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Musculoskeletal disorders in Swedish military aircrew

Screening and clinical examination of the cervico-thoracic region

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Umeå 2021

Dissertation for PhD
ISBN: 978-91-7855-713-4 (print)
ISBN: 978-91-7855-714-1 (pdf)
ISSN: 0346-6612
New series number: 2167
Cover design by Fredrik Brännström, Fredrik Brännström design AB, Stockholm
Electronic version available at: http://umu.diva-portal.org/
Printed by: Cityprint i Norr AB
Umeå, Sweden, 2021

To Anna, Sam and Lilly

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Abstract

Musculoskeletal disorders (MSD) are a common and growing occupational problem in military aircrew. Intervention studies attempting to reduce such issues have only showed limited preventive effects. Furthermore, in-depth knowledge of the clinical presentation of aircrew members with painful episodes is lacking. This thesis was conducted to add evidence to the ongoing work of the Swedish Armed Forces (SAF) for the prevention of MSD. The overall aim of this thesis was to estimate the occurrence of MSD in general and specifically cervico-thoracic pain and its associated factors among SAF aircrew and to evaluate clinically relevant tests, prior to the adaptation of a musculoskeletal screening protocol (MSP) for use in the SAF medical health care system.

All participants included in the four studies of this thesis were employed in the SAF. Two cross-sectional studies (Study I; n=351, Study III; n=73) aimed to establish the occurrence of MSD in aircrew compared with army deployed soldiers (Study I) and between fighter pilots, helicopter pilots and rear crew (Study I), as well as identify associated factors of cervical, thoracic and shoulder region pain (Study I) and cervico-thoracic pain (Study III). Study II had a test-retest design and aimed to examine inter-rater (n=37) and test-retest (n=45) reliability of movement control tests. In study III, test performance was compared between fighter pilots, helicopter pilots and rear crew. Study IV had a cross-sectional (n=18) and a prospective observational cohort (n=47) design and aimed to explore physical symptoms and functional limitations in aircrew with cervico-thoracic pain, establish 12-month cumulative incidence and to identify risk factors for cervico-thoracic pain.

The main findings of this thesis were that when compared to deployed soldiers, military aircrew reported higher prevalence of MSD in the cervical, thoracic, shoulder, and lumbar regions (80% reported at least one painful area during the previous year). Working as aircrew, and a lower rating of one's physical health, were significantly associated with pain in the cervical, thoracic and shoulder regions (Study I). Two physical therapists could reliably rate movement patterns for the majority of movement control tests in the affected areas. Lower reliability was however seen for test-retest conditions (Study II). Movement control and measures of cervical range of motion (ROM), but not cervical strength and endurance, were associated with cervico-thoracic pain among military aircrew. Specifically, less control of both neck and lumbar flexion movements, and lesser cervical flexion ROM were associated with cervico-thoracic pain. Differences were found between fighter pilots, helicopter pilots and rear crew for lumbar flexion movement control and cervical lateral flexion ROM (Study III). Physical symptoms and functional impairments of aircrew with high (pain) intensity,

flight-elicited and work-affecting cervico-thoracic pain showed an individual presentation. Previous pain episodes, lesser cervical flexion ROM, and lesser cervical flexor muscle endurance were identified as risk factors for future cervico-thoracic pain, which had a 12-month cumulative incidence of 23% (Study IV).

Findings from this thesis strongly indicate that MSD in SAF aircrew is an occupational problem that need to be solved. The cervico-thoracic region was especially common in SAF aircrew. Movement control can reliably be assessed, but with less stability for repeated measures. While pain history and physical performance can to some degree be used to identify aircrew at risk for further cervico-thoracic pain, the clinical presentation of their physical symptoms showed individual presentation. The effects of implementing the MSP in the SAF as a primary and secondary preventive intervention, as well as rehabilitative strategies, need be systematically evaluated.

Enkel sammanfattning på svenska

Muskuloskeletala besvär är ett vanligt arbetsrelaterat problem som ökar bland militärt flygande personal. Interventionsstudier med syfte att minska detta problem har endast visat begränsad effekt. Dessutom saknas fördjupad kunskap om hur den flygande personalens besvär yttrar sig kliniskt. Den här avhandlingen genomfördes för att bidra med evidensbaserad kunskap till den Svenska Försvarsmaktens (FM) pågående arbete att förebygga muskuloskeletala besvär. Det övergripande syftet var att kartlägga förekomst av muskuloskeletala besvär generellt och specifikt smärta i nacke/bröstrygg, samt associerade faktorer bland olika kategorier flygande personal. Vidare att utvärdera kliniskt relevanta tester inför anpassning av det muskuloskeletala screeningprotokollet (MSP) för användning inom respektive flygflottiljs försvarshälsa.

Samtliga deltagare i de fyra delstudierna var anställda i FM. Två tvärsnittsstudier (studie I; n=351, studie III; n=73) avsåga att kartlägga förekomsten av muskuloskeletala besvär hos den flygande personalen i jämförelse med soldater under en internationell insats. Dessutom jämfördes grupperna stridspiloter, helikopterpiloter samt helikopterbesättning inbördes (studie I). Faktorer som har samband med smärta i nacke, bröstrygg och skuldra belystes (studie I) och med smärta i nacke/bröstrygg (studie III). Ett nytt batteri av rörelsekontrolltester prövades där såväl interbedömmar (n=37) som test-retest reliabilitet (n=45) utvärderades (studie II). I studie III jämfördes fysisk prestationsförmåga mellan stridspiloter, helikopterpiloter samt helikopterbesättning. Studie IV var en tvärsnitts- (n=18) och prospektiv observationsstudie (n=47) som avsåg att utforska fysiska symptom och funktionsnedsättningar bland flygande personal med smärta i nacke/bröstrygg. Vidare att kartlägga hur många som utvecklar besvär samt att identifiera riskfaktorer för att utveckla detta.

Resultaten från avhandlingen visar att den flygande personalen uppgav högre förekomst av besvär i nacke, bröstrygg, skuldror samt ländrygg (80% rapporterade minst ett besvärsområde under det sista året) jämfört med soldater under en internationell insats. Att vara flygande personal samt uppleva sämre fysiska hälsa hade samband med smärta i nacke, bröstrygg och skuldror (studie I). Två fysioterapeuters bedömning av rörelsemönstret överensstämde för flertalet rörelsekontrolltester i de påverkade kroppsdelarna. Vid upprepat test (test-retest) överensstämde bedömningen av rörelsemönstret sämre (studie II). Bland flygande personal identifierades samband mellan att ange smärta i nacke/bröstrygg och mindre kontroll av rörelse samt nackrörlighet, men inte styrka och uthållighet i nackmuskulaturen. Specifikt fanns ett samband mellan att ange smärta i nacke/bröstrygg och mindre kontroll av framåtböjning av nacke och ländrygg samt mindre rörlighet i framåtböjning av nacken. Skillnader i kontroll av framåtböjning av ländryggen och rörlighet i sidoböjning av nacken fanns mellan stridspiloter, helikopterpiloter samt helikopterbesättning (studie III).

Flygande personal som angav smärta i nacke/bröstrygg hade olika fysiska symptom och funktionsnedsättningar och rapporterade höga smärtnivåer. Detta hade samband med flygning och som också påverkade deras arbete. Ökad risk för att utveckla smärta i nacke/bröstrygg fanns hos flygande personal som tidigare upplevt besvär, hade mindre rörlighet vid framåtböjning av nacken samt en sämre uthållighet i nackens främre muskler. Totalt 23% av den flygande personalen utvecklade sådana besvär under en period på ett år (Studie IV).

Den här avhandlingen visar tydligt att muskuloskeletala besvär framför allt i nacke/bröstrygg hos flygande personal är ett arbetsrelaterat problem som måste åtgärdas. Rörelsekontrolltester hade acceptabel inter-bedömarreliabilitet men resultaten var mindre stabila vid upprepat test. Faktorer som att tidigare ha upplevt besvär och sämre fysisk prestationsförmåga kan delvis användas för att identifiera vilka av den flygande personalen som riskerar att utveckla besvär i nacke/bröstrygg. De som redan har smärta i nacke/bröstrygg uppvisar individuellt olika fysiska symptom och funktionsnedsättningar. Effekten av att implementera MSP såsom primär, sekundär prevention samt rehabiliterande åtgärder behöver systematiskt följas upp.

Abbreviations

ANOVA	Analysis of Variance
BMI	Body Mass Index
CI	Confidence Interval
CROM3	Cervical Range of Motion 3 device
CR10	Borg Category Ratio scale
CT-pain	Cervico-Thoracic pain
FP	Fighter Pilots
Gz	Gravitational force along z-axis (vertical)
HP	Helicopter pilots
IASP	International Association for the Study of Pain
IQR	Inter Quartile Range
MVC	Maximal Voluntarily Contraction
MSD	Musculoskeletal Disorders
MSP	Musculoskeletal Screening Protocol
NVG	Night Vision Goggles
NPRS	Numerical Pain Rating Scale
OR	Odds Ratio
PABAK	Prevalence and bias adjusted Kappa
RC	Rear Crew
ROM	Range of Motion
SAF	Swedish Armed Forces
SD	Standard Deviation

Original papers

This thesis is based on the following original papers which will be referred to in the text by their respective Roman numerals.

I. Tegern M, Aasa U, Ang B.O., Larsson H. Musculoskeletal disorders and their associations with health- and work-related factors: a cross-sectional comparison between Swedish air force personnel and army soldiers. BMC Musculoskelet Disord. 2020;21(1): 303.

II. Tegern M, Aasa U, Ang B.O., Harms-Ringdahl K, Larsson H. Inter-rater and test-retest reliability of movement control tests for the neck, shoulder, thoracic, lumbar, and hip regions in military personnel. PloS One 2018;13(9): e0204552.

III. Tegern M, Aasa U, Larsson H. Cervico-thoracic pain and associated impairments in air force personnel: a cross-sectional study." BMC Musculoskelet Disord. 2021;22(1): 441.

IV. Tegern M, Aasa U, Larsson H. A prospective cohort study on cervico-thoracic pain in Swedish military aircrew: Investigating potential risk factors and exploring physical symptoms
(Manuscript)

Preface

I grew up in the small town of Karlsborg within a stone´s throw away from the runway of the F6 airbase. Practically every adult I knew, my parents included, worked in the Armed Forces. I still remember the roaring sound of the "Viggen" passing over our house (the one with the blue roof) at take-off and landing, especially on Tuesday evenings when our old windows rattled at bedtime. For me, those aircraft have always been up there in the sky. Years later I wrote my bachelor's thesis on loading tests of the knee for use in the Swedish Armed Forces, with the aim of preventing knee-related discharge from basic military training. Back then I wasn´t interested in research, I just wanted to become a skilled physio in orthopedic manual therapy.

Now I'm at the end of an eight-year journey with this thesis. I´m still striving to become a skilled physio, but my interest in research has grown. I've probably spent an equal number of hours on clinical courses as on research courses. For me, I believe that both sides of my professional "me" have gained from keeping one foot in the clinic, and the other foot in research. Today I´m turning the page to a new chapter, only the future can tell how the story continues.

Introduction

This thesis is written within the field of military aviation medicine that addresses health and safety issues of aircrew aiming to enhance performance in the challenging environment of airborne activities. Musculoskeletal disorders in military aircrew have been recognized as a problem in aviation medicine for decades. Few effective solutions to this have, however, been presented. Military aircrew are exposed to various challenges including fast accelerations, disorientation, high altitudes, long flight-times in a thermal and vibrational environment. Technical development has led to advances in aircraft systems such as night-vision goggles and head-up displays that offer an increased operational capability and an advantage in dangerous environments. These technical solutions may, however, have unintended negative consequences on aircrew health and safety through the greater mass to the helmet, which implies an increased burden on the' neck structures of the aircrew. This increased burden, together with a higher operational tempo and poor aircraft ergonomics stresses the importance of new solutions to address the multifactorial problem of MSD among military aircrew.

Aircrew have historically been seen as a particularly homogenous group due to the requirement of passing numerous standardized tests during thorough systematic selection procedures. Despite this some aircrew develop pain while others can continue to work in the challenging environment without such issues. The reasons for this remain largely unclear. The physical (i.e., cabin) environment is hardly changeable. This thesis focuses on the musculoskeletal disorders of Swedish aircrew. Specifically, the focus is on establishing the extent of musculoskeletal disorders. Who develops which disorders and why? How are the disorders characterized, and lastly, what can be done regarding primary, secondary and rehabilitative solutions to prevent a major occupational problem?

The job as military aircrew

Military aircrew train and perform missions that are not only to be undertaken in hostile environment with psychological challenges that comes with the missions, but also the demand on their physiological capabilities is also widely challenged (1). They need to handle numerous tactical and technical systems in-flight with high demands on their awareness of threats in the environment around the aircraft as well as on instruments in the cockpit. Military aircrew also need to be in good general condition to be able to survive in the event of evacuation or if the aircraft has been shot down behind enemy lines (2). On the other hand, they are also required to perform rather lengthy, sedentary office tasks. For example, prior to and after flight missions, the planning, briefing, and de-briefing is completed in close accordance with the flights at the air base in office settings (3).

SAF fighter pilots perform various offensive and defensive maneuvers in aerial combat training in the JAS 39 “Gripen” C/D fighter aircraft. These maneuvers’ cause a rapid onset of high Gz-accelerations on the pilot and increase compression along the spine, dragging the blood away from the brain (4). The JAS 39 has a “anti-G-system” comprised of a pneumatic suit that increases the pressure over the abdomen and legs in response to the instantaneous Gz-level. The seat is reclined 28° to further reduce the effect of Gz (4). The pilots also use strategies to counteract the effect of G-forces on the circulatory system namely anti-G straining maneuvers such as techniques to contract muscles in the trunk end lower extremities together with pressure breathing, are performed. Together, these anti-G strategies increase the physiological tolerance from about 3 G to 9 G (4). High physiological stress is also placed on the musculoskeletal system (3). The load of the head, helmet mask and helmet-mounted equipment (total about 2 kg), under 9 Gz conditions reaches approximately 65 kg (5). The pilot moves their head and neck with great freedom and when performing air combat with an enemy present, they need to look behind the aircraft in the “check-6” position which combines movement into maximal extension, rotation and lateral bending (6). Fighter pilots also constantly scan for targets in air and on land, thereby repeatedly moving their head away from an anatomically neutral position (5). Due to advancements that now enable refueling in air, the length of missions can prolong for several hours.

The SAF helicopter pilots and rear crew operate the helicopter 14 (NH90), 15 (AgustaWestland AW109) and 16 (Sikorsky UH-60M). Two pilots work in the cockpit and to control the helicopter they grasp the cyclic flight stick with their right hand and the collective stick with their left. They control the rudder pedals with their feet that are held off the floor in an open chain. To be able to control the helicopter using both hands and feet, they usually adopt a posture with the torso slightly bent and twisted, and the left shoulder dropped (7). Flying the helicopter is precision multi-task work managing the aircraft with intense visual input. The rear crew include flight engineers and operation specialists. Their tasks vary greatly, including troop management, rescue, operating the door gun, clearance tasks an control of systems (8). Both pilots and rear crew wear heavy protective gear and helmets during flights. Pilots are typically exposed to prolonged static positions while rear crew work more in awkward postures with twisted or bent torsos (8).

Perspectives on pain and musculoskeletal disorders

Definition of pain

The International Association for the Study of Pain (IASP) defines pain as: "*an aversive sensory and emotional experience typically caused by, or resembling that caused by, actual or potential tissue injury*" (9, 10). However, pain is not synonymous with injury, it can occur without injury and remain after the expected healing time of an injury (11). The IASP further highlight that pain should be seen as a personal experience which is influenced by biological, psychological, and social factors. Pain is a different phenomenon than nociception (see below), and humans learn the concept of pain through life experiences (9). Pain can be classified in several ways depending on its severity, duration, etiology, or type based on the suspected underlying mechanism (12).

Types of pain

Nociceptive pain is the default type or mechanism of pain that is used to describe pain arising from a "normally functioning somatosensory nervous system" and is elicited by activation of peripheral nerve ends responding to changes in the tissues (10, 13). It is a warning system that reacts to stimuli that may be of mechanical, chemical, or thermal origin that is potentially harmful to the body and is associated with damage and/or inflammation of body tissues (11, 14). A cascade of chemical substances are released from the damaged tissues or inflammatory cells, causing activation of nociceptors. This increases the sensitivity of the tissues to lower the threshold for stimuli to protect the tissue during healing (14). Mechanical pain is an alternative term that refers to pain associated with activation of nociceptors in innervated tissues such as joints, ligaments, muscles, discs and can also be used to describe symptoms such as arthritis or myofascial pain (12).

Neuropathic pain, in contrast to nociceptive pain, is caused by a disease or lesion to the somatosensory system and does not need nociceptor activation (10, 11). Peripheral neuropathic pain can be elicited in peripheral nerves by mechanical and inflammatory stimuli during prolonged load or as a result of trauma, or second to surgery (11). An example is pain arising from the nerve root secondary to a herniated disk, spinal stenosis or osteophytes narrowing the space for the nerve root (12). It is crucial to differentiate between mechanical and neuropathic pain due to distinctly different treatment decisions (12). However, an individual can present with both nociceptive and neuropathic pain (15).

Nociplastic pain, on the other hand, is not caused by nociceptor activity or damaged function in the somatosensory system, but rather altered nociception where clear evidence of tissue damage (actual or threatening) or lesion to nerves is lacking (10, 13, 16). Affected individuals predominately show hypersensitivity and potentially chronic pain conditions such as fibromyalgia, complex regional pain syndromes, or non-specific low back pain (13). Long-lasting pain of moderate to severe intensity is often observed together with psychological distress, poor conditioning, and sleep problems (11). The different types of pain can sometimes be hard to distinguish in some individuals, and some present with a mix of the various pain mechanisms. However, careful history-taking, and clinical examination often help to differentiate the various contributors to the pain experience to optimize the treatment strategy (11).

The biopsychosocial model of pain

Even though musculoskeletal pain may arise from an inordinate number of structures, signs of damage and degeneration to those structures becomes more prevalent with age and is equally common among symptomatic and asymptomatic individuals (17). Pain should therefore not only be seen as a sign of injury, but rather as the interface between biological and psychological factors, and highly affected by social features. Individuals with pain are therefore managed within a biopsychosocial framework (18). The biopsychosocial model was presented in the field of psychiatry in the 1970s to criticise the dominating biomedical model (19). It is now an established model underpinning that individuals with the same medical diagnosis show heterogeneous and sometimes complex patterns of biological, psychological, and social characteristics (18). The model is not static with equal contribution from the three domains for each individual, rather the relevant contribution varies from person to person and may further vary within individuals over time (Figure 1) (20). An individual approach regarding their treatment is therefore warranted.

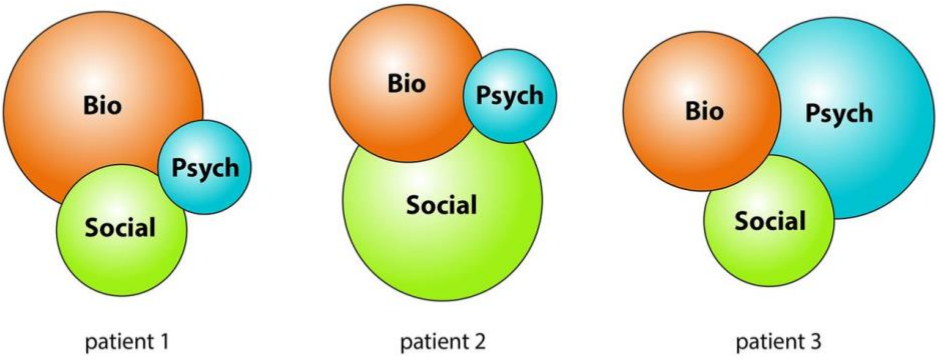

Figure 1. Venn diagram illustrating that the relative contribution of the three features can vary independently for three fictive individuals. Reproduced from (20) with permission from BMJ Publishing Group Ltd (Lic.no. 5164130666103).

Epidemiology of musculoskeletal disorders in Armed Forces

Musculoskeletal disorders (MSD), musculoskeletal pain, and musculoskeletal injuries are commonly used synonymously in the literature reporting on epidemiology in military personnel (21). MSD include painful conditions of the movement system that originate from muscles, nerves, cartilage, ligaments, the skeleton, and tendons (22). Sudden or prolonged physical loading is frequently mentioned as a causative or aggravating factors contributing to MSD (22, 23). Although these factors can be occupational, other activities such as leisure time sports or household activities can also contribute to MSD (22). Nevertheless, MSD are considered a noteworthy occupational problem globally in military cohorts worldwide (21, 24-26), including the Swedish Armed Forces (SAF) (27-35).

