exercises in non-military subjects with neck pain disorders[27,135] and cervicogenic headache.[76,143] Importantly, compliance was considered acceptable (77%), making this a potentially realistic intervention option for the present population. Exercise members showed reduced sternocleidomastoid activity as observed post intervention during active craniocervical flexion in supine. Tracing cases at the 12-month follow-up retrospectively on EMG showed no clear differences between cases that improved and the rest, partly – it is believed – indicating the difficulty of such backward linking analyses. However, at week seven, controls also exhibited some reduction. For this reason, only the highest contraction level reached statistical significance in the present results. Several studies reveal higher surface neck flexor EMG activity in subjects with pain,[75,132] but there seems to be no investigation that follows whether exercise may reduce such activity. Such reduction of surface neck-muscle activity may result in more efficient, or accurate, neck muscle recruitment, hypothetically increasing the endurance time for perceived neck muscle fatigue or pain during flight. However, the present results are limited to the task performed supine, i.e. it is not known whether the results transfer to other posturally-dependent tasks.

Fear-avoidance about physical activity was somewhat reduced in the exercise group, but no between-group differences emerged. Such beliefs have previously been found to predict future spinal pain episodes in civilian subjects[92] and may reorganize neck muscle activity as shown by EMG.[105] However, the failure to reach significance may be because participants were enrolled from the population, rather than from clinics; and because pilots had low initial scores as compared to the general population.[22,92] Future preventive exercise intervention for neck pain may address the phenomenon of fear-avoidance beliefs more directly. Analysis of early predictors in those allocated to the intervention showed that general muscle-strength training had a predictive value for reduction in number of cases. Perhaps pilots who perform strength training more regularly could more efficiently incorporate the intervention with their daily routine.

A logistic regression entering EMG variables, range of motion and fear-avoidance suggested that sternocleidomastoid EMG activity during active craniocervical flexion was the strongest predictor o neck pain. While the EMG activity (coefficient of the five stages) was the strongest predictor of neck pain, logistic regression showed generally high sensitivity for different combinations (87% – 96%), but specificity was low (40% – 54%), admitting a probability of false classification of neck pain when using the test at an *individual* level.

6.2 METHODOLOGICAL CONSIDERATIONS

Several methodological considerations require attention when interpreting the present findings and concern validity and precision.

6.2.1 External validity

External validity concerns the extent to which results may be generalized to other population in other places.

Since subjects were recruited from pilots on operational duty, external validity extends to pilots on active flying duty but not to subjects seeking care. This limitation was felt to be essential in the present work since the aim was to study the phenomenon of pilots' neck pain in the field of early prevention. This was particularly so in view of our experience that pilots rarely seek care for their neck problems, and hardly ever go on sick leave.

Comparing demographics, the present samples were essentially similar to other Swedish studies investigating fighter[5,118] and helicopter pilots[138-140] as well as other international studies investigating military aviators.[10,55,137] While caution should always be exercised when generalizing findings to other populations, we find no reason not to extend the main findings to other modern air forces. The findings reported in this thesis may also be of interest for many other helicopter populations, particularly those flying with NVGs, e.g. the Navy and the Police.

6.2.2 Internal validity and precision

Internal validity is the extent to which an experiment actually measures what it is supposed to measure, while precision refers to the degree of reproducibility.

Design: A limitation in cross-sectional studies is the difficulty of drawing conclusions about the direction of causality. This must be considered when interpreting the present results. It would have been optimal to have data from early pilot selection screening tests, but such material on the neck is limited and was not available for the present work. Regarding sample size across the studies, this was satisfactory for the purpose of the specific study aim. However, in study IV we had hoped to have fewer losses to follow-up (6% at week 7 and 18% at month 12). Part of this loss may be explained by the national reorganization of the Swedish Armed Forces that took place during the study period. This involved some pilots in moves to other parts of Sweden. Along with shortage of research funds, this was also the main reason why we could not collect EMG data at the month-12 follow-up. However, the intention-to-treat approach (forward procedure) most likely affected the present results concerning effects on the proportion of neck-pain cases from baseline to month 12. Considering the results, i.e. exercise members that rated neck pain became fewer and controls that rated neck pain did not, this may theoretically have caused an underestimate of the intervention. A complement regression analysis on baseline data, including EMG and fear-avoidance, revealed no differences between subjects included in intention-to-treat and those who completed the follow-up. Relevant for clinical application, the loss to follow-up was equal between the groups. However, although it is not possible to give a definitive answer as to whether these subjects would actually have affected the results in either direction if data had been available, it was felt that the conclusion still holds good.