Incidence of MSD is the most common cause of evacuation from the battlefield (21) and causes lost time from flying in aircrew (26). A high proportion of MSD occur in in the low back and lower extremities, in particular knee pain, among land-based soldiers (27, 28, 30, 36, 37),whereas aircrew members mainly report MSD affecting the neck and low back (33, 38, 39). The differing occupation-related physical loads likely contribute to differences in which regions are affected since physical loading during daily activities is thought to play a significant role in the occurrence or aggravation of MSD (22). At present, there is no consensus on how to report pain or disorders in military aviators (26) and prevalence rates between similar cohorts varies considerably. For example, the 12-month prevalence for neck pain in fighter pilots ranges from about 19% (40) to 84% (41). Comparison between different cohorts and/or nations is therefore complicated and systematic monitoring within the respective military organizations is needed to lay the ground for effective preventive systems.

Pain in the cervical and thoracic spine in the general population

Neck pain is a globally acknowledged, long-standing public health issue (42-45). Together with low back pain, neck pain constitutes one of the most common causes of disability in the world and accounts for great societal costs and substantial numbers of health care visits (46). Similar to other MSD, neck pain is considered a multifactorial and complex phenomenon, previous episodes often precede new episodes and thus follows an episodic pattern (44). Although the estimated global prevalence of neck pain remained unchanged between 1990 and 2017, the incidence rate has increased in western Europe, especially in the Nordic countries (47). Neck pain is more common among women than men and the 12-month prevalence estimates of neck pain across the sexes ranges mostly between 30-50% both in the general population (44, 45) and among workers (48), and half of all humans will experience neck pain at some point in their lifetime (45). According to the Swedish work environment authority, about 1/3 of workers report pain in their upper back, neck, shoulders, or arms after work each week. Prevalence increased for both sexes between 1991 to 2015 and is higher among women (~40%) compared to men (~30%) (49). Pain in the thoracic region is less studied compared to in the neck or low back pain. In some cases the thoracic and lumbar regions is referred to as “back pain” (31, 50), while in some cases the neck and “upper back” are combined (49). Further, the lesser interest for the thoracic region may, at least partially, be explained by the relatively low life-time prevalence of isolated thoracic region pain (13-17%) (51, 52) compared to pain in the cervical or lumbar region (40% and 57%, respectively) (52). However, pain in the thoracic region often co-exists with other MSD un the upper quarter of the body including pain in the cervical and elbow regions (53) or with whiplash-associated disorders (54). The link between the thoracic and cervical regions based on the above, together with the numerous anatomical structures combining them, is therefore relevant to address in this thesis.

Pain in the cervical and thoracic spine among military air crew

Compared to military occupations which do not work in aircrafts, aircrew report higher prevalence of neck pain internationally (38) as well as in Sweden (55). A systematic review and meta-analysis concluded that 51% of fighter pilots reported neck pain (26) and prevalence among Dutch fighter pilots increased over a seven-year period (56) but this may be dependent on the specific type of aircrafts (57). Prevalence of neck pain for helicopter pilots ranges from 43% to 67% (39, 58) and 45% to 62% for helicopter rear crew (8, 39, 59). Earlier studies reporting prevalence among SAF aircrew have reported 43% (32)and 53% (34) for fighter pilots and 57% (33) for helicopter pilots. Pain in the thoracic region has received less attention in the literature concerning aircrew. However, a prevalence of 28% for Austrian helicopter pilots and 15% for rear crew has been reported in an Austrian study (39). The high prevalence of pain may have a pernicious effect on flight performance, safety and operational readiness among military aviators (60).

In-flight loading

All aircrew wear a helmet in-flight which weighs about 1,5-2 kg. During darker periods, the use of Night Vision Goggles (NVG) enhances their vision, which is necessary in the Swedish winter period but adds weight (approx. 1 kg including batteries and counterweights). Fighter and helicopter pilots also use helmet-mounted displays, providing them with relevant information directly in front of their eyes (7). The joint helmet mounted cuing (i.e., aiming) system is another example of equipment which helps fighter pilots to direct weapon systems at various targets with their eyes (5). The drawback to these systems is the added load to the neck of the aircrew (NVG itself plus and batteries and counter-weights placed on the back of the helmet, about 1 kg) (7). A greater neck muscle load has been observed when aircrew use NVG (61-63). Further, to use the systems fully, aircrew are forced to change their in-flight movement behavior including larger movement amplitudes, and higher frequency of movements away from a neutral position(5, 56, 64), occasionally during high Gz load (5).

Factors associated with neck pain among military aircrew

A recent systematic review and meta-analysis by Wallace et al. (65) concluded that longitudinal studies are lacking in aviation medicine regarding risk factors for neck pain development. Most studies have used a cross-sectional design and some associated factors have been established. Hermes et al. (66) found from univariate analyses (not adjusted) of the medical records of over 5000 US Air Force fighter pilots and over 700 helicopter pilots that the odds for having a cervical disorder was higher for older (≥40 years) fighter pilots but not for helicopter pilots. Verde et al. (57) reported similar results for fighter pilots ≥30 years. Other personal factors, including anthropometrics, seldom show associations with neck pain in fighter pilots (65). However, Harrison et al. (67) showed that helicopter pilots reporting neck pain were significantly shorter than colleagues without neck pain.

Regarding exposure to flight duties, studies have reported that total flight hours is a risk factor for neck pain among fighter pilots (3, 57, 66) and helicopter pilots (58, 67) but neither a meta-analysis nor a study on Swedish helicopter pilots showed no such associations for fighter pilots (65) or helicopter pilots (33), respectively. Further, the use of NVG has been associated with neck pain in fighter pilots (5, 68), helicopter pilots (39, 64) and rear crew (39).

Among fighter pilots, the meta-analysis by Wallace et al (65) showed that the more advanced aircraft (i.e., higher G-capability) the higher odds for neck pain. Another systematic review and meta-analysis (69) found higher prevalence of degenerative findings in the cervical region on magnetic resonance imaging for pilots flying more advanced aircraft. Further, fighter pilots have reported movements during flight to be associated with neck pain. Especially when looking behind the aircraft (i.e., "the check 6 position") (70) and combining e.g., rotation and extension, to remain in eye-contact with the enemy during air combat maneuvering (5)l.

Wallace et al (65) concluded after analyzing 20 (whereof two prospective) studies including 44 factors associated with neck pain that prospective cohort studies with multivariate analyses are needed. Additionally, some evidence suggests that neck pain in military aircrew should be viewed as a biopsychosocial issue and thus a more holistic approach is recommended when developing countermeasures for flight related neck pain (71).

Pain and movement: implications for physiotherapy

Pain theory and motor adaptations

Studies have shown that individuals with pain move differently than pain-free individuals and that motor adaptations may precede or follow the onset of pain or injury (and even the threats of these) (72). These adaptations range from subtle redistribution of muscle activity (within or between) to complete avoidance of movement (15). Theories behind these adaptations are (i) the pathokinesiological model (73) where an injury (or pain) precedes the adaptations and (ii) the kinesiopathological model where repeated and/or biomechanically less advantageous movements are hypothesized to contribute to or pain or pathologies (74-77). For the former, the identification of the patho-anatomical structure and diagnosis is central in the diagnostic process, but may be less important to guide treatment (78). For the latter, intra- and inter-joint relative flexibility, the relative stiffness of connective tissues and muscles, and motor learning following motor performance, are components that determine how movements are being performed in the easiest manner (75, 76). Motor adaptations may be beneficial to provide protection in the short-term to limit further harm (real or anticipated) and modify the distribution of load on a structure by either increasing or reducing motor activity (79). Complex changes on several levels of the motor and sensory systems are involved in this process and may have negative long-term consequences including overloading (muscles, intervertebral discs, joints etc.), decreasing movement and variability if the behavior is maintained for prolonged periods (72). Changes in the recruitment pattern of the cervical flexors have been established in neck pain (80, 81). Because of decreased variability, it is likely that the same structures will be loaded throughout each repetition of these movements and may thus be detrimental for these structures in the long-term (79) with persistent symptoms (15). Further, cognitive and emotional mechanisms, including fear of pain and injury, can underpin avoidant behavior for some individuals, where catastrophizing thoughts or hypervigilance to signals indicating harm can further limit movements (82). The underlying theories to motor control adaptation indicate that a multidimensional approach to assessment may be beneficial in patients with (neck) pain (20).

Motor adaptation may persist beyond the necessary time for tissue healing because the nervous system may be unable to return to a “pre-injury” strategy. The behavior can be maintained by expectations or fear of potential pain, but secondary physiological changes of the tissues (stiffness, atrophy) can further limit the potential to recover (15). Sensitization at a central or peripheral neural level can further contribute to the behavior. Motor adaptation may be relevant if the pain is of neuropathic origin to reduce stress of neural tissues. Central sensitization where the signaling of neurons is amplified after initial damage to the tissues can further be reinforced by cognitive-emotional mechanisms (15).Lastly, previous neck pain is a risk factor for a new episode, suggesting recurrency to be common in neck pain (83).

As presented above, motor adaptations or control during movements in accordance with pain has relied on advanced tools to measure the effect on tissue level. In the clinic, tests are commonly performed to investigate movement control and their reliability is, in general, good (84-86). In this thesis movement control is defined as a clinical observation of a movement or motor recruitment pattern that is being performed in a biomechanically more or less optimal manner and can be tested by assessment of preferred movement biomechanics and movement control tests (77, 78, 87, 88).

Impairments of bodily functions in aircrew with neck pain
It is well established that patients with neck pain present with various impairments of body function (89) including mobility, strength, and motor control deficits (90). Different trainings regimens are the first choice for treatment. Several studies have shown that training can be effective in reducing neck pain among aircrew (91, 92). However, rather few studies have investigated the character of impaired neck function among aircrew with neck pain.

A reduced range of motion has been found among fighter pilots (93) and helicopter pilots (35), whereby both groups displayed lesser sagittal (flexion-extension) and transversal plane (bilateral rotation) ROM compared to pain-free colleagues. These findings were, however contradicted in a study including helicopter pilots and rear crew that showed no such difference (94).

Although lower neck extensor (34) and lateral flexion (95) strength has been reported in fighter pilots with neck pain compared to their pain-free colleagues, other studies on fighter pilots (93, 96) and helicopter pilots (34, 94) found no such difference.

Only one study of 72 Swedish helicopter pilots has examined motor control of the deep cervical flexors and found that altered motor function for pilots with pain but not for those who were pain-free (35) during the cranio-cervical flexor test (80).

Due to the demands during flight on the ability of the aircrews to move their head when shifting their vision between instruments in the cockpit and their surroundings, structures in the cervical and thoracic regions are exposed to impelling loads. Identifying signs of reduced capability in their performance of movements is likely important to target interventions that could reduce the risk of developing disorders in these regions.

Prevention of musculoskeletal disorders

Screening as a primary preventive strategy identifies signs or known risk factors for a health condition before a condition has been developed (97). It is commonly used in the health care system to e.g., prevent cardiovascular mortality (97). Also, screening for risk factors for the development of sports injuries is common, but the effectiveness in accurately predicting sports injuries is debated (98). The use of screening has also been used in armed forces for decades with tests usually measuring fitness, general movement function, and flexibility (25, 99). The prevention of pain and injuries has been stated as important in the military aviation community (1). Today, it is mandatory to pass an annual medical examination for all aircrew to retain their flight status. Some nations also use additional tests including fitness, strength and mobility of the neck, or the functional movement screen in their preventive work (2). The scientific literature on effective prevention programs is, however, sparse.

A combination of questionnaire data and movement tests could predict upper quadrant injury in military personnel (100), thus showing a potential primary preventive effect. One preventive strategy may be neck training, as shown by Tucker et al. (3) who found that a higher frequency of neck training lowered the number of post-flight neck pain episodes. As a treatment strategy, training may be of importance as tertiary strategies. For example, self-administered training programs have been effective in reducing neck pain prevalence in Swedish helicopter pilots (91) and Danish fighter pilots (92).

Motor adaptations may precede or follow pain (15), As illustrated in Figure 2, musculoskeletal injury can be seen on a continuum from fully healthy to permanently disabled. This supports the rationale that most health conditions benefit from early intervention in terms of the health status of the aircrew, treatment outcome, and operational readiness (2).

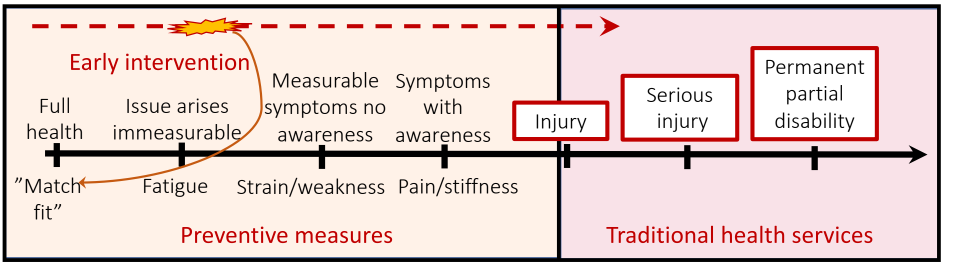

Figure 2. Aircrew Wellness status as a continuum, adapted from the Royal Australian Air Force (2).

SAF prevention: The Musculoskeletal Screening Protocol

The very first work covering prevention of injuries among soldiers in the Swedish armed forces (SAF) was the development of the “Ranger test”, a loaded step-up test (20 kg backpack) on a 0.4 m bench with a minimum of 75 repetitions used to assess the muscular performance of ranger applicants. The test was shown to identify poor performance in soldiers that was indicative for premature discharge from Ranger service (37). Following the Ranger test, the Musculoskeletal screening protocol (MSP) was developed. At the time, about 13% of conscripts failed to complete their basic military training mostly due to MSD. The MSP showed to be effective in reducing the number of premature discharges from basic military training (27). In 2010 it was decided to implement the concept “Optimize the training” which includes the MSP, in the SAF with the aim of improving longevity of staff in all trades. The overall aim of the MSP is to identify risk factors for MSD or early signs of MSD, low rating of health and low physical performance. The MSP has been implemented throughout army, marine and navy units. It is part of the standard procedures when soldiers are being deployed. Almost 9400 individuals were included and participated during the development of the system. The MSP consists of several parts. First a questionnaire is answered covering personal, social, and demographic data. Then, questions cover previous (12-months) and present occurrence of physical/musculoskeletal complaints or injuries (i.e., MSD) for ten body regions including Numerical pain rating scale (NPRS) intensity for any ongoing MSD. They also rate how often they perceive their complaints and if they have been off duty or sought medical care. Further questions cover physical exercise and training habits, food, tobacco, sleep problems, motivation, preparation for their duty, as well as five questions regarding how they perceive the state of their physical health, mental health, social environment, physical environment, and work ability. The questionnaire has been tested for reliability and translated into English (101) (submitted). The protocol continues with a test battery of knee-loading, muscle performance/endurance and flexibility (27, 102).

The MSP not only identifies risk factors for or the occurrence of MSD, it also covers individual and organizational intervention strategies to manage the identified problems to enhance participation in the military service (30, 103, 104). The work is described and regulated in a SAF manual/guidebook (105) and will be further developed with strategies for the categories of personnel investigated in the present thesis. One key player/function is the physiotherapist working at the unit, who has the responsibility of gathering the information from the MSP and planning the appropriate intervention for the personnel in collaboration with instructors and commanders.

Theoretical framework

The ability process

The underlying theoretical framework for the MSP and this thesis is the "ability process" (103) which has been an established process in the SAF to identify those who are at risk of MSD and to promote health and operational readiness. As shown in figure 3, through the identification of relevant personal information, testing of functional capacity and using knowledge of the relevant job demands, a potential gap between the requirements in the job and the capacity of the individual can be identified. With this information different strategies to promote health, prevent development of MSD and treat those who are currently suffering from an MSD can be initiated. The ability process aligns well with the biopsychosocial model (19), where a health problem is considered to have contributions from biological, psychological and social factors.

When developing prevention strategies for MSD, it is important to first assess the incidence and severity of MSD, as well as investigate the risk factors for and the underlying mechanisms behind the MSD, before designing interventions (106). The results from this thesis will, hopefully, contribute to the existing MSP with relevant methods to identify military aircrew at risk for MSD.

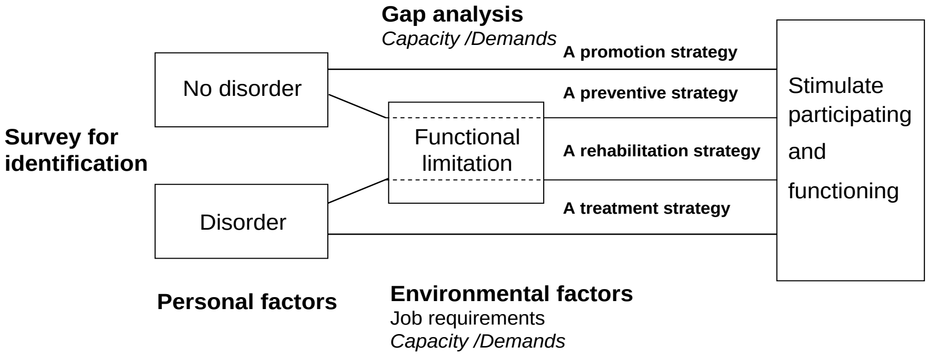

Figure 3. The “ability process”. Reprinted, with permission from Larsson H. Premature discharge from military service: Risk factors and preventive interventions. Stockholm: Karolinska Institutet; 2009.

Rationale for the thesis

Military aircrew members constitute a rather homogenous, well-trained, and well-selected occupational group. Despite this, they present with a disproportionately high prevalence of musculoskeletal pain affecting predominately the neck. Previous Swedish and international studies have indicated that this prevalence has also increased over the years. There are several impairments believed to be associated with this pain, but the scientific evidence is conflicting. Further, for this highly trained occupational group, occurrence of pain may affect their ability to do their work and may be a safety concern in certain situations. Prevention of such episodes is thus considered important and should be prioritized.

The knowledge on the occurrence of this problem is, however, sparse in the Swedish Air Force today. To develop a systematic and efficient prevention system, the extent of the problem as well as any factors associated with its presence should be established. The occupational demands and physical exposures experienced by aircrew are likely contributing to pain. There is however a lack of longitudinal studies which have identified risk factors for the development of pain. While the design of air crafts and personal protective gear are hard to adapt, a deeper understanding of who develops pain and how the pain is characterized may help support affected aircrew members.

Research on aircrew members experienced pain, their physical capacity to deal with the challenges associated with the helicopter and jet aircraft environment, and whether these capabilities are associated with, or indicative of future pain episodes may provide insights into this problem. The systematic prevention program adapted and implemented in the SAF requires reliable and valid measurements that include clinical tests to identify capacity limitations for the development of pain in aircrew. A need for advancement in the military aeromedical field is warranted with the goal of improving the physical health of the Air Force.

Aims

The overall aim of this thesis was to estimate the occurrence cervico-thoracic pain and its associated factors among Swedish aircrew members and to evaluate clinically relevant tests, prior to the adaptation of a musculoskeletal screening protocol (MSP) for use in the Swedish Air Force medical health care system.

Specific aims

-To investigate the prevalence of MSD in Swedish military aircrew and army soldiers (Study I).

-To investigate individual, health and work-related factors associated with MSD (Study I).

- To investigate the inter-rater and test-retest reliability of a battery of clinical tests for evaluating movement control in the neck, shoulders, thoracic, lumbar, and hip regions in Swedish military personnel (Study II).

-To examine associations between pain in the cervical and thoracic regions, movement control, active cervical range of motion, and muscle strength and endurance in the same regions among Swedish military aircrew (Study III).

-To compare test performance in movement control, active cervical range of motion, and muscle strength and endurance between fighter pilots, helicopter pilots and rear crew (Study III).

-To explore physical symptoms and functional limitations in Swedish military aircrew with cervico-thoracic pain (Study IV).

-To determine the one-year cumulative incidence of cervico-thoracic pain among Swedish aircrew members (Study IV).

-To identify potential risk factors from baseline measures of self-report and physical performance with future cervico-thoracic pain among Swedish aircrew members (Study IV).

Materials and Methods

Study design

This thesis contains four studies (Table 1) and is based on three data collections performed at different locations in the SAF. Study I was based on data collected in an earlier study on soldiers being deployed to service in Afghanistan and a new data collection from two air force bases (A and B). Data from airbase B also contributed to Study III and IV. Study II was based on a data collection at three workplaces in the SAF, including soldiers, officers, and civilian employees. An overview of all participants demographic data is provided in Table 2.

Table 1. Overview of studies in this thesis.

	Study design	Study sample	Data collection	Analysis
Study I	Cross-sectional	166 military aircrew, 185 deployed soldiers	Questionnaire	Logistic regression
Study II	Test-retest	37/45 SAF employees	Test 1: two independent raters. Test 2: one rater	Intra-rater and test-retest reliability
Study III	Cross-sectional	36 fighter pilots, 18 helicopter pilots, 19 rear crew	Test battery at the air base	Logistic regression
Study IV	Cross-sectional, Longitudinal	18/47 military aircrew	Baseline: Questionnaire and test-battery at the air base. Follow-up until 12 months: Questionnaire	Logistic regression

Study participants

Table 2. Demographic characteristics of participants in the respective studies.

	n	Sex Male %	Age Mean (SD)	Weight, kg Mean (SD)	Height, m Mean (SD)
Study I					
Military aircrew	166	100	39 (8)	82 (8)	1.81(0.05)
Deployed soldiers	185	100	34 (8)	84 (8)	1.82 (0.05)
Study II					
SAF Soldiers, officers and civilian employees	37[A]	62	36 (10)	79 (13)	1.78 (0.10)
	45[B]	71	35 (10)	78 (13)	1.78 (0.10)
Study III					
Fighter pilots	36	100	35 (7)	81 (7)	1.82 (0.06)
Helicopter pilots	18	100	43 (8)	85 (12)	1.80 (0.06)
Rear crew	19	100	43 (7)	79 (7)	1.78 (0.06)
Study IV					
Military aircrew	18[C]	100	42 (7)	82(10)	1.80 (0.07)
Military aircrew	47[D]	100	38 (8)	79 (9)	1.81 (0.06)

A: Intra-rater (n=37), B: test-retest (n=45), C: Cross-sectional, D: Longitudinal

Study I

Participants were recruited from three cohorts: SAF aircrew from two airbases and one cohort of SAF soldiers from an army unit preparing for deployment to Afghanistan. Participants were all in active duty. From the first air base, all helicopter pilots and rear crew, and from the second air base, all helicopter pilots and rear crew together with fighter pilots were included. Participants from the third cohort (deployed soldiers) were employed as soldiers or officers at one army unit. The aircrew members (n = 181, 38 ± 9 years) were significantly older than the deployed soldiers (n = 354, 29 ± 9 years), and only three females were in service at the two air bases. The exclusions criteria were (i) female sex, (ii) age <25 years, and for aircrew, (iii) <10 h logged flight hours the previous year. Therefore, 166 aircrew members and 185 deployed soldiers were included.

Study II

Participants were recruited via advertisement at three different workplaces of the SAF. Their specific occupations were as soldiers, officers or civilians working with administration or education-related tasks. Thirty-seven participants (23 males) aged 36 ± 10 years were tested in the inter-rater study, and 48 participants were tested on the first occasion in the test-retest reliability part. Three participants were lost to the second test occasion due to sick leave, therefore 45 participants (32 males) aged 35 ± 10 years were included in this analysis. In total, 25 persons (all from the same workplace) were included in both the inter-rater and test-retest analysis.

Study III and IV
Participants were recruited from one air base, 73 SAF aircrew (all male) divided into 36 fighter pilots aged 35 ± 7 years, 18 helicopter pilots aged 43 ± 8 years and 19 rear crew aged 43 ± 7 years listed on flight duty, non were excluded. These participants also provided data for Study I in this thesis.

Ethics

Ethical approval was granted in advance by the Regional Ethical Review Board in Stockholm for Study 1 (DNR:2010/1423–31/5), amendment DNR:2013/2039-32/5 and DNR:2013/144–31/2), Study II (amendment 2015/493-32) and for Study III and IV (DNR:2013/144–31/2, amendment DNR:2015/493–32). The participants were given both oral and written information and provided their written informed consent prior to participation in accordance with the declaration of Helsinki. Risks for the participants integrity and health were deemed small for most parts in all studies and caution was taken in all parts of data collection.

Data collection

Procedure

In all four studies, participants answered the self-administered MSP questionnaire addressing MSD and individual, health and work-related factors, presented in detail below. In Study II and in the longitudinal part of Study IV, a shortened version of the MSP questionnaire was used.

Study I: The MSP questionnaire was administered once to the participants. For aircrew members, the questionnaires were answered when the researchers visited their respective air base. The soldiers answered the questionnaire when they were undergoing medical checks in preparation for international deployment to Afghanistan.

Study II: A short version of the MSP questionnaire was administered once to the participants and following a standardized test procedure, they performed 15 tests of movement control. The test performance was rated by two observers. One of the observers performed a re-test 2-7 days later.

Study III: The MSP questionnaire was administered once to the participants over the course of about six months. Directly thereafter, in a standardized order, they performed eight tests of movement control of the spine, measured active cervical range of motion, as well as isometric strength and endurance in cervical flexion and extension.

Study IV: The baseline-assessment for Study IV is presented under Study III above. Participants who reported on-going pain problem were individually assessed by a physical therapist. Participants without pain at baseline were prospectively followed up every 3-4 months until 12 months later the with a short version of the MSP questionnaire. Follow-up questionnaires were administered to the air base on the occasions when data was collected for Study III and IV.

Questionnaire

Data regarding demographics, MSD, health rating, physical training habits, and work exposure were collected in all studies using a questionnaire previously used in studies on SAF soldiers (27, 28, 30, 104, 107) which is used in the ongoing work in SAF (Appendix A). The questionnaire has been tested for reliability (101, 103). A summary of items from the questionnaire and physical performance tests studied is presented in Table 3.

Table 3. Items analyzed in the thesis.

Person-related	**Study**	**Work related**	**Study**
Sex	II	Occupation	I, II, III
Age	I, II, III, IV	Annual flight hours	I, III, IV
Body mass	I, IV	Total flight hours	I, III, IV
Body height	I, IV	Motivated to tasks	I, IV
Body mass index	I	Physically prepared	I, IV
Pain history	IV	Mentally prepared	I, IV
Self-rated health	I, III, IV	Sick leave	I, IV
Self-assessed capacity	I, III, IV	Affected work ability	IV
Physical activity level	I, III	**Physical performance**	
Pain intensity rating	I, II, III, IV	Movement control	II, III, IV
Borg CR10	III, IV	Strength	III, IV
Tobacco use	I, IV	Endurance	III, IV

Anthropometrics
The participants reported age (years), body height (m) and body mass (kg). Body mass index (BMI) was calculated as kg/m^2.

Health related questions
In Study I, III and IV, five questions regarding self-rated general health in the MSP questionnaire was used. The questions were first developed for Air Force pilots (108). A seven-point scale with answers ranging from "very poor" to "excellent, cannot be better" was used for: How do you experience your [i] "physical health" [ii] "mental health" [iii] "social environment" [iv] "physical environment" and [v] "work ability". For the analyses, the answers were collapsed and coded into: poor (≤3), good (4-5), or excellent (≥6), as previously described (28).

In Study I, the use of Tobacco was assessed by two questions: "Do you use smokeless tobacco (i.e., snus)?" and "Do you smoke?" with answers yes or no.

In Study I and III, leisure-time physical activity level was measured with two questions according to weekly occurrence on two intensity levels [i]; high/average, or [ii] low intensity. A 5-point scale with answers; never, irregular, 1, 2 or ≥ 3 times per week was used. The answers were converted to a score ranging from 0 to 16 points and thereafter grouped into; "low/inactive" (≤5), "active" (6– 11), and "highly active" (≥12) in accordance with previous studies (28, 104). Further, their weekly occurrence of muscular strength, cardiorespiratory and neck exercises were reported in Study IV. Due to an ongoing revision of the MSP questionnaire, questions regarding sleep problems have shifted and are not included for analysis within this thesis.

Work related questions
In Study I, II and IV aircrew members reported the numbers of flight hours during the last 12 months and for their entire career. In Study I and IV, the participants motivation and preparation to perform their work tasks were assessed by the questions: "Are you motivated to perform your work tasks?", "Are you sufficiently mentally prepared to perform your work tasks?", "Are you sufficiently physically prepared to perform your work tasks?", with answers yes or no. The total and annual flight hours, respectively, were reported.

Operational definition of musculoskeletal disorders
The definition of MSD in the ongoing work in SAF, as well as in this thesis, is described by the questions: "Have you had any *musculoskeletal complaints or injuries* during the last year?" and "Do you still have these at present?". These two questions provide the 12-months and point prevalence of MSD. Participants

reported their answers for 10 predefined anatomical regions. For those with present episodes (i.e., point prevalence), their current pain intensity from 0 to 10 using the NPRS was rated. MSD is considered as a synonym to musculoskeletal pain. The questions were answered once in Study I and III, twice Study II for those who participated in test-retest analyses up to four times in Study IV.

Outcome definition

For Study I and II, MSD for any region (i.e., total prevalence) as well as each of the predefined regions were reported for the 12-months and point prevalence. In Study I, two combined regions: the upper quarter (i.e., the cervical, thoracic, and shoulder regions) and lower extremities (i.e., the hips, knees, lower leg, and feet). were reported. For the logistic regression, the 12-month prevalence of upper quarter and lumbar region MSD were used. In Study III and IV, the cervical and thoracic region were combined into the "cervico-thoracic region" and for the logistic regressions, the point prevalence was reported as the primary outcome. Further questions on the consequences of MSD including any sick leave (due to their MSD) were answered with yes or no in study I and IV. In study IV, how the participants were coping was covered by questions on care seeking, affected work ability, association with/interference with flight duties.

Measures

A test battery was developed, and the components are described below.

Movement control tests

In Study II, III and IV, a test battery assessing movement coordination strategies (88) where tests of preferred movement patterns (77) and/or the ability to control movements in one region while moving an adjacent one (88). The tests were derived from descriptions by Sahrmann (75, 76), and Comerford and Mottram (87) was developed. The tests were selected due to their common use in clinical practice and are summarized in Table 4, while a detailed description of the tests is presented in in Appendix B. The tests were discussed within the research group and with experienced clinicians for their face and content validity. Video together with verbal instructions for each test was used for each test in a standardized order. Three rehearsals were performed to ensure familiarization with the movement to be tested, thereafter they performed the movement. The physical therapist rated whether the participant could (1) or could not (0) perform the movement according to the grading criteria, based on their visual observation. Palpation was only allowed for one (the Shoulder lateral rotation) test.

Table 4. Movement control tests used in this thesis presented in the same sequence as they were performed, the position in which the test was performed, and the study they were used in.

Movement control tests	Tested side	Study no.
Shoulder flexion test	Left/right	II
Test position: Standing **Aim:** Assess the ability to move the arm into flexion to about 180° with ≈60° upward rotation and no excessive winging, excessive elevation/abduction/forward tilt/downward rotation of the scapula or medial rotation of the humerus.		
Shoulder extension test	Left/right	II
Test position: Standing **Aim:** Assess the ability to extend the arm to about 15° while retaining a neutral position of the scapula.		
Shoulder lateral extension test	Left/right	II
Test position: Standing **Aim:** Assess the ability to laterally rotate the shoulder to about 45° while retaining a neutral position of the scapula.		
Chest lift test		II, III, IV
Test position: Sitting, feet supported **Aim:** Assess the ability to extend the thoracic spine (lifting the chest) without anterior pelvic tilt and lumbar extension.		
Neck flexion in sitting test		II, III, IV
Test position: Sitting, feet supported **Aim:** Assess the ability to flex the neck to 45°–50° with contribution of both lower (≈35°) and upper cervical spine without cervical anterior translation/ diminished anterior sagittal plane rotation.		
Neck extension in sitting test		II, III, IV
Test position: Sitting, feet supported **Aim:** Assess the ability to extend the neck to ≈85° with contribution of both lower (≈70°) and upper cervical spine without mid-cervical anterior translation rotation.		
Neck rotation in sitting test	Left/right	II, III, IV
Test position: Sitting, feet supported **Aim:** Assess the ability to rotate the neck to about 70°–80° without concurrent neck or shoulder movements.		

Continued.

Movement control tests	Tested side	Study no.
Pelvic tilt test		II, III, IV
Test position: Sitting, feet supported		
Aim: Assess the ability to rotate the neck to about 70°–80° without concurrent neck or shoulder movements.		
Forward lean test		II, III, IV
Test position: Sitting, feet supported		
Aim: Assess the ability to flex the hip/lean forward to about 30° without lumbar flexion.		
Single knee extension test	Left/right	II
Test position: Sitting, feet unsupported		
Aim: Assess the ability to extend the knee to about 10°–15° from full extension without lumbar flexion or rotation.		
Double knee extension test		II
Test position: Sitting, feet unsupported		
Aim: Assess the ability to extend both knees to about 10°–15° from full extension without lumbar flexion.		
Neck flexion in supine test		II, III, IV
Test position: Supine, straight legs		
Aim: Assess the ability to smoothly flex the neck using all cervical segments without excessive anterior translation.		
Leg lift test	Left/right	II
Test position: Supine, crook-lying		
Aim: Assess the ability to flex the hip joint to about 120° without lumbar flexion or posterior pelvic tilt.		
Neck extension in quadruped test		II
Test position: Quadruped		
Aim: Assess the ability to smoothly extend the cervical spine using all cervical segments without excessive posterior translation.		
Rocking forward test		II
Test position: Quadruped		
Aim: Assess the ability to extend the hips to about 0° in quadruped position without lumbar extension.		

Cervical range of motion
In Study III and IV, active cervical range of motion (ROM) was measured using the Cervical Range of Motion 3 (CROM3) device (Performance Attainment Associates, Roseville, MN) in flexion, extension, axial rotation left and right, and lateral flexion left and right. The CROM3 device (Figure 4) has two gravity-controlled balls as well as a magnetic compass to measure movements in three planes of movement and has shown good reliability and validity (109, 110). The participants sat on a bench in a neutral up-right position with hips and knees in about 90° and their hands on their thighs. Three repetitions were performed, and the highest value was used. The physical therapist controlled adjacent regions with his hands to ensure that only cervical movements in the intended direction were performed.

Isometric strength and endurance in cervical flexion and extension
In Study III and IV, isometric strength and endurance in cervical flexion and extension was measured using fixed dynamometry (Advanced Force Gauge, Mecmesin Ltd., Slinfold, West Sussex, UK) with two test leaders present. The device measured the maximal voluntarily contraction (MVC) in cervical flexion and extension in an upright sitting position, firmly fixated with a rigid band. Cervical flexion was tested first, directly followed by tests for extensors. The participants sat on a bench with their back against a rigid square block with a firm band over their sternum, arms resting at their sides and only the tip of their toes resting on the floor. and the same procedure as for flexion was performed (Figure 4).

Prior to all tests, participants were asked about any ongoing pain in the spine, specifically the cervical region, that could interfere or be aggravated by the test, to decide whether to proceed. A 7–8 min circulatory warm up was performed on a rowing machine followed by five submaximal isometric contractions with a gradual increase in force against the hand of the test leader. A firm headband attached the participants head to the dynamometer. Protraction was avoided by asking the participants to keep their chin down. A maximum of three submaximal isometric contractions were performed to ensure that the dynamometer was aligned perpendicular to the head band, that the headband fit well and to ensure that no pain was provoked by the test. The strength test consisted of three trials where they gradually ramped the force up to their maximum over about three seconds. The rest between trials was one minute. The average of the two highest recordings multiplied by the lever arm (measured with a ruler as the vertical distance between force transductor of the dynamometer and the spinous process of C7 [marked a priori with a pen]), were used as their MVC.

Following three minutes of rest, the submaximal endurance test with a force representing 50% of their MVC followed. The primary test leader monitored the force and gave verbal feedback to the participant if the force deviated 10 N from the intended force. The secondary test leader kept the time and asked the participant for their perceived exertion at 15 s intervals using the Borg CR10 scale (held in front of them) (111). Criteria to interrupt the test were: (i) deviating 10 N below the intended force despite two encouragements, (ii) a exertion rating ≥ 7 on the Borg CR10 scale, or (iii) if any pain was experienced.

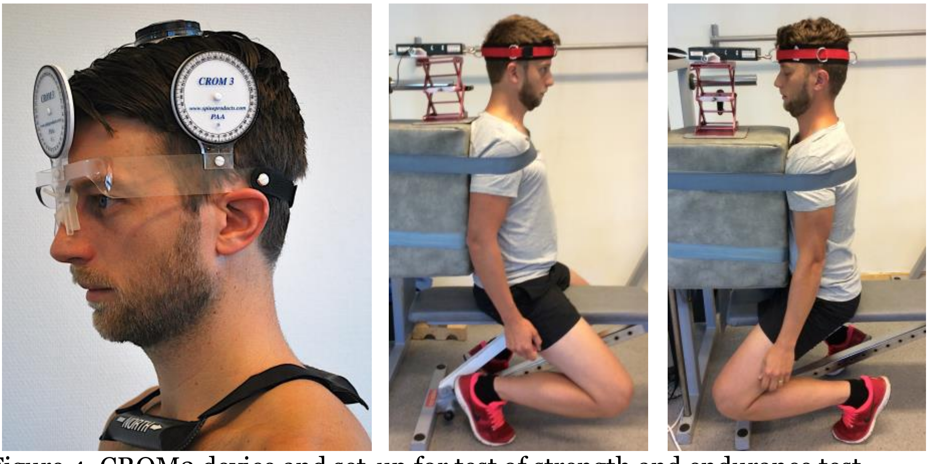

Figure 4. CROM3 device and set-up for test of strength and endurance test.

Individual clinical examination of physical symptoms and functional limitations in aircrew with cervico-thoracic pain

Aircrew members in Study IV who reported pain in any region on the day of testing were individually examined by the physical therapist in a one-on-one session in a separate room at the airbase using the process of clinical reasoning (112-114). Information from the MSP questionnaire were discussed first followed by a more detailed subjective examination (112) according a chart produced for the purpose of the study. Signs and symptoms of serious pathology (i.e., red flags, yes/no) were screened (112). The onset of pain, duration (years, months, or days), variation during the day, and the character of the pain (9, 10) were covered. They were asked to name any postures and movements that eased or aggravated their symptoms, if any specific activities were limited due to their symptoms and if they avoided pain or activities in any way. Further, they were asked how they coped with their symptoms and their own thoughts on their symptoms. The subsequent physical examination was based on their individual subjective examination (112, 114).

The physical examination began with an assessment of the aircrew´s posture (115) motor behavior (15) of the movements that the aircrew mentioned during the subjective examination to be associated with their pain symptoms (114, 116) followed by secondary tests to assess if their symptoms were changed by modifying postures or movements (to distribute the load more evenly (117, 118). If the subjective or physical examination findings indicated contribution of peripheral neurogenic (10) and/or nociplastic pain (16) this was further examined The examination also included specific movement control, muscle performance or joint function (angular and translatory movements) assessment in the specific region if deemed necessary (112).

Statistical analyses

An overview of the statistical methods used in this thesis is presented in Table 5.

Participant characteristics

Demographic data were presented as relative frequencies with 95% confidence intervals (CI), or means with standard deviation (SD), or medians with interquartile range. To asses normal distribution of data, q-q-plots were checked visually, and Shapiro-Wilk tests were applied together with values of skewness and kurtosis. Non-parametric tests were performed in case of non-normal distribution. Bonferroni corrections were applied when needed.

Differences of group means for continuous data, i.e., differences regarding age, body height, body mass, and body mass index (BMI) were analyzed by One-way Analysis of variance (ANOVA) and Student's t-test. Categorical variables, health- and work- related factors, and non-normally distributed variables were analyzed by the Kruskal Wallis test and Mann Whitney U test, and the latter test was also used for maximal pain intensity rating (NPRS) in Study I, III and IV. The Chi-square test or Fisher's exact test were used for dichotomous variables.

Table 5. Statistical methods used in this thesis.