Selection bias: Subjects recruited non-random direct from the helicopter bases (*papers III and IV*) flew helicopters MBB BO 105 CB-3 (HKP 9) and Agusta A 109-E (HKP 15) more than those recruited at the Aeromedical Centre (*papers I and II*). These aircraft were the main types in operation at the largest of these bases. These aircraft were more commonly flown with NVGs, and this sample therefore differed somewhat from the samples recruited at the Aeromedical Centre. Given the nature of the experimental trial in studies III and IV, this may have affected the results. The sample could perhaps more correctly be described as "helicopter pilots on active flying duty that commonly fly with NVGs". Further, some of the helicopter pilots recruited for studies I and II at the Aeromedical Centre may later have been recruited to studies III (and IV) at the local bases. Since the periodical examinations at the Centre are based on number of years on duty, and this applies to all pilots employed in the Swedish Air Force, such re-participation ought to be random. Although it is unknown why some pilots chose not to participate, these were few and the experience is that most pilots want to participate since they are interested and concerned about their work and its known overall risks.

Exercise intervention: The intervention was basically based on knowledge gained during the period of the studies, from our previous clinical experiences and evidence from the general population.[72,76,79] While developing the intervention we sought helicopter pilots' opinions on what was practicable as regards their duty. It was clear that an everyday exercise intervention must be time-effective and flexible, and we aimed as far as possible to achieve this. Here, importantly, regimen compliance at 77% was considered acceptable, and the intervention was considered potentially realistic in this population.

A difficulty of controlled trials using untreated controls is that subjects allocated to controls are withheld the intervention. For the present purpose (*paper IV*) the effect of the intervention was unknown at the time of study entry and all subjects were free to seek care in any matter. Controls were also offered the exercise intervention after the intervention period, but only a few asked for exercises. This, probably, reflects the pilots' beliefs that the study was still going on. It is not known, however, whether the somewhat positive effects that emerged in controls on surface sternocleidomastoid activity and fear-avoidance may be ascribed to "cross-talk" exercises that control members may have done during the trial, although analysis showed that there was no change in their overall time spent on physical training. The observed effect in controls may also, in part, reflect attention from the research team, including encouragement by medical personnel to continue with ordinary training.

EMG: With surface electrode recording technique, signals are likely to be collected from other nearby muscles than those overwhich they have been applied. The present aim was not to selectively record signals from a specific muscle, rather to collect signals from a muscle group, i.e. neck extensors and flexors. Here, the electrode placement was located as previously defined,[41,138] and we sought to follow procedure and recommendations for sensor placement.[69] Signals for extensors, with electrodes overlying the upper neck splenius capitis, may have included signals from e.g. semispinalis. Concerning the flexors, the sternocleidomastoid is a relatively well defined muscle, although it cannot be ruled out that signals picked up with the recording technique from the sternocleidomastoid may have included activity from deeper layers, and that such activity may have been included in the testing of active craniocervical flexion. This does not however change the conclusion that helicopter pilots with acute and subacute state of neck pain had higher surface sternocleidomastoid activity than controls, but should be considered when comparing lower levels of contraction to higher. This, along with better accuracy of data, was the reason for estimating the linear coefficient obtained from the five active craniocervical flexion EMG values for further analysis in this thesis.

Further, amplitudes obtained from active craniocervical flexion testing were normalized and expressed as a percentage of a submaximal reference voluntary electrical activation, %RVE (head lift in supine), a method previously used for normalizing the superficial neck flexors in this test.[75,132] Although such relative values do not reflect maximal effort, or %MVE, this was felt to be most appropriate for addressing the present study aim, particularly since the sample included subjects with ongoing pain. This aspect was also considered when choosing level of load relevant to the frequency measures. Here, the 30s contraction interval in study III, as compared to 40s for sitting in study II, was chosen since a time frame of 30s had appeared sufficient for measurement stability in another study from our group prior to the present study III.[138] EMG initial median frequency is a useful variable when normalizing the slope of the median frequency as used here, thus eliminating possible differences between subjects in subcutaneous tissue structures.[12] The initial frequency variable itself seems to have good reliability,[138] and high discriminatory power between low-back pain patients and healthy subjects.[38] However, questions about its validity remain. As regards test position, while the upright test postures, resembling those of a pilot while flying, were considered to be optimal, the supine test against the weight of the head, used out at the local bases (*papers III and IV*), was most practical and did not require extra equipment.