Statistics	Study I	II	III	IV
Descriptive				
Numbers	•			•
Percentage with CI	•	•	•	•
Mean with SD	•			•
Median with IQR	•		•	
Median with 25th-75th quartiles				•
Differences between groups				
Students t-test		•		
ANOVA	•		•	
Kruskal Wallis test	•		•	
Mann Whitney U test	•			
Pearson Chi-square test	•		•	
Fishers exact test	•			
McNemar test		•		
Bonferroni adjusted p-value	•		•	
Associations				
Univariate analysis	•		•	•
Logistic regression	•		•	•
Incidents proportions with CI				•
Spearman´s r	•		•	•
Reproducibility				
Percentage agreement		•		
Cohen's Kappa		•		
PABAK		•		

CI = Confidence Interval (95%); SD = Standard Deviation; IQR = Inter-quartile range; ANOVA = Analysis of variance; PABAK = Prevalence and bias adjusted Kappa.

Occurrence of musculoskeletal disorders

The prevalence of MSD was analyzed with the Pearson Chi-square test or Fisher's exact test and reported as relative frequencies with 95% CI in all four studies. Cumulative incidence of cervico-thoracic pain was calculated as the proportion with 95% CI of reported new episodes among those who were pain-free at baseline in Study IV.

Associations between independent variables and Musculoskeletal disorders
In Study I and III, odds ratios with corresponding 95%CI were calculated for the association between independent variables and the outcome using binary logistic regressions. The same statistics were used in Study IV to identify potential risk factors for the outcome. The analyses began with univariate regressions for independent variables through purposeful selection and associations at $p<0.20$ were used at this step. All independent variables were then entered in a multivariable regression model and a stepwise backward deletion process removing all non-significant (p-value > 0.05) variables, leaving only variables significantly associated with the outcome (119). Confounders (i.e., (i.e., age, occupation, adjoining region pain prevalence), defined as a > 10% change in OR between the adjusted and crude model, were checked for a priori and interaction was checked between variables in the model.

Levels of reliability
The inter-rater and test-retest reliability of a novel movement control test battery was examined in Study II. A power analysis was performed prior to Study II and with an agreement of 90%, CI of 20%, and a chance agreement of 50%, the required sample size was estimated to be 35 participants (120). Cohens Kappa-coefficients are commonly used in reliability studies where the outcome is on a dichotomous scale, e.g., the identification of pathology on radiographs (yes/no), or pass/fail of a test. The agreement beyond chance (121) for inter-rater reliability between the two physical therapists´ and the test-retest reliability of one physical therapists rating of test 1 and test 2 were analyzed by calculating kappa coefficient with 95% CI (121). Percentage agreement and prevalence-adjusted bias-adjusted kappa coefficients (PABAK) aided the interpretation of reliability (122). For this thesis, also the average agreement for the entire test battery was calculated.

The strength of agreement according Landis and Koch is commonly interpreted as follows: <0 poor agreement, .01–.20 slight agreement, .21–.40 fair agreement, .41–.60 moderate agreement, .61–.80 substantial agreement, and .81–.99 almost perfect agreement (121). The McNemar test was used to evaluate any systematic change (i.e., possible learning effect from test 1 to test 2) and the number of passed tests was compared between participants with and without MSD using student´s t-test.

Calculations were performed using IBM SPSS Statistics for Windows, version 22 (Study II), 23 (Study I), version 27 (Study III-IV) and 28 (Study IV) (IBM Corp., Armonk, N.Y., USA). A p-value < 0.05 was considered statistically significant.

Results

The demographic characteristics of the participants in the respective studies are presented in Table 2 (Methods). For aircrew presented in Study I, Helicopter pilots had 2500 (1963-3210) career flight hours logged that were significantly ($p<0.01$) higher than fighter pilots 1300 (700-2000) h and rear crew 900 (240-1587) h. Helicopter pilots had significantly ($p<0.01$) higher number of flight hours for the last 12 months: 130 (95-193) h compared to rear crew (100 (60-120) h, but not significantly higher than fighter pilots: 120 (110-140) h.

Occurrence of musculoskeletal disorders in Swedish Armed Forces personnel

In Study I, MSD were found to be common in several body regions in military aircrew, as well as army deployed soldiers, 80.7% of aircrew and 71.9% of deployed soldiers reported MSD somewhere in their bodies (i.e., ≥1 region) during the last 12 months. The point prevalence was significantly higher ($p=0.01$) for aircrew compared to deployed soldiers, 53.6% and 40.0% respectively. Further, significantly ($p<0.01$) higher 12-month prevalence was reported in the cervical (27.7%), thoracic (31.3%), shoulder (24.1%) and the lumbar (38.0%) regions for the aircrew compared to deployed soldiers (10.8%, 12.4%, 12.5% and 22.2%, respectively). Significantly higher point prevalence was found for aircrew compared to deployed soldiers in the cervical (14.5% and 5.6%) ($p=0.01$), shoulder (13.9% and 6.5%) ($p=0.03$) and the lumbar regions 18.7% and 7.1%) ($p<0.01$).

The cervical, thoracic and shoulder regions were combined into an "upper body" region with both significantly higher ($p<0.01$) 12 months prevalence (54.8%) and 26.1%) and point prevalence (31.3 and 13.6%), and pain intensity rating (for ongoing pain) at a median of 3 (2.5-5.5) and 2 (1-3) out of 10, respectively, compared to deployed soldiers. For this thesis, also prevalence for the combined cervico-thoracic region was investigated with a significantly (<0.01) higher 12-month prevalence (45.8%) compared to deployed soldiers (18.4%). The corresponding point prevalence was 21.7% and 10.3%, respectively ($p<0.01$).

In Study II, soldiers, officers, and civilian personnel reported a 12-month prevalence of MSD somewhere in their bodies (i.e., ≥1 region) of about 65%, and for point prevalence about 44%, with the lumbar region being most reported.

Prevalence of cervico-thoracic pain among aircrew

As mentioned above, high prevalence of cervico-thoracic pain was seen for the aircrew included in Study I (Figure 5). The distribution in anatomical regions was however not significantly different between fighter pilots, helicopter pilots, and rear crew with each other. The cervical and thoracic region emerged as highly reported body regions for this population.

In Study III, 56% of aircrew at one air base had reported pain in the cervico-thoracic region during the preceding year, while 30% reported ongoing episodes with median pain intensity rating at 4.5 (range 1-8).

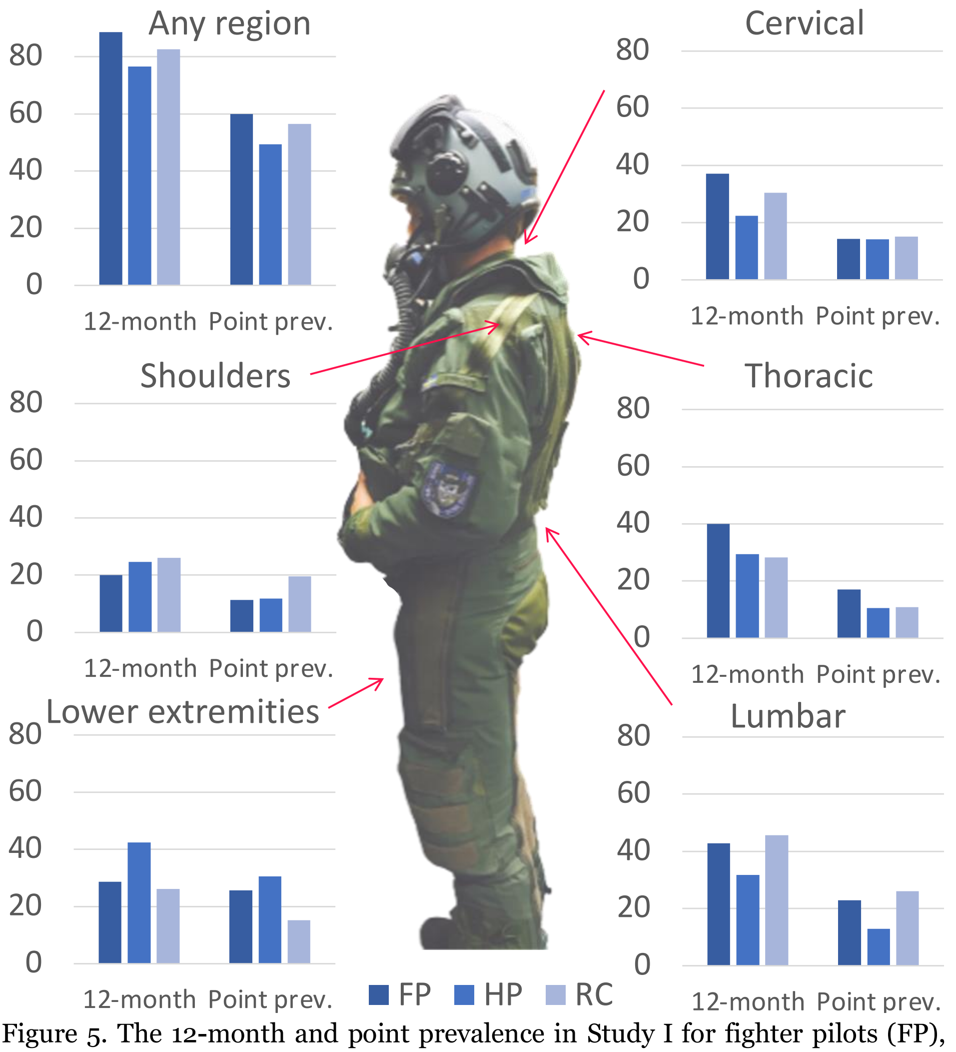

Figure 5. The 12-month and point prevalence in Study I for fighter pilots (FP), helicopter pilots (HP) and rear crew (RC), respectively, for selected body regions.

Cumulative incidence of cervico-thoracic pain among aircrew

Aircrew members that did not report any ongoing pain episodes at baseline in Study IV were prospectively followed with repeated questionnaires for about 12 months and showed a cumulative incidence of 23,4% (95% CI: 13-37%) reporting at least one episode. Their median (range) pain intensity rating was 3 (1-8, one missing).

Reliability of movement control test

The overall and test-by-test percentage agreement, Kappa coefficients and PABAK for inter-rater and test-retest reliability of tests to assess aircrews' preferred movement strategies and movement coordination strategies in Study II is presented in Table 6.

Inter-rater

Overall percentage agreement for all tests were 81.5%, kappa:0.58 and PABAK: 0.63. Percentage agreement ranged from 60% to 97% and the kappa coefficient from .19 to .95 for inter-rater reliability. These levels are interpreted as "slight" to "almost perfect" agreement according to Landis and Koch. (121). Seven out of 15 tests showed at least "substantial" agreement (>.60) and with PABAK calculation three additional tests also reached the level.

Test-retest

Overall percentage agreement for all tests were 74.4%, kappa:0.45 and PABAK: 0.49. Percentage agreement ranged from 64% to 84% and the kappa coefficients from .26 to .65. These levels are interpreted as "fair" to "substantial" agreement according to Landis and Koch. (121). Only 2 out of 15 tests showed at least "substantial" agreement (>.60) but with PABAK calculation one more test reached that level. There was, however, no systematic change in the number of passed tests, nor any difference in performance between participants with or without MSD.

Table 6. Percentage agreement, Kappa coefficients and Prevalence-And-Bias adjusted Kappa (PABAK) coefficients of movement control tests in the inter-rater (n=37) and test-retest (n=45) analyses.

Movement control tests	**Inter-rater**			**Test-retest**		
	%	*K*	PABAK	%	*K*	PABAK
Shoulder flexion L	89.2	.78	.78	66.7	.34	.33
Shoulder flexion R	97.3	.95	.95	77.8	.55	.56
Shoulder extension L	70.3	.40	.41	75.6	.51	.56
Shoulder extension R	75.7	.44	.51	64.4	.26	.29
Shoulder lat. rotation L	73.0	.45	.46	77.8	.54	.56
Shoulder lat. rotation R	83.8	.46	.68	80.0	.58	.60
Shoulder tests overall	**81.6**	**.62**	**.63**	**73.7**	**.46**	**.48**
Neck flexion in sitting	89.2	.44	.78	68.9	.32	.38
Neck extension in sitting	81.1	.57	.62	75.6	.36	.56
Neck rotation L	89.2	.71	.78	66.7	.32	.33
Neck rotation R	83.8	.64	.68	82.2	.60	.64
Neck flexion in supine	91.9	.84	.84	73.3	.41	.47
Neck extension in quad.	59.5	.19	.19	66.7	.30	.33
Chest lift	78.4	.48	.57	80.0	.57	.60
Neck tests overall	**81.9**	**.55**	**.64**	**73.3**	**.41**	**.47**
Pelvic tilt	89.2	.44	.78	84.4	.65	.69
Forward lean	83.8	.66	.68	71.1	.39	.42
Single knee extension L	89.2	.78	.78	73.3	.38	.47
Single knee extension R	83.8	.65	.68	84.4	.63	.69
Double knee extension	86.5	.69	.73	77.8	.53	.56
Leg lift L	78.4	.57	.57	77.8	.55	.56
Leg lift R	75.7	.49	.51	66.7	.27	.33
Rocking forward	62.2	.23	.24	71.1	.42	.42
Thoracic, lumbar, and hip tests overall	**81.1**	**.56**	**.62**	**75.8**	**.48**	**0.52**
Overall	**81.5**	**.58**	**.63**	**74.4**	**.45**	**.49**

K = Kappa coefficient, L = left side, R = right side, Quad = Quadruped.

Physical performance test

In Study III and IV, tests of physical performance were performed. In Study III, aircrew with ongoing cervico-thoracic pain were compared with pain-free colleagues. The results are presented in the following section regarding factors associated with cervico-thoracic pain. It should however be noted that data were missing for both the flexor strength test (n=10 in the pain group, n=6 in the pain-free group) and extensor strength test (n=12 in the pain group and n=6 in the pain-free group), which may have influenced the results. In Study IV, the objective was to identify baseline risk factors for future episodes of cervico-thoracic pain. Missing data were n=3 for the strength and endurance tests.

In Study III, the performance of movement control, ROM and cervical strength and endurance was compared between fighter pilots, helicopter pilots and rear crew. In demographics, the helicopter pilots and rear crew were significantly older than fighter pilots. Helicopter pilots had significantly more flight hours logged during their career compared to fighter pilots, who in turn had significantly more flight hours logged compared to rear crew (see Study III for details). In the analyses, few differences were observed in physical performance tests with Bonferroni adjusted the p-values (0.05/3). Rear crew showed significantly ($p<0.01$) less control of the “forward lean test” (37% passed) compared to both fighter pilots (86% passed) and helicopter pilots (78% passed). In cervical ROM, a significant difference ($p < 0.01$) was found for right lateral flexion where fighter pilots had higher ROM (40.3°) compared to helicopter pilots (36.2°) and rear crew (33.4°). Finally, a trend ($p=0.03$) was seen towards higher left lateral flexion for fighter pilots compared to rear crew, and higher cervical flexor strength fighter pilots compared to rear crew.

Factors associated with musculoskeletal disorders

Binary regression models identified associations between independent, personal, health, and work-related factors and pain in the upper body and lumbar region (Study I), test performance and pain in the cervico-thoracic region (Study III), and risk factors for the development of pain in the cervico-thoracic region (Study IV). The final regression models are presented in table 7. In general, most participants rated excellent health and were physically active, and smoking was rarely observed. See Study I and IV for details.

Upper body and lumbar region MSD

In Study I, univariate regression analyses of self-reported questionnaire items identified eight factors that were forwarded to the multivariate model. In the final model, one work-related factor (being employed as aircrew) and one health-related factor (rating one’s health less than optimal) emerged as significantly

(<0.01) associated with 12-month prevalence of pain in the upper body region. The OR:s were 3.22 and 1.94, respectively. For this thesis, the model was repeated with cervico-thoracic pain as the dependent variable, and the OR:s were 3.7 and 1.99, respectively ($p<0.01$). The same two factors as identified above were also significantly ($p<0.01$) associated together with two personal factors (age and body height) for pain in the lumbar region. Taken together, the final model included: being aircrew (OR 2.07), a physical health rating as less than excellent (OR 1.94), being older (OR 1.03) and taller (OR 1.05). The final models were unadjusted since none of the potential confounders or interactions significantly affected the OR.

Cervico-thoracic pain

In Study III, univariate regression analyses for a set of physical performance tests and ongoing cervico-thoracic region pain identified three movement control tests and five ROM tests that were forwarded to the multivariate model. In the final model, performance of three tests were lower among those who reported cervico-thoracic pain, less control of the movement control tests "neck flexion in sitting" (OR 3.61) and "forward lean" (OR 3.43) together with less cervical flexion ROM (OR 0.93) as significantly ($p<0.05$) associated with cervico-thoracic pain. The final model was unadjusted since none of the potential confounders or interactions significantly affected the OR.

Risk factors for cervico-thoracic pain

In Study IV, the risk for developing cervico-thoracic pain was regressed against independent, personal, health, and work-related factors together with a set of physical performance tests. Univariate regression analyses for identified four factors that were forwarded to the multivariate model. In the final model, a history of cervico-thoracic pain (OR 22.39), less cervical flexion ROM (OR 0.78) and shorter time for cervical flexor endurance time (OR 0.91) were significantly ($p<0.05$) associated with cervico-thoracic pain in the final model. The final model was unadjusted since none of the potential confounders or interactions significantly affected the OR.

Table 7. Factors significantly associated with upper quarter, lumbar region, and cervico-thoracic pain, reported as odds ratios.

	Study I Aircrew (n= 166) Deployed soldiers (n=185)				Study III Aircrew (n=73)		Study IV Aircrew (n=47)	
	Upper quarter		Lumbar region		Cervico-thoracic		Cervico-thoracic	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Demographic								
Occupation								
Aircrew	3.22	2.03-5.11	2.07	1.24-3.44				
Deployed soldiers	1.0	(ref)	1.0	(ref)				
Age (years)			1.03	1.00-1.06				
Height (cm)			1.05	1.00-1.09				
Health-related								
Physical health								
Excellent	1.0	(ref)	1.0	(ref)				
<Excellent	1.94	1.22-3.09	1.9	1.17-3.20				
Previous CT-pain							22.39	1.79-281
Physical capapcity								
Neck flexion in sitting								
Controlled					1.0			
Uncontrolled					3.61	1.06-12.34		
Forward lean								
Controlled					1.0			
Uncontrolled					3.43	1.04-11.37		
Neck flexion ROM					0.93	0.89-0.99	0.78	0.64-0.96
Flexor endurance (s)							0.91	0.83-0.99

Physical symptoms and functional limitations in aircrew with cervico-thoracic pain

Twenty-two out of 73 aircrew members in Study IV reported current cervico-thoracic pain at present and were subsequently examined by the physical therapist. Since three of them had additional pain in other body parts than in the cervico-thoracic region (nociceptive mechanical/inflammatory low-back/knee pain) and one was not available, these four were therefore not included in the analyses. Thus, 18 aircrew members were included in the analyses for physical symptoms in Study IV.

All aircrew described their pain to be localized to the cervico-thoracic region and that the pain was clear and proportionate to aggravating and easing factors. This was confirmed in the physical examination where the physical therapist, for example, was able to ease their pain through specific adjustments in spinal postures and movements. The pain was considered to be mostly of nociceptive character because it was localized, it could be provoked and eased by distributing the movement along the spine and there were no obvious signs of nociplastic pain. Notably, there was a variation in which movements were most pain sensitive. In two of the aircrew, signs and symptoms of other pain mechanisms, such as peripheral neuropathic pain, were also evident. One of these also reported pain which presented with headache. Three of them reported earlier disk prolapses with related physical symptoms.

The duration of pain ranged from 1 to 20 years and was most often characterized by an insidious onset, with current pain intensity (NPRS 0-10) at median 5 (range 2-8), and all but one reported daily pain or pain a few times per week. Eight reported that their pain affected their work ability; one of the aircrew was currently not allowed to fly and six had been off-duty during the last year due to their pain. Most could give examples of flight-related factors and situations that increased their pain and described how they tried to avoid these situations. They reported pain provoked by mechanical spinal loading linked to activities of work involving G-forces (only fighter pilots), wearing equipment, and sitting for long periods. Four of the aircrew reported that their pain was not flight-related.