Questionnaires: The questionnaire used in study I was originally developed[65] through items derived from the Nordic Musculoskeletal Questionnaire.[86] It had not itself been tested properly for precision, although the items used indicated good stability (unpublished data). However, the questions used were subjected to a face validity procedure including pilots. It has also previously been found useful when studying neck problems in the Swedish Air Force.[4,5] Along with international partners we are now developing an international questionnaire for use with military pilots, one that that aims to tackle more accurately the issues related to flying, but also work-related issues *not* related to flying. Further, although the modified Fear-Avoidance Beliefs Questionnaire has been used with subjects with and without neck and back pain,[22,53,92] and seems to correlate with the original version,[92] we have found no proper investigation if its precision. In addition, it is unknown how valid results from the general population would be in the present population: Precision should be investigated with pilots before further use.

6.3 GENERAL DISCUSSION

The present work contributes to existing knowledge of how functional impairments occur in air force pilots with neck pain. Such knowledge was found to be limited in the initial phase of the present research, although several authors had addressed the importance of preventive neck muscle exercise prevention.[3,6,67,83,144] Measures used concerned largely impairments at body-function level. The present results should therefore be interpreted in the light of these limitations rather than covering various dimensions of disability in an biopsychosocial approach.[124] According to the ICF classification, the present approach to the pilots' impairments may be interpreted to mean that the problem lies with the pilot. As mentioned in the Introduction, the focus is necessarily on the individual since cabin ergonomics in many military aircraft is unfortunately not very susceptible to change, and several of these aircraft will still be operational for many years to come.

An important thread running throughout the present research was that a helicopter pilots' previous neck pain was associated with present pain (*paper I*), that pain-free episodes in pilots that reported neck pain were found with altered EMG motor function (*papers II and III*), and that this was sometimes alleviated with neck/shoulder exercise (*paper IV*). Here, prospectively, it would be interesting to further see whether altered activity may predict further episodes. Given such a hypothesis, it seems feasible to reduce such activity with the present neck/shoulder exercises, and recurrence could be targeted more explicitly.

How to define good improvement in the context of prevention? As discussed under Findings, one-third of the general population seem to suffer from neck pain in a year.[50] A challenging question is whether a reduction to one-third in the course of a year should be considered of preventive significance in our pilot population, or should a lower prevalence be expected? It is believed that pilots on active flying duty and commonly flying with NVGs cannot be expected to have lower a prevalence than that in the general population. While being improved, or "being better"[13] could certainly mean different things for different individuals,[13] preventive action in the air force should include encouraging pilots to take an active role in their own health. This is a cornerstone of physiotherapy interventions[123] and concerns the importance of coaching. It is hoped that the present findings can elucidate this particular field and facilitate further research into neck pain.

6.3.1 Future research

Neck pain in air force pilots is a challenging medical problem. The work reported in this thesis has identified areas in which more research is warranted.

There is a need for

- studies of the causality between altered neck motor function during pain-free episodes and further episodes of neck pain,
- further *in vivo* flight investigation of the relevance of movement behavior and perceived fatigue to in-flight neck pain,
- further investigation of sensitive and clinically useful screening tests to predict neck pain, including fear-avoidance beliefs,
- exercise intervention-trials tailored for *fighter* pilots that includes requirements for accuracy of movement control before adopting strengthening exercises,
- an international collaboration project to collect knowledge for developing management guidelines for the prevention of neck pain in air force pilots. Such collaboration should consider a biopsychosocial approach,
- in the long term, cabin ergonomics in military aircraft should receive more attention, particularly in view of advances in aircraft performance and demands for more personal equipment, as well as longer missions.

6.3.2 Clinical implications

The message of this thesis is that early prevention for neck pain is helpful in the air force. It seems that such prevention should start early in the pilot's career. An exercise intervention that emphasizes neck and shoulder motor control and movement quality could be used in helicopter pilots. The results suggest that fighter pilots in particular should train strengthening neck exercises. Overall, the work provides some evidence of the importance of observing any aberrant activity of superficial muscles and inspecting movement quality when examining patients' or pilots' performance status.

7 CONCLUSIONS

- Neck pain was common in air force helicopter pilots. An episode of previous neck pain was the strongest risk factor. Of those experiencing neck pain, about half reported that their pain interfered with their flying duty and leisure time activities.