Discussion

The main findings of this thesis were that MSD were common in Swedish military aircrew and 4/5 reported at least one problem during the previous year. No statistically significant differences were shown in pain prevalence between fighter pilots, helicopter pilots and rear crew. Additionally, compared to deployed soldiers, aircrew were more prone to report pain in the cervical and lumbar regions, as well as the shoulders during the previous year and at present. This was also the case for the thoracic region for the previous year only. They also reported higher pain intensity rating. Working as aircrew, and lower rating of ones´ physical health, was significantly associated with pain in the cervical, thoracic and shoulder regions. Results from the movement control test battery indicated that Two physical therapists could reliably rate movement pattern for the majority of movement control tests in the affected areas. Lower reliability was established in test-retest conditions, but that lower degree of stability was not attributed to a learning effect. Added to a compound test battery, movement control and measures of cervical range of motion but not cervical strength and endurance were associated with cervico-thoracic pain among military aircrew. Specifically, less control of both neck and lumbar flexion movements, and lower cervical flexion ROM were associated with cervico-thoracic pain. Comparison of fighter pilots, helicopter pilots and rear crews´ performance showed that lumbar flexion movement control and cervical lateral flexion ROM, were different between groups. Physical symptoms and functional impairments of aircrew with high intensity, flight elicited and work affecting cervico-thoracic pain showed an individual presentation. Previous pain episodes, lower cervical flexion range of motion, and lower cervical flexor muscle endurance were identified as risk factors for future cervico-thoracic pain.

Occurrence of musculoskeletal disorders in Swedish Armed Forces personnel

We wanted to investigate the extent of MSD in aircrew, and to compare their prevalence with a group of soldiers as the first step (106) to develop the MSP for aircrew. Over 80% of aircrew and over 70% of deployed soldiers reported MSD during the previous year, with the upper quarter of the body and the lumbar region the most common affected part for aircrew, while the lower extremities and lumbar region were most common among deployed soldiers in Study I. This prevalence for deployed soldiers is in line with previous studies (24, 28, 36, 123). The proportion of reported MSD is about two-fold for the regions in the upper quarter of the body in aircrew compared to deployed soldiers. This finding is supported by Lawson et al. who found increased odds for neck pain among pilots compared to army officers representing several NATO countries (38). Further, 56% reported cervico-thoracic pain during last 12 months, and 30% still had ongoing pain in Study III, indicating that this is a work-related problem among Swedish military aircrew.

Prevalence of cervico-thoracic pain among aircrew

Considering the knowledge on neck pain in the general population (44, 47), the male, physically active and full-time working military aircrew presented within this thesis have a rather high prevalence of MSD affecting the cervical and thoracic region, as well as the shoulders. These findings were expected, since previous studies have found even higher prevalence than in Study I and III among fighter pilots (26, 92) (51-82%) helicopter pilots (33, 39, 58) (43-67%), and rear crew (8, 39) (45-62%) and the in-flight load on these structures are significant. Regarding the lesser studied thoracic region, prevalence among aircrew (31.3%) was in line with that of Posch et al. who found a prevalence of 28% for Austrian helicopter pilots and 15% for rear crew (39). Similar prevalence among workers (30%) have been found (124).

In-flight loads such as G-forces during flying (69), and moving the head during G-maneuvers for fighter pilots (70), disadvantageous postures or work tasks in helicopters for helicopter pilots and rear crew (8), and the use of helmet-mounted equipment for helicopter pilots (33, 64) as well as for fighter pilots (5, 68), have been associated with cervical region pain. An increased strain on cervico-thoracic muscles in static laboratory situations (63) and in controlled centrifuge measures (61) has been suggested to explain the link between pain and use of helmet-mounted equipment. Interestingly, despite different physical exposure during work tasks, no statistically significant differences in distribution and prevalence of MSD were shown between fighter pilots, helicopter pilots, and rear crew. This is further supported by a systematic review and meta-analysis including fighter pilots helicopter pilots and transportation pilots (69), which showed no significant differences for cervical and lumbar region pain prevalence. This indicates the complexity behind work-related disorders with support from the biopsychosocial model of pain (20, 71), and studies have shown that fighter pilots reporting high number of desk hours to also be associated with neck pain (3, 40).

Cumulative incidence of cervicothoracic pain among aircrew

A recent systematic review concluded that longitudinal studies on pain incidence in fighter pilots are lacking (65). This makes it hard to compare the cumulative incidence from Study IV, where it was found that 23.4% of the aircrew that were pain-free at baseline reported that they had experienced an episode of cervico-thoracic pain during the following year. This number is lower compared to studies investigating period prevalence of neck pain among fighter pilots (92), helicopter pilots (33, 39, 58), and rear crew (8, 39). One reason behind this difference might be that these studies used a cross-sectional design, while we used a longitudinal design in Study IV with the point prevalence of cervico-thoracic pain at the time when the aircrew answered the questionnaire as the outcome. If a prevalence for a certain time-period (i.e., last 1-3 month), the cumulative incidence would likely be higher.

Reliability of movement control test

Reliable tests are important when assessing physical characteristics of aircrew members. We therefore developed a novel test protocol containing 15 movement control tests to assess aircrews´ movement coordination strategies (88) and performed tests on a sample of SAF employees. The overall agreement for inter-rater was 81,5%, Kappa: 0.58 and PABAK: 0.63. Two physiotherapists were in "substantial" agreement 4/5 times and with adjusted Kappa, coefficients. Specifically, 7 (10 with PABAK) of the 15 tests reached a substantial to almost perfect inter-rater agreement in Study II with kappa coefficients (0.19 to 0.95) in line with movement control tests for cervical (84) and lumbar (125, 126) regions. This is, however, somewhat lower than reached in cervical and shoulder region in two other studies where video-recordings of tests were rated (85, 127). Only the study by Monnier et al. (125) used live observations as performed in Study II.

The test-retest reliability of movement control tests has not been as extensively studied as inter-rater, where in many cases video recordings are being used. The overall agreement was 74,4%, Kappa: 0.45 and PABAK: 0.49. However, only two (three with PABAK) of the 15 tests reached at least substantial agreement with kappa coefficients (0.26–0.65) close to those reached by Monnier et al. among Swedish Marines (125). Previous findings, however, suggest that experienced clinicians can assess cervical and lumbar region movement control rather reliably if the movement is performed similarly (84, 126) as is the case when the same video-recordings are being analyzed on two separate occasions. In conclusion, two raters could reliably rate movement pattern for the majority of tests. Lower reliability was established in test-retest conditions, but that lower degree of stability was not attributed to a learning effect.

Physical performance test

Tests of physical performance were included in Study III and IV. In Study III, aircrew with ongoing cervico-thoracic pain were compared with pain-free colleagues, and the performance of the three groups (fighter pilots, helicopter pilots and rear crew) were also compared. The comparison regarding pain is discussed in the following section regarding factors associated with cervico-thoracic pain, but as presented in the results section, the number of missing data in strength and endurance tests is noteworthy and caused by ethical reasons to reduce the risk of harm. Despite this, two aircrew members experienced worsening of neck symptoms during the strength test of cervical extensors. The test was immediately aborted so that any potential pain emanating from this procedure would not subsequently influence forthcoming tests and thus no worsening of existing symptoms was evident post-test. In Study IV, the objective was to identify baseline risk factors for future episodes of cervico-thoracic pain. Missing data were n=3 for the strength and endurance tests.

Few differences were shown in movement control, active cervical range of motion, and muscle strength and endurance when compared between fighter pilots, helicopter pilots and rear crew in Study III. Rear crew showed significantly ($p<0.01$) less control of the “forward lean test” compared to both fighter pilots and helicopter pilots. This difference may be related to rear crew being exposed to more awkward postures with bent and twisted torsos, together with material handling compared to helicopter pilots (8).

In cervical ROM, a significant difference ($p < 0.01$) was found for lateral flexion to the right where fighter pilots had higher ROM compared to helicopter pilots and rear crew. The difference in ROM could be related to the fact that fighter pilots moves their cervical spine to extreme positions of combined extension, rotation and lateral flexion, occasionally under high G-forces, to maintain visual contact with their enemy (70). Fighter pilots were also younger than rear crew (35 vs. 43 years) and cervical ROM decreases with higher age (128), but there were only weak correlations between lateral flexion ROM and age were evident in our data. The physical therapist was blinded during tests of movement control and ROM to avoid bias. This is, however, not representative of regular clinical practice, nor needed in future work in the SAF.

Factors associated with musculoskeletal disorders

Upper body and lumbar region MSD

To further develop the MSP, 351 aircrew members and deployed soldiers answered the MSP questionnaire in Study I with demographic, health and work-related questions. A logistic regression analysis was performed that included earlier established important factors in studies on Swedish army soldiers and conscripts (28, 104). These studies have reported that MSD prevalence, physical inactivity, smoking, and self-reported lower ratings of mental health have been shown to be important risk factors for premature discharge from service for Swedish conscripts (28). The analysis identified two factors to be significantly associated with having upper quarter MSD. First, increased odds for employed as aircrew members compared to deployed soldier (OR 3.22) is supported by findings from a study where air force pilots had higher odds of reported neck pain compared to army officers (38), but few comparative studies exists. Regarding physical work environment relevant for aircrew, associations between neck-shoulder disorders and static or repetitive neck flexion and/or shoulder flexion loads have been established (129). Further, especially relevant for helicopter pilots and rear crew, causative effect of manual material handling, vibration, trunk flexion or rotation for shoulder complaints have been established in longitudinal studies (130). Taken together, these loads may contribute to the higher odds for aircrew compared to deployed soldiers seen in Study I. Second, similar to the study by Larsson et al., a less than excellent rating of the state of their physical health (OR 1.94) emerged as significantly associated with upper quarter MSD. The objective of the study, however, was to investigate the premature discharge rate of army recruits from military service due to MSD (28). Nevertheless, the findings indicates that the rating is indicative of MSD in military cohorts.

Further, being an aircrew member (OR 2.07), older age (OR 1.03), taller body height (OR 1.05), and rating the state of their physical health to be less than excellent (1.94) were factors significantly associated with MSD in the lumbar region. Shorter or taller than average body height has previously been shown to be associated with back pain in SAF marines (36) and increased age likely follows the natural pattern as observed for the general population (131). In conclusion, valuable information in the developmental process of a preventive tool for SAF aircrew indicates that the MSP questionnaire may be useful regarding individual, work, and health-factors.

Cervico-thoracic pain

The two movement control tests that were significantly associated with cervico-thoracic pain, the “neck flexion in sitting” (OR=3.43) and the “forward lean” (OR=3.61*)* tests both assesses the ability of the aircrew to perform smooth, controlled movements in the sagittal plane. This is perhaps associated with the biomechanically less advantageous sitting postures in the cockpit which are associated with the shape of the back rest and safety vest worn (56). Further, an increased muscular strain as indicated by greater electromyographic activation levels (61-63), is likely caused by the in-flight adopted flexed postures and repeated movements that are biomechanically less favorable (62, 63).

The less control of the “neck flexion in sitting” test is in conformity with findings on Swedish helicopter pilots (35) and individuals (132, 133) with neck pain. These studies observed a higher superficial sternocleidomastoid muscle activity during the cranio-cervical flexion test. A possible explanation to the fact that most movement control tests were not associated with cervico-thoracic pain is the large heterogeneity in neuromuscular adaptations accompanying pain disorders (18).

Generally, less ROM was observed for aircrew with cervico-thoracic pain in all movement. However, only flexion ROM (OR=0.93) remained significantly associated vid cervico-thoracic pain in the final model. Previous findings are conflicting. Studies on fighter pilots (93) and helicopter pilots (35) have found lesser flexion-extension and bilateral rotation for those with pain, also shown for extension among helicopter pilots (134), while no such difference were found in another study on helicopter pilots and rear crew (94). However, an adequate level of ROM is likely important for aircrew to perform their tasks and to maintain an adequate field of view while scanning their surroundings. It is hypothesized that if ROM is restricted in one region, then this movement is likely compensated for by an adjoining region which can subsequently experience pain (77).

No difference was observed between aircrew with and without cervico-thoracic pain for strength and endurance of cervical flexors and extensors, but these results should be interpreted with caution given the large amount of missing data, as discussed above. Similar to measures of ROM, the literature is conflicting. Our findings are in line with the lack of differences found in studies on fighter pilots (93, 96) and helicopter pilots (34, 94, 134), whereas Ang et al., conversely, reported lower extensor strength in fighter pilots with neck pain compared to their pain-free colleagues (34). In conclusion, the test protocol developed in this thesis gave some indication of its potential use in SAF aircrew as described from these analyses.

Risk factors for cervico-thoracic pain

We attempted to identify risk factors for new pain episodes among aircrew who were pain-free at baseline. Three of the variables included in the data collection were significantly indicative of reporting cervicothoracic pain at 12-month follow-up. First, having had previous pain episodes in the same region during 12 months prior to baseline increased the risk. Earlier studies have also reported previous pain as a risk indicator for new episodes in fighter pilots (68) and helicopter pilots (33). Previous pain episodes or injuries might indicate the recurrent nature of pain in this region (44). This implies that secondary and tertiary measures (135) are warranted for these primary episodes. Second, we found that lower flexion ROM was associated with a higher the risk of developing pain.

We also found that lower flexor endurance at baseline was significantly associated with a higher risk of reporting cervico-thoracic pain at the 12-month follow-up, there are no earlier studies including aircrew that have reported measures of neck endurance and its association with or risk for pain. Still, our results are supported by cross-sectional studies showing that the time in “deep neck flexor endurance test” was significantly shorter for Spanish military personnel with chronic non-specific neck pain and kinesiophobia when compared to their pain-free colleagues

(136). Also, among individuals (civilians) with non-specific neck pain, shorter flexor and extensor endurance time was shown when compared to pain-free individuals (137). Not only shorter endurance time, but also fatigue as indicated by electro myography assessment has been shown for individuals with cervical radiculopathy (138), and helicopter pilots with neck pain (34). Among fighter pilots, it has been shown that they are significantly stronger than army conscripts in cervical flexors and extensors but they performed significantly shorter neck extensor endurance time (55). Lower flexor endurance of cervical muscle seems to be important, but the underlying reason for their lower endurance is uncertain. Tests of endurance may be relevant to consider in future work regarding prevention of pain in aircrew.

Physical symptoms and functional limitations in aircrew with cervico-thoracic pain

To further deepen the understanding of aircrew with cervico-thoracic pain, we performed a one-on-one individual clinical examination of 18 aircrew members in Study IV. The aircrew examined reported relatively high pain intensity (median 5) and most of them reported daily pain or pain a few times per week. This is in a way contradictory to the fact that all but one was in active flight duty and most of them reported their health to be good or excellent. There is, of course, a complex relationship between pain, loading, dosage of exposure, and general health in military aircrew (71) One reason could however be that their pain was predominantly of a nociceptive mechanical (10) character with pain that they can understand and to cope with. This might be reflected by their own thoughts and experiences that their pain can be eased if they avoid certain movements or activities and exercise more. Further, most of the aircrew reported specific activities to be pain provoking. When the physical therapist manually supported the aircrew to alter the movement pattern during pain provoking movements (77, 117) in the physical examination, the pain was eased for the majority. Together, these features may reflect primarily peripherally mediated nociceptive processes, and although they had experienced pain for such an extended period (from 1 to 20 years), none of them, showed symptoms of nociplastic pain that was widespread with a disproportionate mechanical stimulus–pain response (16).

In conclusion findings from the individual examination of painful experiences in Study IV showed a broad palette with regards to the distribution of pain, individual impairments, and affected activities. These findings confirm that patients with the same medical diagnosis can show heterogeneous patterns of biological, psychological, and social characteristics (18) and that the relative contribution from the three domains for each patient is not static (20).

Methodological considerations

Several methodological considerations need to be discussed when interpreting the findings from this thesis.

Study design and participants

Several designs were used to be able to answer research questions regarding the prevalence and incidence of MSD and pain, the reliability of a novel test protocol, and to describe aircrew members physical symptoms and functional pain and functional limitations. In Study I, II and IV the cross-sectional design could answer questions regarding prevalence of MSD or pain and associations with personal, health, and work-related factors, and physical performance. The limitation with this design is that no associations on regarding causality can be drawn. In Study II, a test-retest design reported the reproducibility of the movement control tests with live observations. This is a commonly used method in the clinic, but few scientific studies have used this approach. Video recordings or more advanced methods could contribute with perspectives on reliability in terms of variability. Lastly, a longitudinal design was used to assess any causality between baseline measures and future pain episodes. More longitudinal studies are needed which include larger samples of aircrew to investigate preventive effects of regular screening or monitoring of aircrew, preferably with relevant sub-group comparisons.

The included samples in this thesis were all active SAF employees. Study I, II and IV included fighter pilots, helicopter pilots and rear crew cohorts from two air bases. The findings are therefore likely to be representative of other SAF aircrew. Further, with the aim to develop early preventive strategies, the inclusion of active-duty aircrew furthers strengthens the validity of the findings from this thesis. Regarding external validity, the findings are likely also relevant for other Air Forces for two main reasons. First, the SAF use similar aircrafts and associated systems as in other nations. Second, aircrew are considered a homogenous group and the cohorts in this thesis show similar demographics as in other Air Forces. Due to that insufficient sample sizes in Study III and IV, further sub-group comparisons were not possible for estimating the effect of different individual, work, and psychosocial factors for the three groups respectively. However, given the distinction in external physical exposure, preventive and clinical attention may still need to be specific to fighter pilots, helicopter pilots and rear crew (34). Lastly, one major limitation regarding validity, is that women were only included in Study II, while no females were included from Air Force cohorts because only three women were available. The proportion of female aircrew is slowly increasing, and they should therefore be included in future studies.

Ethical considerations

The participants were given both oral and written information and gave their written informed consent prior to participation in accordance with the declaration of Helsinki. Given the nature of a military population under study, especially aircrew members, confidentially together with the possibility to withdraw their consent, was stressed during the recruitment and data collection. In Study II-IV non-fatiguing, low load (active) movement control tests common in clinical practice were performed in a standardized order. Given the nature of such tests, the risk of injury was considered low. In Study III and IV, maximal active cervical ROM was examined, and strenuous tests to measure maximal isometric neck strength and submaximal endurance were performed in accordance with several previous studies. Pain can be experienced during ROM tests, but the risk for injury was considered low. Prior to strength and endurance tests, aircrew received verbal information regarding the purpose and performance of tests and were further asked for any ongoing pain that could interfere with or be aggravated by the test. After assuring that they were comfortable performing such tests, a warmup and procedures to familiarize the participants with the isometric test condition, including instructions to gradually increase the load during trials. These tests were a-priori considered to possibly trigger symptoms. In Study IV, individual subjective and physical examinations were performed according to common clinical practice. Sensitive and private information could be revealed, and pain could be provoked during tests during this process. Participants were instructed to seek further medical attention when deemed necessary.

Data collection

Questionnaire

Data regarding demographics, musculoskeletal disorders, health rating, physical training habits, and work exposure were collected in all studies using a questionnaire previously used in studies on SAF soldiers (27, 28, 30, 104, 107). The questionnaire (together with tests) has also been implemented in ongoing work in SAF at entry to service, as well as pre- and post-deployment. The questionnaire has good reliability (103), and a test-retest reliability and translational study has recently been submitted to a scientific journal for peer-review (101), Although it has not been validated against a gold standard, the long clinical use among several thousand SAF employees, and several revisions during this time, mean that the face validity has been assessed throughout this process.

The questionnaire includes questions covering aspects that can be of interest for MSD. It is not designed to be a comprehensive research instrument, rather an easy screening tool to prioritize who needs the appropriate intervention. As such, the five questions concerning self-rated health (108) were first developed for SAF fighter pilots in the 1990´s. They are thought to capture “daily form” rather than to be an indicator of lack of health or risk factor for MSD. The idea was to use it as a day-to-day self-assessment of the pilot’s health state, i.e., “am I ready to fly?”. However, low rating (≤2 out of 7) of physical (“how is the perception of your body”) or mental (“how is the perception of your mental state”) health has in previous studies on Swedish conscripts been a risk factor for leaving basic training prematurely (28) In daily use, a low rating on these questions will always be prioritized for follow-up.

The same definition of MSD (i.e., “*any musculoskeletal complaints or injuries during (i) the last year?” and (ii) at present”)* as in the above cited studies has been used for the MSP in this thesis. In-line with a recent NATO-report (2), the importance of capturing early symptoms is stressed in the MSP process. With the aim of developing primary, secondary, and tertiary prevention strategies, it is reasonable not to use a certain pain intensity rating or to only include what can be believed as work-related symptoms. Prevalence and incidence measures in military aircrew are dependent on the definition of the outcome, but there is a risk for recall bias when using questionnaires (26). Further, to only include MSD episodes derived from medical records entails a risk to underestimate the occurrence, since military personnel may be hesitant to seek medical attention (139). However, as noted by Riches et al., standardization of pain definitions in the future is required for researchers to compare the burden of pain in aircrew (26).