- Helicopter pilots in an acute ongoing phase of neck pain as well as those in a subacute phase had increased surface sternocleidomastoid activity as compared to pain-free controls when performing active craniocervical flexion in a supine position.

- Fighter pilots with frequent episodes of neck pain have lower neck extensor strength than pain-free controls, possibly indicating an inability to protect and stabilize the head and neck in high-G_z environments. Such strength differences were not apparent between helicopter pilots with frequent neck pain and those without.

- In sitting, less EMG frequency shift in the sternocleidomastoid muscle was obtained during sustained contraction against moderate load in helicopter pilots with frequent neck pain. This may reflect impaired neck muscle fatigue function rather than degree of fatigue.

- Helicopter pilots with acute ongoing neck pain had reduced neck range of motion and rated higher fear-avoidance beliefs about physical activity than pain-free controls did.

- A supervised neck/shoulder exercise intervention had a positive preventive effect in reducing neck pain cases in helicopter pilots. Exercise members reduced their surface sternocleidomastoid activity to some extent, but there was no effect on fear-avoidance beliefs about physical activity. The intervention may be used for early prevention in helicopter pilots.

8 ACKNOWLEDGEMENTS

The people who have helped me in this work are too many to be mentioned here, though all are thanked. I would like to express my sincere gratitude in particular to:

Karin Harms-Ringdahl, my main supervisor. Thank you for taking me under your wing. You introduced me, you supported me, and you were always there when I needed you; that really count. Thank you for sharing your broad scientific knowledge and for thoroughly guiding me through the research process: thank you for believing in me,

Jan Linder, my co-supervisor, for your great support; for sharing your profound knowledge while keeping both feet firmly on the ground. Thank you also for friendship, good laughs; and for your belief in me,

Andreas Monnier, co-author and friend. Thank you for your great clinical skill, for the hours and days you spent with “doggy jobs with questionnaires”. Thank you also for the “disagree!” discussions that kept us awake when traveling between Stockholm and Linköping,

Marcus Thuresson, my fellow researcher and co-author, for all discussion and support. Thank you also for statistical advice, sharing many good moments. I miss you in our group,

My closest colleagues and friends, Annette Heijne, Birgitta Nordgren, Charlotte Lünning-Bergsten, Elena Tseli, Wim Grooten, Jan Johansson and Maria Hagströmer, for being such true friends, for good laughs and for being there for me,

Lena Nilsson-Wikmar, our second-in-command, for supporting me and for generously providing departmental time for me,

Helga Hirschfeld: thank you for being so kind and considerate. It has meant the world at the very end of this writing. I will never forget that. Thank you also Ingrid Claesson for being there for me, cheered me up,

My colleagues at the research lab for support in the final stages,

Wim Grooten, again, for your never-ending support. Now I look forward to further “unfruitful” discussions that end late,

Elisabeth Olsson, for being generous and putting faith in me,

My research group: Helena Larsson, Britt Elfving, Anna Tollbäck, Lisbeth Broman, Margareta Hansson, Inga Arvidsson, Christina Olsson, Catharina Bexander and all you others who asked valuable questions and supported me, Tim Crosfield, for great support, for always being there when needed. Thank you in particular for your fantastic support towards the end of this work; quite beyond words! Thank you also for wise English-language revision and for humor,

All my dear colleagues and the staff at the Division of Physiotherapy for your cheerful support,

Berit Lennström and Solvig Asplund for friendship and for being there for me,

Elisabeth Berg, statistician, for your great skill and support through the years,

My mother, father and sister. You are my castle. I'll soon be back with you,

Emma Måndroppe, my fantastic wife. I can't express how much you mean to me. Though I can't pay you back the time I stole from us, I'll do all I can do to show my true gratitude,

Noah, our son. Like in the song, "the day you were born was the first day of my life".

I would further like to express my great appreciation to the pilots themselves. They freely gave their time and volunteered to participate in the studies. Without their great interest and will to take part, the project would never have flown.

The staff of the Aeromedical Centre, Stockholm, thank you for all your support and kindness in tailwinds and headwinds.

The staff of the Base Medical Service at the Eastern Naval Base and Malmen Air Base, Swedish Armed Forces, for making research accommodation available and for administering the questionnaires.

Financial support for the work underlying this thesis was gratefully received from the Swedish Defense Research Agency (FOI) and from Karolinska Institutet.

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