Prevalence was reported for each body region in Study I, whereas in following logistic regression analyses, the upper quarter (i.e., the cervical, thoracic, and shoulder regions) was used, and cervico-thoracic region were used in Study III-IV, were reported. These new definitions in this thesis were based partly on the observation of the common co-existence in cervico-thoracic region pain (140), as well derived from clinical reasoning regarding the numerous structures spanning over this region. The question remains, however, as to the “correct” definition for the most common pain problem among military aircrew.

Measures

Performance outcomes of physical tests in the MSP is today important for identifying an individual’s capacity in relation to their exposure. For example, if a ranger applicant fails to perform 75 step -ups with a 20 kg back-pack, that person is at increased risk of failing the basic military training period. Also common in other Air Forces, tests for flexibility, general fitness, and neck strength is implemented at various stages (2). The effectiveness of such preventive measures has however not yet been presented in the scientific literature, but has been encouraged (1).

Movement control tests

A tests battery protocol was developed to assess aircrews´ movement coordination strategies (88) among aircrew. Tests were selected for their common use in assessment of patients with MSD and were derived from the literature (75, 76, 87). The kappa-coefficients for inter-rater reliability were higher compared to test-retest reliability. These levels of agreement might vary due to the instrument itself, the tester, the person being tested, or the circumstances under which the measurements are taken (141). It is unclear whether the physical therapist judged the movements differently or if participants moved differently on test 1 and test 2. Movement variability is, however, observed even for pain-free individuals (78) in order to adapt to changes in the external environment and to variations in internal physiology in order to ensure a motor solution to these change (142, 143) This may therefore also partly explain the differences in ratings between test 1 and test 2. Pain also induces motor adaptations and causes a more constrained, stereotypical movement pattern (15). The time interval of a minimum of two and a maximum of seven days was chosen to minimize the risk of a learning effect (122), and no such systematic effect was observed in our study as indicated by the non-significant McNemar test.

Test used in Study III and IV were chosen based on results from Study II. In Study II, only two out of eight tests were associated with experiencing cervico-thoracic pain. A possible reason is the large heterogeneity in the neuromuscular adaptations accompanying pain disorders (18). In Study IV, cervico-thoracic pain episodes could not be predicted by the performance of movement control tests, also shown for back pain among SAF marines where similar tests to control the lumbo-pelvic region were used (29, 31). Motor adaptations have a role in the recurrence of spinal pain (15), but the usefulness of assessing these adaptations as performed in this thesis with a dichotomy, can be questioned. These adaptations can be subtle and therefore hard to judge based on the "pass or fail" dichotomy, especially since palpation was not allowed. Palpation is commonly used in clinical situations (74, 117, 144) and is also described in the original tests (75, 76, 87). Also different from clinical practice, the physical therapist was blinded to whether the aircrew had pain or not during test to avoid bias. Further, a more comprehensive scoring system (86), or electronic devices (145) could be useful to investigate movement coordination strategies in military aircrew. Also, assessment of flexibility and movement quality in cockpit could provide new insights into aircrews´ movement behavior under realistic conditions.

Cervical range of motion

The CROM3 device from Study III and IV is considered reliable and valid among individuals with neck pain (109, 110). During the tests, the aircrew sat on a bench in a neutral up-right position with their hips and knees in about 90° flexion. Tests were standardized regarding the number of repetitions and procedures to ensure that pure maximal) cervical ROM was measured. Similar devices have been used in other studies among fighter pilots (93) and helicopter pilots (35, 134) that strengthens the validity of our findings. Only flexion was significantly less among aircrew with cervico-thoracic pain compared to pain-free colleagues. Still, from in-flight observations and discussions with aircrew, the importance of cervical mobility remains important. For example, helicopter pilots adapt a flexed trunk posture with depressed shoulders, thus their potential ROM can be reduced from these adaptations. Further, rear crew work in awkward postures with a bent and rotated trunk, occasionally with their upper torsos outside the fuselage to increase their field of view during landing, rescue operations or material handling. Lastly, to view behind the aircraft, fighter pilots grab a handle with their left hand to rotate their trunk maximally to increase their field of view. Theoretically, if there is a restriction in one part of the kinetic chain or a movement segment, movements will likely be compensated by adjoining segments. These segments can subsequently become painful if the movement pattern persists over time (77). This is important for aircrew, since they wear a heavy helmet with added visual aids, a flight suit, and life-vests (56) that limit the variability of postural adaptations and constrains their cervical flexibility as well as increasing muscular strain (61). Taken together, measurement of cervical flexibility is important to measure in aircrew, but this measure may not capture all aspects of flexibility.

Isometric strength and endurance in cervical flexion and extension

The isometric strength and endurance tests in cervical flexion and extension performed in Study III and IV, were measured using fixed dynamometry. The device has not been tested for reliability in clinic but has certain industrial standards for its reliability given from the manufacturer. Test with hand-held dynamometers are considered to be reliable in tests on individuals with or without neck pain and pain .(146) Previous studies have used similar techniques and set-ups to estimate MVC in studies including fighter pilots (93, 96) and helicopter pilots (34, 94, 147), with contradictory findings regarding the association between strength and neck pain. In Study III and IV, there were no associations with ongoing or future episodes of cervico-thoracic pain. The values for both measurements varied considerably. For strength measures, it is unclear whether all aircrew exerted their true maximal effort can be raised. For endurance, the flexor test emerged as a risk factor for future cervico-thoracic pain episode in Study IV. In-line with recommendations (95) the endurance test was performed at 50% of the MVC test The test was aborted when aircrew rated their exertion to be seven or more on the Borg CR10-scale (111). This scale could also have been utilized to estimate exertion also during the maximal-strength test. Muscular strength may be impaired in individuals with neck pain (90) but its suitability for aircrew remains uncertain. Aircrew with neck pain may not be representative of other groups with neck pain, since aircrew are stronger in their neck muscles compared to army conscripts (55). Further, our population were still working and rated high levels of general health, which is also different to the normal population (47). The procedures to measure neck strength and endurance among aircrew should be reviewed. As discussed earlier regarding missing data from strength and endurance tests, the data from measured strength and endurance is uncertain, and the procedures for testing needs revision in future work.

Individual clinical examination of physical symptoms and functional limitations in aircrew with cervico-thoracic pain

We explored the physical symptoms and functional limitations associated with cervico-thoracic pain in a one-on-one individual clinical examination as commonly performed in clinical practice. We thereby gained knowledge of aircrew members´ individual physical symptoms and functional limitations, and potential risk factors for future cervico-thoracic pain episodes, to inform the practice of the Air Force health service. In the individual examination in study IV, there is a risk of selection bias with this limited number of aircrew members examined. Further, regarding bias, the individual examination was performed by an experienced physical therapist. Their experiences will influence the assessment and conclusions of the findings from aircrew with pain.

Statistical analyses

One strength of this thesis is the inclusion of entire cohorts to strengthen the conclusions being drawn. For these cohorts, logistic regression models were used in Study I, III and IV to analyze associations between a binary outcome (MSD or pain [yes/no]) and several independent variables. This method was considered suitable given the multifactorial origin of MSD, where several independent variables may be of relevance to the disorder and can thus be accounted for as potential confounders. After checking univariate associations, independent variables at $p<0.2$ were forwarded to an initial model. Thereafter, they were sequentially removed until only significantly associated variables ($p<0.05$) remained in the model.

The regression models in Study I, II and IV were all presented as the crude models since we found no evidence of any confounding effect and the Hosmer and Lemsehow tests (119) were non-significant, meaning that the model-fit was better than by chance. Finally, the already implemented questionnaire was used to estimate the prevalence of MSD in this thesis as it is used in daily practice. The MSP questionnaire is used as a screening tool to identify individuals with ongoing or past MSD and low health status, but the questionnaire may be sub-optimal in determining risk factors in regression analyses as compared to more comprehensive outcome measures.

In Study II, percentage agreement, kappa coefficients (121) and prevalence-adjusted bias-adjusted kappa coefficients (PABAK) aided the interpretation of reliability for each test (122). For this thesis, the average agreement for the entire test battery was also calculated. A power calculation was performed revealing that 35 participants were needed. We included 37 and 45 participants, respectively, and believe that the numbers were sufficiently for the analyses. However, a limitation with kappa coefficients is that they are prevalence-sensitive (122), meaning that the rate of pass/fail of a test for one of the groups being compared will impact the coefficient. PABAK is a measure of how well tests would "perform" under the best distribution in the two-times-two cross-tabulation. By reporting percentage agreement, kappa coefficients and PABAK, interpretation of the tests´ reliability can be enhanced.

One limitation is the sample size of Study IV, where the CI of the ORs in the logistic regressions indicate that too few study participants were included, and interpretation of the exact ORs is therefore limited. However, the finding that few of the measures included in this study could be considered important risk factors for developing pain is probably not explained by the sample size. Instead, we believe a more likely explanation is that the distribution of test results rated good/bad, high/low, were mostly equally distributed among pain-free military crew and those reporting pain at the 12-month follow-up. Further, regarding sample size in Study IV, we explored the symptoms behind cervico-thoracic pain in detail from 18 aircrew members with cervico-thoracic pain. There is a risk of selection bias with this limited number of aircrew examined. Further, regarding bias, the individual clinical examination was performed by an experienced physical therapist. Their experiences will influence the assessment and conclusions of the findings from aircrew with pain.

Implications

Important steps for the development of prevention strategies for MSD have been taken in this thesis with the "ability process" (103) as foundation. For SAF aircrew, the incidence and severity of MSD, as well as risk factors for MSD, have been estimated, and attempts to explore the underlying and associated factors to MSD have been compiled. The results suggest that the MSP concept may offer primary and secondary preventive effects if implemented, since risk factors for future pain episodes and factors associated with ongoing pain could be identified with a questionnaire and physical performance tests.

This is important considering that no prevention program has been developed despite the fact that earlier studies up to 2009 on SAF aircrew provided valuable insights regarding neck pain and effective training regimens. The findings of this thesis suggest that information about previous and ongoing MSD, self-rated health, measures of ROM, and muscular performance should now be included in the annual medical examination of SAF aircrew. SAF aircrew need effective, early prevention of pain and functional impairments to reduce potential future limitations in operational readiness.

Future research

Future research should include large cohorts and longitudinal designs with multivariate statistics to investigate the potential preventive effects of systematic screening of risk factors for MSD in longitudinal studies with multivariate statistics and causal interference, preferably with repeated follow-ups and the inclusion of organizational interventions. Assessment of movement coordination strategies in the cockpit may benefit from additional technical solutions and heightened grading criteria, both clinically and scientifically, with and without helmet-mounted displays. Muscle capacity is likely an important factor, but new methodologies are required for sufficient assessment.

The following are specific suggestions for future research:

- Investigate in-flight exposure of load among aircrew, as well as their job demands in order to better design preventive measures.
- Assess flexibility and movement quality in the cockpit to provide new insights into movement behaviors of aircrew under realistic conditions.
- Perform prospective studies with large (ideally international) cohorts and multivariate analyses to reflect the multifactorial nature of MSD.
- Perform single-subject experimental studies to gain in-depth knowledge regarding experiences of pain affecting the work of aircrew.
- Evaluate the effect of comprehensive interventions that not only take the individual into account, but also organizational factors.

Conclusions

MSD are an occupational problem affecting the majority of Swedish Armed Forces aircrew. When compared to deployed soldiers, military aircrew reported higher prevalence of MSD in the cervical, thoracic, shoulder, and lumbar regions. About 80% reported at least one painful area during the previous year. In a logistic regression model, being employed as aircrew, and lower rating of ones´ physical health, was significantly associated with pain in the cervical, thoracic and shoulder regions.

A clinical tests battery was compiled to assess movement control in affected areas. Reliability analyses revealed that two physical therapists could reliably rate movement patterns for the majority of the included tests. Lower reliability was however seen for test-retest conditions.

Movement control and measures of cervical ROM but not cervical strength and endurance were cross-sectionally associated with cervico-thoracic pain among military aircrew. In a logistic regression model, less control of both neck and lumbar flexion movements, and lesser cervical flexion ROM were associated with cervico-thoracic pain. Further, differences were found between fighter pilots, helicopter pilots and rear crew for lumbar flexion movement control and cervical lateral flexion ROM.

Individual clinical examination of aircrew with cervico-thoracic pain showed a high pain intensity of flight elicited and work affecting pain. Their physical symptoms and functional impairments could be modulated by modifying their movements, suggesting that nociceptive pain and mechanical factors behind their symptoms. The 12-month cumulative incidence of cervico-thoracic pain was 23%. A logistic regression model identified previous pain episodes, lesser cervical flexion ROM, and lesser cervical flexor muscle endurance, as risk factors for future cervico-thoracic pain.

Since findings from this thesis strongly indicate that MSD in SAF aircrew are a significant occupational problem that has not yet been solved, it is now important that the musculoskeletal system is considered in the annual medical examination within the SAF. The results suggest that the musculoskeletal protocol, which is already implemented and regulated in the SAF manual/guidebook, is adjusted and implemented also for SAF aircrew.

Acknowledgement

I could never have made this work by my own! There are too many people to thank for making this work possible, my very special thanks goes to:

Ulrika Aasa, main supervisor, for all the mentoring, guidance, questioning and challenges. Always responding whenever, wherever, ready for discussion.

Björn Äng, co-supervisor, for sharing your long experience, statistical skills and all scientific discussions.

Karin Harms-Ringdahl, co-supervisor, for sharing your immense wisdom, experience and calm. A true inspiration!

All participants, for taking your time, sharing your experiences and introducing me in your exciting work.

Helena Larsson, principal investigator for the project and co-author, the MSP and this thesis would not exist if it weren't for you.

Lisbet Broman, "data-handling specialist", always with that extra eye on the databases, charts and tables. Always willing to help whenever needed.

Monika Seth, super-physio and invaluable support in data collection in Study II. For being a great friend and all good times in St Louis and at conferences world-wide.

All PhD-colleagues, for time spent reading and critically reviewing manuscripts as well as fun time at PhD-lunches and brännbollsspel.

Heidi Nedergård, you are the best! We did it! For always seeing the positive side of things. Now let´s buy that tractor so we can get some job done.

Andrew Strong, for always helping with my not so English English, and all truly important chat about motor control and running shoes.

Anna Stecksén, for being such a nice friend, cheering and supportive, and for great coffee-hang at Kahls.

Jonas Markström, Tobias Stenlund, Lars Berglund, Sara Lundell, Past PhD-colleagues and roommates, for being the best support, always there when there´s a bump in the road.

Beatrice Pettersson, Erik Frykholm, Jerry Öhlin and again Heidi, “Finish the thesis squad”, for great pomodoro-time and virtual hang in between and for leading the way. I finished last but who´s counting, right?

Daniel Jansson and Frida Degerstedt, Present PhD-colleagues and roomies, for always checking that I´m ok and for not stealing all my chocolate.

Eva Tengman, Gudrun Johansson, Chatarina Carlén, Colleagues at UMU, for great support, advice and guidance in the academic world.

Alexandra Halvarsson, Marie Kierkegaard, Andreas Monnier, Martina Bergenroth, Elinor Nordström, Colleagues at NVS, for all help, cheers and scientific and not so scientific discussions.

Past and present co-workers at Min Hälsa and Sports medicine, thank you all for asking how I´m doing and making my physio-work so inspiring.

Pierre Moffjärd, part-time physician, part-time house constructor. Thank you for generously lending me your fantastic “cabin” in Hemavan during my writing-expedition. Invaluable!

My mother, father and sister, thank you for your enormous support, love and help with whatever I ask for.

My amazing wife Anna, this thesis would not exit if it weren´t for you. Thank you for your, love, time, patience and all fika. You mean the world to me.

My even more amazing children Sam and Lilly, sorry for all the time spent away collecting data, attending conferences and courses, and the grumpy face during the very last month’s finishing this thesis. Now we´re going skating, right?

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Appendix

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21. *Anncristine Fjellman-Wiklund*. Musicianship and teaching. Aspects of musculoskeletal disorders, physical and psychosocial work factors in musicians with focus on music teachers. Umeå University Medical Dissertations, New series no 825, 2003 (Department of Community Medicine and Rehabilitation, Physiotherapy)
22. *Börje Rehn*. Musculoskeletal disorders and whole-body vibration exposure among professional drivers of all-terrain vehicles. Umeå University Medical Dissertations, New series no 852, 2004 (Department of Public Health and Clinical Medicine, Occupational Medicine)
23. *Martin Björklund*. Effects of repetitive work on proprioception and of stretching on sensory mechanisms. Implications for work-related neuromuscular disorders. Umeå University Medical Dissertations, New series no 877, 2004 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit, Umeå University, The Center for Musculoskeletal Reseach, University of Gävle, Umeå, and Alfta Forskningsstiftelse, Alfta)
24. *Karin Wadell*. Physical training in patients with chronic obstructive pulmonary disease – COPD. Umeå University Medical Dissertations, New series no 917, 2004 (Departments of Community Medicine and Rehabilitation, Physiotherapy; Public Health and Clinical Medicine, Respiratory Medicine and Allergy, Surgical and Perioperative Sciences, Sports Medicine)
25. *Peter Michaelson*. Sensorimotor characteristics in chronic neck pain. Possible pathophysiological mechanisms and implications for rehabilitation. Umeå University Medical Dissertations, New series no 924, 2004 (Departments of Surgical and Perioperative Sciences, Sports Medicine Unit, University of Umeå, Southern Lappland Research Department, Vilhelmina, Centre for Musculoskeletal Research, University of Gävle, Umeå)
26. *Ulrika Aasa*. Ambulance work. Relationships between occupational demands, individual characteristics and health related outcomes. Umeå University Medical Dissertations, New series no 943, 2005 (Department of Surgical and Perioperative

Sciences, Sports Medicine and Surgery, University of Umeå and Centre for Musculoskeletal Research, University of Gävle)

27. *Ann-Katrin Stensdotter*. Motor Control of the knee. Kinematic and EMG studies of healthy individuals and people with patellofemoral pain. Umeå University Medical Dissertations, New series no 987, 2005 (Department of Community Medicine and Rehabilitation, Physiotherapy)
28. *Tania Janaudis Ferreira*. Aspects of muscle function and training with oxygen in patients with chronic obstructive pulmonary disease – COPD. Umeå University Licentiate Thesis, 2005 (Department of Community Medicine and Rehabilitation, Physiotherapy)
29. *Erik Rosendahl*. Fall prediction and a high-intensity functional exercise programme to improve physical functions and to prevent falls among older people living in residential care facilities. Umeå University Medical Dissertations, New Series no 1024, 2006 (Department of Community Medicine and Rehabilitation, Geriatric Medicine and Physiotherapy)
30. *Michael Stenvall*. Hip fractures among old people. Their prevalence, consequences and complications and the evaluation of a multi-factorial intervention program designed to prevent falls and injuries and enhance performance of activities of daily living. Umeå University Medical Dissertations, New Series no 1040, 2006 (Department of Community Medicine and Rehabilitation, Geriatric Medicine and Physiotherapy)
31. *Petra von Heideken Wågert*. Health, physical ability, falls and morale in very old people: the Umeå 85+ Study. Umeå University Medical Dissertations, New Series no 1038, 2006 (Department of Community Medicine and Rehabilitation, Geriatric Medicine and Physiotherapy)
32. *Karl Gisslén*. The patellar tendon in junior elite volleyball players and an Olympic elite weightlifter. Umeå University Medical Dissertations, New Series no 1073, 2006 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit)
33. *Gerd Flodgren*. Effect of low–load repetitive work and mental load on sensitising substances and metabolism in the trapezius muscle. Umeå University Medical Dissertations, New series no 1130, 2007 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit, Centre of Musculoskeletal Research, University of Gävle, Umeå, and the Department of Community Medicine and Rehabilitation, Rehabilitation Medicine)
34. *Staffan Eriksson*. Falls in people with dementia. Umeå University Medical Dissertations, New series no 1135, 2007 (Department of Community Medicine and Rehabilitation, Physiotherapy and Geriatric Medicine)
35. *Jonas Sandlund*. Position-matching and goal-directed reaching acuity of the upper limb in chronic neck pain: Associations to self-rated characteristics. Umeå University Medical Dissertations, New series no 1182, 2008 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit, Umeå University, Centre of Musculoskeletal Research, University of Gävle, Umeå)
36. *Gunilla Larsson*. Motor function over time in Rett syndrome-loss, difficulties and possibilities. Umeå University Licentiate Thesis, 2008 (Department of Community Medicine and Rehabilitation, Physiotherapy)
37. *Charlotte Åström*. Effects of vibration on muscles in the neck and upper limbs. With focus on occupational terrain vehicle drivers. Umeå University Medical Dissertations, New series no 1135, 2008 (Department of Community Medicine and Rehabilitation, Physiotherapy)
38. *Ellinor Nordin*. Assessment of balance control in relation to fall risk among older people. Umeå University Medical Dissertations, New series no 1198, 2008 (Department of Community Medicine and Rehabilitation, Physiotherapy)
39. *Bertil Jonsson*. Interaction between humans and car seat. Studies of occupant seat adjustment, posture, position and real world neck injuries in rear-end impacts. Umeå

University Medical Dissertations, New Series no 1163, 2008 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit)

40. *Jenny Röding*. Stroke in the younger. Self- reported impact on work situation, cognitive function, physical function and life satisfaction. A national survey. Umeå University Medical Dissertations, New series no 1241, 2009 (Department of Community Medicine and Rehabilitation, Physiotherapy)
41. *Therese Stenlund*. Rehabilitation for patients with burn out. Umeå University Medical Dissertations, New series no 1237, 2009 (Department of Public Health and Clinical Medicine, Occupational and Environmental Medicine)
42. *Elisabeth Svensson*. Hand function in children and persons with neurological disorders. Aspects of movement control and evaluation of measurements. Umeå University Medical Dissertations, New series no 1261, 2009 (Department of Community Medicine and Rehabilitation, Physiotherapy)
43. *Helena Nordvall*. Factors in secondary prevention subsequent to distal radius fracture. Focus on physical function, co-morbidity, bone mineral density and health-related quality of life. Umeå University Medical Dissertations, New series no 1252, 2009 (Department of Community Medicine and Rehabilitation Physiotherapy and Department of Surgical and Perioperative Sciences, Orthopaedics)
44. *Ingela Marklund*. Intensivträning av nedre extremitet för personer med stroke– effekter och upplevelser. Umeå University Licentiate Thesis, 2009 (Department of Community Medicine and Rehabilitation, Physiotherapy)
45. *Ulrik Röijezon*. Sensorimotor function in chronic neck pain. Objective assessments and a novel method for neck coordination exercise. Umeå University Medical Dissertations, New series no 1273, 2009 (Department of Community Medicine and Rehabilitation, Physiotherapy, Centre of Musculoskeletal Research, University of Gävle, Umeå)
46. *Birgit Enberg*. Work experiences among healthcare professionals in the beginning of their professional careers. A gender perspective. Umeå University Medical Dissertations, New series no 1276, 2009 (Department of Community Medicine and Rehabilitation, Physiotherapy and Department of Public Health and Clinical Medicine, Epidemiology and Public Health Sciences)
47. *Per Jonsson*. Eccentric training in the treatment of tendinopathy. Umeå University Medical Dissertations, New series no 1279, 2009 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit)
48. *Taru Tervo*. Physical activity, bone gain and sustainment of peak bone mass. Umeå University Medical Dissertations, New series no 1282, 2009 (Department of Surgical and Perioperative Sciences, Sports Medicine, Department of Community Medicine and Rehabilitation, Geriatric Medicine, Department of Community Medicine and Rehabilitation, Rehabilitation Medicine)
49. *Kajsa Gilenstam*. Gender and physiology in ice hockey: a multidimensional study. Umeå University Medical Dissertations, New series no 1309, 2010 (Department of Surgical and Perioperative Sciences, Sports Medicine Unit)
50. *Margareta Eriksson*. A 3-year lifestyle intervention in primary health care. Effects on physical activity, cardiovascular risk factors, quality of life and costeffectiveness. Umeå University Medical Dissertations, New series no 1333, 2010 (Department of Community Medicine and Rehabilitation, Physiotherapy and Department of Public Health and Clinical Medicine, Epidemiology and Public Health Sciences)
51. *Eva Holmgren*. Getting up when falling down. Reducing fall risk factors after stroke through an exercise program. Umeå University Medical Dissertations, New series no 1357, 2010 (Department of Community Medicine and Rehabilitation, Physiotherapy and Department of Public Health and Clinical Medicine, Medicine)
52. *Tania Janaudis Ferreira*. Strategies for exercise assessment and training in patients with chronic obstructive pulmonary disease. Umeå University Medical Dissertations,

New series no 1360, 2010 (Department of Community Medicine and Rehabilitation, Physiotherapy)

53. *Sólveig Ása Árnadóttir*. Physical activity, participation and self-rated health among older community-dwelling Icelanders. A population-based study. Umeå University Medical Dissertations, New series no 1361, 2010 (Department of Community Medicine and Rehabilitation, Physiotherapy)
54. *Maria Wiklund*. Close to the edge. Discursive, embodied and gendered stress in modern youth. Umeå University Medical Dissertations, New series no 1377, 2010 (Department of Public Health and Clinical Medicine, Epidemiology and Global Health and Department of Community Medicine and Rehabilitation, Physiotherapy)
55. *Catharina Bäcklund*. Promoting physical activity among overweight and obese children: Effects of a family-based lifestyle intervention on physical activity and metabolic markers. Umeå University 2010 (Department of Food and Nutrition)
56. *Helene Johansson*. En mer hälsofrämjande hälso- och sjukvård: hinder och möjligheter utifrån professionernas perspektiv. Umeå University Medical Dissertations, New series no 1388, 2010 (Department of Public Health and Clinical Medicine, Epidemiology and Global Health)
57. *Håkan Littbrand*. Physical exercise for older people: focusing on people living in residential care facilities and people with dementia. Umeå University Medical Dissertations, New series no 1396, 2011 (Department of Community Medicine and Rehabilitation, Geriatric Medicine and Physiotherapy)
58. *Marlene Sandlund*. Motion interactive games for children with motor disorders. Umeå University Medical Dissertations, New series no 1419, 2011 (Department of Community Medicine and Rehabilitation, Physiotherapy)
59. *Ann Sörlin*. Health and the Elusive Gender Equality. Can the impact of gender equality on health be measured? Umeå University Medical Dissertations, New series no 1420, 2011 (Department of Public Health and Clinical Medicine, Epidemiology and Global Health)
60. *Björn Sundström*. On diet in ankylosing spondylitis. Umeå University Medical Dissertations, New series no 1440, 2011 (Department of Public Health and Clinical Medicine, Rheumatology)
61. *Gunilla Stenberg*. Genusperspektiv på rehabilitering för patienter med rygg- och nackbesvär i primärvård. Umeå University Medical Dissertations, New series no 1482, 2012 (Department of Community Medicine and Rehabilitation, Physiotherapy and Umeå centre for Gender Studies)
62. *Mia Conradsson*. Physical exercise and mental health among older people - measurement methods and exercise effects with focus on people living in residential care facilities. Umeå University Medical Dissertations, New series 1537, 2012 (Department of Community Medicine and Rehabilitation, Geriatric Medicine)
63. *Mattias Hedlund*. Biomechanical and Neural Aspects of Eccentric and Concentric Muscle Performance in Stroke Subjects. Implications for resistance training. Umeå University Medical Dissertations, New series no 1510, 2012 (Department of Community Medicine and Rehabilitation, Physiotherapy)
64. *Joakim Bagge*. TNF-alfa och neurotrophins in achilles tendinosis. Umeå University Medical Dissertations, New series no 1538, 2013 (Department of Integrative Medical Biology, Anatomy and Department of Surgical and Perioperative Sciences, Sports Medicine)
65. *Gunilla Larsson*. Motor development, mobility and orthostatic reactions in Rett syndrome. Loss of function, difficulties and possibilities. Umeå University Medical Dissertations, New series no 1566, 2013 (Department of Community Medicine and Rehabilitation, Physiotherapy)
66. *Ludvig J Backman*. Neuropeptide and catecholamine effects on tenocytes in tendinosis development. Studies on two model systems with focus on proliferation and apoptosis. Umeå University Medical Dissertations, New series no 1572, 2013

(Department of Integrative Medical Biology, Anatomy and Department of Surgical and Perioperative Sciences, Sports Medicine)

67. *Sven Blomqvist*. Postural balance, physical activity and capacity among young people with intellectual disability. Umeå University Medical Dissertations, New series no 1579, 2013 (Department of Community Medicine and Rehabilitation, Physiotherapy)
68. *Eva Tengman*. Long-term consequences of anterior cruciate ligament injury. Knee function, physical activity level, physical capacity and movement pattern. Umeå University Medical Dissertations, New series no 1631, 2014 (Department of Community Medicine and Rehabilitation, Physiotherapy)
69. *Andre Nyberg*. Single limb exercises in patients with chronic obstructive pulmonary disease. Feasibility, methodology, effects and evidence. Umeå University Medical Dissertations, New series no 1645, 2014 (Department of Community Medicine and Rehabilitation, Physiotherapy)
70. *Maria Strömbäck*. Skapa rum. Ung femininitet, kroppslighet och psykisk ohälsa – genusmedveten och hälsofrämjande intervention. Umeå University Medical Dissertations, New series no 1655, 2014 (Department of Community Medicine and Rehabilitation, Physiotherapy, Clinical Science, Psychiatry and Umeå Centre for Gender Studies, National Research School for Gender Studies)
71. *Joakim Bjerke*. Gait and postural control after total knee arthroplasty. Umeå University Medical Dissertations, New series no 1664, 2014 (Department of Community Medicine and Rehabilitation, Physiotherapy)
72. *Elisabet Sonntag-Öström*. Forest for rest. Recovery from exhaustion disorder. Umeå University Medical Dissertations, New series no 1667, 2014 (Department of Public Health and Clinical Medicine, Occupational and Environmental Medicine)
73. *Maria Sehlin*. Resistance breathing with PEP and CPAP. Effects on respiratory parameters. Umeå University Medical Dissertations, New series no 1674, 2014 (Department of Surgical and Perioperative Sciences, Anaesthesiology and Intensive Care Medicine, Department of Community Medicine and Rehabilitation, Physiotherapy, Department of Radiation Sciences, Biomedical Engineering)
74. *Petra Pohl*. Falls in older community-dwelling women and men: risk factors and safety strategies. Fall risk awareness, fear of falling, and preferred exercise properties from a gender perspective. Umeå University Medical Dissertations, New series No 1692, 2015 (Department of Community Medicine and Rehabilitation, Physiotherapy)
75. *Gudrun Johansson*. Clinical and kinematic assessments of upper limb function in persons with post-stroke symptoms. Umeå University Medical Dissertations, New series No 1722, 2015 (Department of Community Medicine and Rehabilitation, Physiotherapy)
76. *Camilla Sandberg*. Physical performance, physical activity, body composition and exercise training in adults with congenital heart disease. Umeå University Medical Dissertations, New series No 1758, 2016 (Department of Public Health and Clinical Medicine, Medicine, Department of Community Medicine and Rehabilitation, Physiotherapy)
77. *Tobias Stenlund*. Seated postural reactions to mechanical shocks. Laboratory studies with relevance for risk assessment and prevention of musculoskeletal disorders among drivers. Umeå University Medical Dissertations, New series No 1780, 2016 (Department of Community Medicine and Rehabilitation, Physiotherapy)
78. *Anna Bråndahl*. Rehabilitation after stroke with focus on early supported discharge and post-stroke fatigue. Umeå University Medical Dissertations, New series No 1817, 2016 (Departments of Public Health and Clinical Medicine, Medicine, and Community Medicine and Rehabilitation, Physiotherapy)
79. *Lars Berglund*. Deadlift training for patients with mechanical low back pain: a comparison of the effects of a high-load lifting exercise and individualized low-load motor control exercises. Umeå University Medical Dissertations, New series No 1806,

2016 (Department of Community Medicine and Rehabilitation, Physiotherapy, Department of Surgical and Perioperative Sciences, Orthopaedics)

80. *Peter Flank*. Spinal cord injuries in Sweden: studies on clinical follow-ups. Umeå University Medical Dissertations, New series No 1824, 2016 (Department of Community Medicine and Rehabilitation, Rehabilitation Medicine)
81. *Annika Toots*. Gait speed and physical exercise in people with dementia. Umeå University Medical Dissertations, New series No 1866, 2016 (Department of Community Medicine and Rehabilitation, Geriatric medicine and Physiotherapy)
82. *Cecilia Wahlström Edling*. Musculoskeletal disorders in music teachers and their view on young music student' health – Visions and reality in contradiction. Umeå University Licentiate Thesis 2017. (Department of Community Medicine and Rehabilitation, Physiotherapy and Umeå Centre for Gender Studies)
83. *Åsa Svedmark*. Neck pain in women – Effect of tailored and impact of work environment. Umeå University Medical Dissertations, New series No 1916, 2017 (Department of Community Medicine and Rehabilitation, Physiotherapy)
84. *Anna Stecksén*. Stroke thrombolysis on equal terms? Implementation and ADL outcome. Umeå University Medical Dissertations, New series No 1917, 2017 (Department of Public Health and Clinical Medicine, Medicine, and Department of Community Medicine and Rehabilitation, Physiotherapy)
85. *Kristina Hörnberg*. Aspects of physical activity in rheumatoid arthritis. Associations with inflammation and cardiovascular risk factors. Umeå University Dissertations, New series no 1949, 2018 (Department of Public Health and Clinical Medicine, Rheumatology)
86. *Elisabeth Pietilä-Holmner*. Multimodal Rehabilitation of Patients with Chronic Musculoskeletal Pain, focusing on Primary Care. Umeå University Medical Dissertations, New series No 1970, 2018 (Department of Community Medicine and Rehabilitation, Rehabilitation medicine)
87. *Sara Lundell*. COPD in primary care. Exploring conditions for implementation of evidence-based interventions and eHealth Care. Umeå University Medical Dissertations, New series No 1982, 2018 (Department of Community Medicine and Rehabilitation, Physiotherapy) and Department of Radiation Sciences, Radiation physics and Biomedical Engineering)
88. *Frida Bergman*. Active workstations – a NEAT way to prevent and treat overweight and obesity. Umeå University Medical Dissertations, New series No 1981, 2018 (Departments of Public Health and Clinical Medicine, Medicine and Community Medicine and Rehabilitation, Physiotherapy)
89. *Haleluya Moshi*. Traumatic spinal cord injuries in rural Tanzania. Occurrence, clinical outcomes and life situation of persons living in the Kilimanjaro region. Umeå University Medical Dissertations, New series No 1988, 2018 (Department of Community Medicine and Rehabilitation, Physiotherapy.)
90. *Claes Göran Sundell*. Low back pain in Adolescent Athletes. Umeå University Medical Dissertations, New series No 2014, 2019 (Department of Community Medicine and Rehabilitation)
91. *Viktoria Wahlström*. Intervention for increased physical activity among office workers. Umeå University Medical Dissertations, New series No 2053, 2019 (Department of Public Health and Clinical Medicine, Section for Sustainable Health)
92. *Anna Sondell*. Exercise and team rehabilitation in older people with dementia: applicability, motivation and experiences. Umeå University Medical Dissertations, New series No 2064, 2020 (Department of Community Medicine and Rehabilitation, Physiotherapy)
93. *Veronica Lundberg*. Children with Juvenile Idiopathic Arthritis, Health-related quality of life and participation in healthcare encounters. Umeå University Medical Dissertations, New series No 2088, 2020 (Department of Community Medicine and Rehabilitation, Physiotherapy)

94. *Åsa Karlsson.* Team-based home rehabilitation after hip fracture in older adults – effects, experiences and impact of dementia. Umeå University Medical Dissertations, New series No 2112, 2021 (Department of Community Medicine and Rehabilitation, Geriatric medicine and Physiotherapy)
95. *Linda Månsson.* Digital fall prevention for older adults – Feasibility of a self-managed exercise application and development of a smartphone self-test for balance and leg strength. Umeå University Medical Dissertations, New series No 2113, 2021 (Department of Community Medicine and Rehabilitation, Section of Physiotherapy, and Department of Radiation Sciences, Radiation Physics and Biomedical Engineering)
96. *Beatrice Pettersson.* Fall prevention exercise for older adults – Self-management with support of digital technology. Umeå University Medical Dissertations, New series No 2122, 2021 (Department of Community Medicine and Rehabilitation, Section of Physiotherapy)
97. *Erik Frykholm*. The relevance and assessment of limb muscle function in individuals with chronic obstructive pulmonary disease, New series No 2145, 2021 (Department of Community Medicine and Rehabilitation, Section of Physiotherapy)
98. *Heidi Nedergård*. Taking the next step. Whole-body biomechanical gait analysis, and user-perspectives on robotic-assisted gait training post-stroke. Umeå University Medical Dissertations, New series No 2151, 2021 (Department of Community Medicine and Rehabilitation, Section of Physiotherapy)
99. *Jerry Öhlin.* Gait speed, physical activity, cognitive function and dementia: associations in cross-sectional and longitudinal srudies and validity of a physical activity questionnaire in very old people. Umeå University Medical Dissertations. New series No 2146, 2021 (Department of Community Medicine and Rehabilitation, Department of Public Health and Clinical Medicine, Department of nursing, Geriatric medicine and Physiotherapy)

Frågeformulär Flygande personal i FM

Enkäten läses av din fysioterapeut/sjukgymnast.

Datum: ....

Idnr: .... Ålder: .... Kön: ☐ Man ☐ Kvinna

Namn: ....

Flj/Div: .... Befattning: ....

Civilstånd ☐ Gift/sambo ☐ Ensamstående ☐ Särbo

Hemmav.barn ☐ Nej ☐ Ja Antal: Ålder: ....

Kroppslängd: ....

Kroppsvikt: ....

1. Vilken är den vanligast förekommande flygplans-/helikoptertyp som du flugit alt arbetat i som besättning under senaste 12-månaders perioden?

   Militärt: .... Civilt: ....

   Antal flygtimmar de senaste 12 månaderna? Militärt: .... Civilt: ....

   Har du tjänstgjort som flyginstruktör under perioden? ☐ Nej

   Ja ☐ ≤ 10 tim ☐ 11-20 tim ☐ 21-30 tim ☐ 31-40 tim ☐ 40-50 tim ☐ > 50 tim

   Totala antalet flygtimmar ....

Fysiska besvär/skador

1. Har du haft besvär/skada från någon kroppsdel?

	Besvär/skada **senaste året**?		Besvär/skada **nu**?		Har besvären/skadan påverkat din arbetsförmåga?		
Nacke	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Bröstrygg/ mellan skulderbladen	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Ländrygg/svank	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Bäcken/höft	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Axel/skuldra, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Axel/skuldra, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Armbåge, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Armbåge, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Hand, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Hand, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Knä, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Knä, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Underben, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Underben, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Fot, vänster	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket
Fot, höger	☐ Nej	☐ Ja	☐ Nej	☐ Ja	☐ Nej	☐ Ja, litet	☐ Ja, mycket

2. Du som svarat att du har **besvär/skada nu** ange på den streckade linjen vilken kroppsdel du har ***besvär i nu*** och markera med ett kryss i rutan graden av besvär och ange hur ofta du har besvär.

Hur ofta har du haft dessa besvär?

2a. ....

Inga besvär alls 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ Värsta tänkbara besvär

☐ Sällan – någon gång/månad
☐ Ofta – några ggr/vecka
☐ Alltid – mer eller mindre dagligen

2b. ....

Inga besvär alls 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ Värsta tänkbara besvär

☐ Sällan – någon gång/månad
☐ Ofta – några ggr/vecka
☐ Alltid – mer eller mindre dagligen

2c. ....

Inga besvär alls 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ Värsta tänkbara besvär

☐ Sällan – någon gång/månad
☐ Ofta – några ggr/vecka
☐ Alltid – mer eller mindre dagligen

2d. ....

Inga besvär alls 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ Värsta tänkbara besvär

☐ Sällan – någon gång/månad
☐ Ofta – några ggr/vecka
☐ Alltid – mer eller mindre dagligen

3. Har du under de senaste 12 månaderna varit befriad från din tjänstgöring/stannat hemma på grund av dina besvär? ☐ Nej ☐ Ja

4. Har du sökt vård för dina besvär? ☐ Nej ☐ Ja

Om ja, vad? ....

5a. Om du har besvär men är i arbete, modifierar/ ändrar du dina ordinarie arbetsuppgifter?

- ☐ Nej
- ☐ Ja, jag undviker flygpass och tar mer skrivbordsarbete
- ☐ Ja, jag försöker ändra flygpassens karaktär (t ex mindre G)
- ☐ Ja, jag försöker anpassa sittställningen
- ☐ Ja, jag försöker korta ner flygpasset
- ☐ Ja, beskriv ....

....

5b. Vad/vilken situation eller aktivitet utlöser huvudsakligen besvären?

- ☐ Flyguppdrag med lång flygtid
- ☐ Period med intensiv flygning (många timmar på kort tid)
- ☐ G-profilen flera/många belastningar med hög G
- ☐ Annat, ange vad ....

- ☐ Besvären har **inte** samband med flygningen, utan utlöses vanligtvis av andra orsaker!

Fysisk prestation

5. Hur upplever du att du klarar den *fysiska* delen av din tjänst?

Avseende muskelstyrka		Avseende kondition	
	☐ Mycket bra		☐ Mycket bra
	☐ Ganska bra		☐ Ganska bra
	☐ Varken bra eller dåligt		☐ Varken bra eller dålig
	☐ Ganska dåligt		☐ Ganska dåligt
	☐ Mycket dåligt		☐ Mycket dåligt

Fysisk aktivitet och träning

6. Kryssa i hur ofta du ägnar dig åt fysisk aktivitet och träning på låg respektive måttlig till hög ansträngningsnivå

Hur ofta ägnar du dig åt fysisk aktivitet och träning på **låg ansträngningsnivå** (tex lugna promenader och cykelturer)?	☐ Aldrig ☐ Oregelbundet ☐ 1 gång/vecka ☐ 2 ggr/vecka ☐ 3 ggr/vecka ☐ 4 ggr/vecka eller mer	Hur ofta ägnar du dig åt fysisk aktivitet och träning på **måttlig till hög ansträngnings-nivå** (du har högre puls, blir andfådd och svettig)?	☐ Aldrig ☐ Oregelbundet ☐ 1 gång/vecka ☐ 2 ggr/vecka ☐ 3 ggr/vecka ☐ 4 ggr/vecka eller mer

7. Vilken typ av fysisk träning utför du?

☐ Tränar ej

☐ Styrketräning .... ggr/v

☐ Konditionsträning .... ggr/v

☐ Kombination av båda .... ggr/v

☐ Annat .... ggr/v

Mat- och tobaksvanor

8. Äter du frukost varje dag? ☐ Nej ☐ Ja
9. Äter du lagad mat 2 ggr/dag? ☐ Nej ☐ Ja
10. Snusar du? ☐ Nej ☐ Ja, antal portioner/dag? ....
11. Röker du? ☐ Nej ☐ Ja, antal cigaretter/dag? ....

Sömn

12. Upplever du att du har sömnproblem?

Aldrig	Sällan *(Någon, några ggr/år)*	Ibland *(Flera ggr/mån)*	Ofta *(1-2 ggr/vecka)*	För det mesta *(3-4 ggr/vecka)*	Alltid *(5 ggr eller mer/vecka)*
☐	☐	☐	☐	☐	☐

Motivation och psykisk/fysisk förberedelse

13. Är du motiverad att genomföra dina arbetsuppgifter? ☐ Nej ☐ Ja
14. Tycker du att du är tillräckligt psykiskt förberedd? ☐ Nej ☐ Ja
15. Tycker du att du är tillräckligt fysiskt förberedd? ☐ Nej ☐ Ja

Fritid

16. Vad är din huvudsakliga fritids-sysselsättning?
T ex fallskärmshoppning, simning, paddling? ....

Upplevd hälsa

Det vanligaste sättet att analysera upplevelsen av den egna hälsan är att känna efter hur tillståndet i kroppen och huvudet upplevs jämfört med tidigare. Några precisa svar om hälsa finns inte. Hälsa är en upplevelse och upplevelser är inte exakta.

Hur upplever du din fysiska hälsa?
I denna skattning ligger din samlade upplevelse av läget i din fysiska kropp, dvs. var du befinner dig på linjen *icke sjuk – sjuk.*

Mycket dåligt	☐	1
Dåligt	☐	2
	☐	3
Varken bra eller dåligt	☐	4
Bra	☐	5
	☐	6
Utmärkt, kan inte vara bättre	☐	7

Hur upplever du din psykiska hälsa?
I denna skattning ligger din samlade upplevelse av läget i din psykiska kropp, dvs. var du befinner dig på linjen *må bra – må dåligt*.

Mycket dåligt	☐	1
Dåligt	☐	2
	☐	3
Varken bra eller dåligt	☐	4
Bra	☐	5
	☐	6
Utmärkt, kan inte vara bättre	☐	7

Hur upplever du läget i din fysiska miljö?
I begreppet ligger din samlade upplevelse av läget i din omgivande fysiska miljö.

Mycket dåligt	☐	1
Dåligt	☐	2
	☐	3
Varken bra eller dåligt	☐	4
Bra	☐	5
	☐	6
Utmärkt, kan inte vara bättre	☐	7

Hur upplever du läget i din sociala miljö?
I begreppet ligger din samlade upplevelse av läget i din sociala miljö.

Mycket dåligt	☐	1
Dåligt	☐	2
	☐	3
Varken bra eller dåligt	☐	4
Bra	☐	5
	☐	6
Utmärkt, kan inte vara bättre	☐	7

Hur upplever du din arbetsförmåga?
I begreppet ligger din samlade skattning av din upplevda förmåga att klara de uppgifter du har framför dig.

Mycket dåligt	☐	1
Dåligt	☐	2
	☐	3
Varken bra eller dåligt	☐	4
Bra	☐	5
	☐	6
Utmärkt, kan inte vara bättre	☐	7

Description of movement control tests with grading criteria used in study II.

Prior to each test, a short video of the test was shown to the participants together with verbal instructions. The participants repeated the movement three times to ensure familiarization with the movement to be tested, thereafter they performed the movement and the PTs rated them as either “optimal” or “non-optimal” movement patterns (i.e. “pass” or “fail” of the test). The tests have been presented earlier in text books [1-3]. Since this study didn´t include palpation in the rating of the tests, the grading criteria had to be slightly adapted to serve to the design of this study. In the case of a non-optimal rating, the PTs noted the reason according to the pre-defined grading criteria (see below). No feedback regarding test outcome was given during or after the test. The order of the tests was maintained throughout the study, beginning with tests involving standing followed by sitting, supine, and quadruped test positions (However, the tests are here presented according to body regions).

	Start position	End position
Shoulder flexion test [1] The purpose was to assess the ability to move the arm into flexion to about 180° with ≈60 °upward rotation and no excessive winging, excessive elevation/abduction/forward tilt/downward rotation of the scapula or medial rotation of the humerus.		

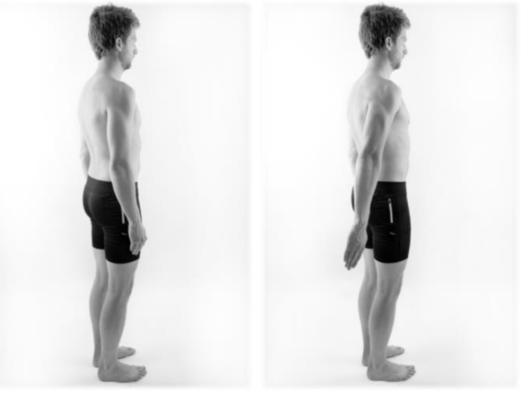
Participants were standing tall, the arm resting by the side with the scapula in a neutral position, and the glenohumeral joint in neutral rotation (palm in). From this position, participants were instructed to lift the right arm to full shoulder flexion, and then to return to the start position.

Grading criteria: The test was evaluated as passed if there was a flexion to about 180° with a sufficient upward rotation of the scapula (about 60°) such that the angulus inferior reached the mid-line of the lateral side of the thorax. It was evaluated as failed if there was winging, excessive elevation or abduction, forward tilt, or downward rotation of the scapula or if there was medial rotation of the humerus during shoulder flexion.

Published in: Tegern M, Aasa U, Äng BO, Harms-Ringdahl K, Larsson H (2018) Inter-rater and test-retest reliability of movement control tests for the neck, shoulder, thoracic, lumbar, and hip regions in military personnel. PLOS ONE 13(9): e0204552.

Shoulder extension test
Adapted from [3]

The purpose was to assess the ability to extend the arm to about 15° while retaining a neutral position of the scapula.



Participants were standing tall, with the arm resting by the side with the scapula in a neutral position and the glenohumeral joint in a neutral rotation (palm in). From this position, participants were instructed to extend the glenohumeral joint to about (-)15° while keeping the scapula neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if there was an extension of the glenohumeral joint with only minimal movements of the scapula. It was evaluated as failed if there was winging, elevation, forward tilt, or downward rotation/adduction of the scapula or if there was medial rotation of the humerus during shoulder extension.

Shoulder lateral rotation test
Adapted from [3]

The purpose was to assess the ability to laterally rotate the shoulder to about 45° while retaining a neutral position of the scapula.

Participants were standing tall with the elbow by the side flexed 90°, the scapula in a neutral position, and the glenohumeral joint in a neutral rotation (palm in). From this position, participants were instructed to laterally rotate the glenohumeral joint to about 45° while keeping the scapula neutral, and then to return the arm back to the start position. The PT palpated the medial border of scapula during the test to assess if the neutral position was retained.

Grading criteria: The test was evaluated as passed if there was a lateral rotation of the glenohumeral joint to about 45° without movements of the scapula. It was evaluated as failed if there was forward tilt, downward rotation, or adduction of the scapula or if there was an anterior glide of the humeral head during shoulder lateral rotation.

Neck flexion in sitting test
Adapted from [2]

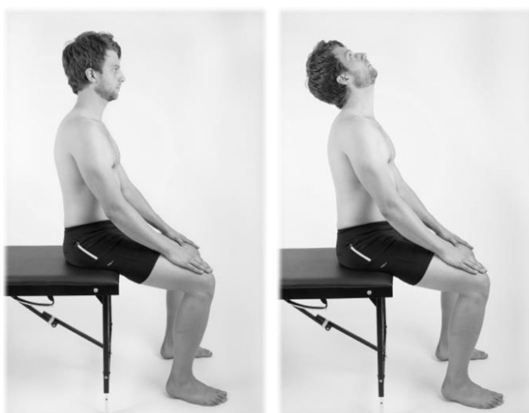
The purpose was to assess the ability to flex the neck to 45°–50° with contribution of both lower (≈35°) and upper cervical spine without cervical anterior translation/ diminished anterior sagittal plane rotation.

Participants were sitting on a bench with the feet on the floor, hands on the thighs and the neck, and back and shoulders in a neutral position. From this position, participants were instructed to flex their neck as far as possible, and then to return to the start position. The participants were instructed not to move the upper body during the movement.

Grading criteria: The test was evaluated as passed if the lower and upper cervical spine was contributing to flexion concurrently to 45°–50° (visually, whereof about 35° was performed in the lower cervical spine). It was evaluated as failed if there was increased or decreased flexion in the lower cervical spine, if there was increased or decreased flexion in the upper cervical spine, or if there was an anterior translation (head forward) of the head and cervical spine with diminished anterior sagittal plane rotation during neck flexion.

Neck extension in sitting test
Adapted from [2]

The purpose was to assess the ability to extend the neck to ≈85° with contribution of both lower (≈70°) and upper cervical spine without mid-cervical anterior translation.



Participants were sitting on a bench with the feet on the floor, hands on the thighs and the neck, and the back and shoulders in a neutral position. From this position, participants were instructed to extend the neck as far as possible to look up at the ceiling, and then to return to the start position. The participants were instructed not to move the upper body or the shoulders during the movement and to keep the mouth closed.

Grading criteria: The test was evaluated as passed if the lower and upper cervical spine was contributing to extension concurrently to about 85° (visually, whereof about 70° was performed in the lower cervical spine). It was evaluated as failed if there was increased or decreased extension in the lower cervical spine, if there was increased or decreased extension in the upper cervical spine, or if there was a mid-cervical anterior translation (hinge) during neck extension.

Neck rotation test
Adapted from [3]

The purpose was to assess the ability to rotate the neck to about 70°–80° without concurrent neck or shoulder movements.

Participants were sitting on a bench with the feet on the floor, hands on the thighs and the neck, and the back and shoulders in a neutral position. From this position, participants were instructed to turn the head to the side as far as possible without bending the neck, and then to return to the start position. The participants were instructed not to move the upper body or the shoulders during the movement.

Grading criteria: The test was evaluated as passed if there was a cervical rotation to 70°–80° with no concurrent flexion (eyes kept horizontal) or extension or any shoulder movements. It was evaluated as failed if there were flexion, or lateral flexion of the neck or an excessive or early rotation in the thoracic spine or movements of the scapula during neck rotation.

Neck flexion in supine test
Adapted from [2]

The purpose was to assess the ability to smoothly flex the neck using all cervical segments without excessive anterior translation.

Participants were in a supine position on a bench, their arms lying on their belly with their head resting on a small towel to allow the neck to be in a neutral position. From this position, participants were instructed to flex their upper cervical spine by lightly holding the chin in followed by lifting the head off the bench without lifting the back, and then to return to the start position with a maintained upper cervical flexion.

Grading criteria: The test was evaluated as passed if the participant was able to smoothly flex their neck using all cervical segments, and then return to start position. The test was evaluated as failed if there was an excessive anterior translation in relation to the amount of anterior sagittal rotation or if the movement was jerky, indicating impaired muscle-recruitment pattern between intrinsic and extrinsic neck flexors.

Neck extension in quadruped test
Adapted from [2]

The purpose was to assess the ability to smoothly extend the cervical spine using all cervical segments without excessive posterior translation.

Participants were in a quadruped position, with their hands under the shoulders, the neck, back, and shoulders in a neutral position, and looking down between their hands. From this position, participants were instructed to extend their neck thus looking straight ahead, and then to return to the start position.

Grading criteria: The test was evaluated as passed if the participant was able to smoothly extend their cervical spine using all cervical segments and return to start position. It was evaluated as failed if there was an excessive posterior translation in relation to the amount of posterior sagittal rotation seen as overactive levator scapulae, indicating impaired muscle-recruitment pattern between intrinsic and extrinsic flexors.

Chest lift test
Adapted from [3]

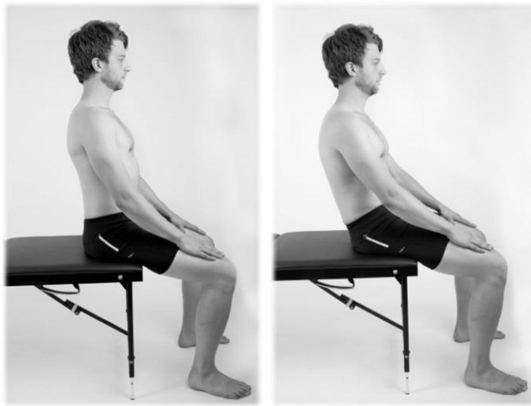
The purpose was to assess the ability to extend the thoracic spine (lifting the chest) without anterior pelvic tilt and lumbar extension.

Participants were sitting on a bench with the feet on the floor, hands on the thighs and the neck, and low back and shoulders in a neutral position. The thoracic region was in slight flexion. From this position, participants were instructed to extend the thoracic region thus moving the sternum up and forward while keeping the lumbar region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if there was a thoracic extension lumbo-pelvic movements. It was evaluated as failed if there was anterior pelvic tilt and lumbar extension during thoracic extension.

Pelvic tilt test
Adapted from [3]

The purpose was to assess the ability to tilt the pelvis posteriorly without thoracic flexion.

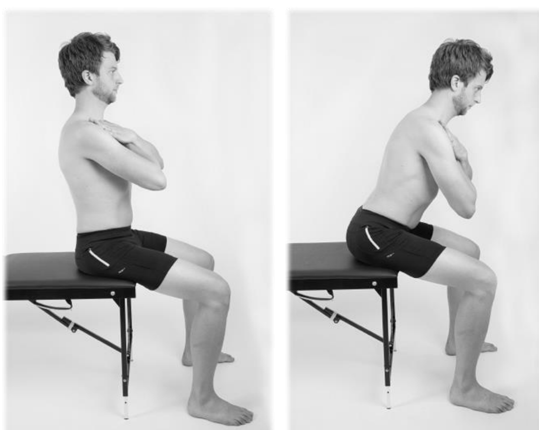


Participants were sitting on a bench with the feet on the floor, hands on the thighs and the neck, and the back and shoulders in a neutral position. From this position, participants were instructed to actively roll the pelvis backwards into posterior pelvic tilt while keeping the thoracic region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if there was a posterior pelvic tilt without thoracic flexion. It was evaluated as failed if there was a thoracic flexion during pelvic tilt.

Forward lean test
Adapted from [3]

The purpose was to assess the ability to flex the hip/lean forward to about 30° without lumbar flexion.

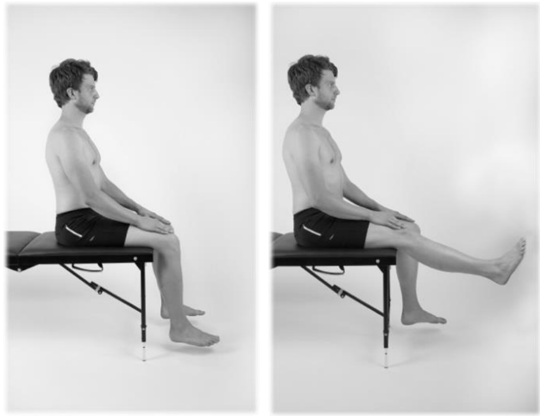


Participants were sitting on a bench with the feet on the floor, arms crossed on the chest and the neck, and the back and shoulders in a neutral position. From this position participants were instructed to flex their hips thus leaning their upper body forward to about 30° of flexion while keeping the lumbar region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if there was a hip flexion without lumbar flexion. It was evaluated as failed if there was a lumbar flexion or active extension during hip flexion.

Single knee extension test
Adapted from [3]

The purpose was to assess the ability to extend the knee to about 10°–15° from full extension without lumbar flexion or rotation.



Participants were sitting on a bench with the feet unsupported, hands on the thighs and the neck, and the back and shoulders in a neutral position. From this position, participants were instructed to extend the knee to about 10°–15° from full extension while keeping the lumbar region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if the participant was able to extend the knee without lumbar flexion or rotation. It was evaluated as failed if there was lumbar flexion or rotation during knee extension.

Double knee extension
Adapted from [3]

The purpose was to assess the ability to extend both knees to about 10°–15° from full extension without lumbar flexion.

Participants were sitting on a bench with the feet unsupported, hands on the thighs and the neck, and the back and shoulders in neutral position. From this position, participants were instructed to extend both knees to about 10°–15° from full extension while keeping the lumbar region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if the participant was able to extend the knees without lumbar flexion. It was evaluated as failed if there was lumbar flexion during knee extension.

Leg lift test
Adapted from [1]

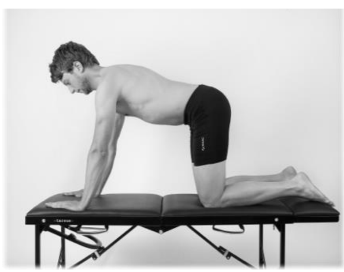
The purpose was to assess the ability to flex the hip joint to about 120° without lumbar flexion or posterior pelvic tilt.


Participants were in a supine position on a bench, hips and knees flexed about 45° with their arms crossed on their chest and the head resting on a small towel. The PT first examined the passive range of motion in the hip. From this position, participants were instructed to flex the hip to about 120° while keeping the lumbo-pelvic region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if the hip was flexed to 120° without lumbar flexion and posterior pelvic tilt. It was evaluated as failed if there was lumbar flexion and/or posterior pelvic tilt during hip flexion.

Rocking forward test
Adapted from [3]

The purpose was to assess the ability to extend the hips to about 0° in quadruped position without lumbar extension.




Participants were in a quadruped position, with their hands under their head, and the neck, back, and shoulders in a neutral position, looking down between their hands. From this position, participants were instructed to rock forward from the hips and shift their body weight forwards over their hands to about 0° of hip flexion while keeping the lumbar region neutral, and then to return to the start position.

Grading criteria: The test was evaluated as passed if the upper body and thighs were in line (about 0° of hip flexion) without lumbar extension. It was evaluated as failed if there was lumbar extension and/or anterior pelvic tilt during hip extension.

References

1. Sahrmann S. Diagnosis and treatment of movement impairment syndromes. St. Louis, Mo. ;: Mosby; 2002.

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3. Comerford M. Kinetic control : the management of uncontrolled movement. In: Mottram S, editor. Rev. ed. ed. Chatswood, N.S.W.: Chatswood, N.S.W. : Elsevier Australia; 2012.