A Prospective Cohort Study on Risk Factors for Cervico-Thoracic Pain in Military Aircrew

Matthias Tegern; Ulrika Aasa; Helena Larsson

BACKGROUND: Military aircrew frequently report cervico-thoracic pain and injury. The relationship between risk factors and future pain episodes is, however, uncertain. The aim of this study was to identify risk factors for cervico-thoracic pain and to determine the 1-yr cumulative incidence of such pain.

METHODS: A total of 47 Swedish aircrew (fighter and helicopter pilots and rear crew) without pain in the cervico-thoracic region were surveyed about work-related and personal factors and pain prevalence using the Musculoskeletal Screening Protocol questionnaire. They also performed tests of movement control, active cervical range of motion, and isometric neck muscle strength and endurance. Aircrew were followed for a year with questionnaires. Logistic regressions were used to identify potential risk factors for future cervico-thoracic pain.

RESULTS: Previous cervico-thoracic pain (OR: 22.39, CI: 1.79–280.63), lower cervical flexion range of motion (OR: 0.78, CI: 0.64–0.96), and lower neck flexor muscular endurance (OR: 0.91, CI: 0.83–0.99) were identified as risk factors for reporting cervico-thoracic pain. At follow-up, 23.4% (CI: 13.6–37.2) had reported cervico-thoracic pain during the 12-mo follow-up period.

DISCUSSION: The Musculoskeletal Screening Protocol can identify risk factors for cervico-thoracic pain. The link between cervico-thoracic pain and previous pain, as well as lower performance of neck range of motion and muscular endurance, highlights the need for primary and secondary preventive action. The findings from this study can facilitate the development of such pain prevention programs for aircrew.

KEYWORDS: fighter pilots, helicopter pilots, rear crew, physical performance, longitudinal, cervico-thoracic pain.

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Musculoskeletal disorders (MSD) or pain episodes in military aircrew (i.e., fighter pilots, helicopter pilots, and rear crew) are prevalent in the cervical and thoracic regions.[22,23,26] About every other aircrew member reports pain in the cervical region.[22,23,27] Also, pain in the thoracic region has begun to receive attention in the literature.[22,26] The high prevalence of pain may have a pernicious effect on flight performance, safety, and operational readiness among military aircrew.[10]

Various personal and work-related risk factors for pain in the cervical region have been suggested. Regarding personal factors, older age among fighter pilots[13] and shorter body height among helicopter pilots[12] have been associated with pain in the cervical region. Regarding work factors, studies have reported that aircrew are exposed to high loading during flight duty, including G_z-forces and/or prolonged exposure to static conditions.[11,28] The total number of flight hours have been reported as contributing to pain in several studies;[12,13,28] however, neither a meta-analysis on fighter pilots[33] nor a study on Swedish helicopter pilots[2] showed such association. Further, aircrew use safety vests and flight helmets,[11] and the use of night-vison goggles is associated with pain in the cervical region.[6,11,30] Apart from the physical demands, psychosocial

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factors, including being mentally and physically tired after the working day and feeling annoyed by others, can be associated with cervical region pain.[8] Thus, the experience of pain can be considered multifactorial and shall, therefore, be viewed within a biopsychosocial framework.[29]

In Sweden, the Musculoskeletal Screening Protocol (MSP)[18,19] was developed to capture information about risk factors seen as early signs of MSD in military personnel. The MSP includes a questionnaire and physical tests and has identified multiple factors, including previous pain episodes, lower rating of physical health, and impairments of physical performance, to be important to prevent drop-out from military basic training.[19] When implemented in the air force, new screening tests are added for aircrew. To decide which potential risk factors need to be added to the protocol, longitudinal associations between risk factors and future pain need to be established. However, most earlier studies about pain and their associations with potential risk factors in military aircrew have been of cross-sectional design. Studies examining physical performance have shown that aircrew reporting pain in the cervical and/or thoracic region showed less cervical range of motion (ROM),[4,7,27] lower muscle strength,[3] and altered movement coordination strategies.[4,27] However, the causality between physical impairments and pain remains unclear, but identifying signs of reduced capability in aircrews' performance of movements may be important to reduce the risk of developing pain in these regions. Prospective cohort studies with multivariate analyses are therefore needed to investigate their longitudinal associations.[27,33] Thus, the aim of this study was to identify risk factors for cervico-thoracic pain and to determine the 1-yr cumulative incidence of such pain. It was hypothesized that items from the MSP questionnaire and/or physical performance tests would predict future episodes of cervico-thoracic pain.

METHODS

Subjects

This study had a prospective observational cohort design. The study population consisted of 51 fighter (FP) and helicopter pilots (HP) and helicopter rear crew (RC) [mean (SD) age: 38 (8) yr, height: 1.81 (0.06) m, mass: 81 (8) kg] from one Swedish air base, who were listed as being on flight duty, were free from pain in the cervico-thoracic region at baseline (June to November 2015), and were asked to participate in the study. They gave their informed written consent prior to participating in the study. FP operated in the JAS 39 "Gripen" C/D aircraft, while HP and RC operated in the 14 (NH90) or 10 (Eurocopter AS332 Super Puma) helicopters. Cross-sectional data from this baseline data collection has been presented elsewhere.[27] The follow-up period lasted for approximately 12 mo. Four subjects were lost throughout the 12-mo follow-up period [change of workplace ($N = 3$), parental leave ($N = 1$)]. The analysis, therefore, included 47 military aircrew ($N = 26$ FP, 9 HP, 12 RC). The Regional Ethical Review Board in Stockholm approved the study (DNR:2013/144-31/2 and DNR:2015/493-32).

Equipment

The Swedish Armed Forces MSP questionnaire[18,19,26] covers occurrence of MSD in 10 predefined body regions using 2 questions: "Have you had any musculoskeletal complaints or injuries during the last year?" and "Do you still have these at present?". Only subjects answering no on the second question regarding pain in the cervical and/or thoracic region were included in the study. A short version of the MSP questionnaire was made to investigate the cumulative incidence of cervico-thoracic pain. The questionnaire covered occurrence of MSD, including pain intensity rating. Pain was defined as any reported ongoing complaints or injuries in the cervical and/or thoracic region. Subjects also rated their current pain intensity from 0 to 10 using the Numerical Pain Rating Scale (NPRS).

Possible risk factors were collected from the MSP questionnaire. Background data including age, body height, body mass, and their annual flight hours and total (career) flight hours were reported. Body mass index was calculated as body weight/body height^2 ($kg \cdot m^{-2}$). Questions covering exercise habits were answered. First, the weekly number of 1) light and 2) moderate-to-vigorous physical activities, respectively, were reported on a 5-point scale: never; irregular; or 1, 2, or ≥3 times per week. In accordance with previous studies,[19,26] this rating was added and converted to a score ranging from 0–16 points and thereafter grouped into: "inactive/low" (≤5); "active/average" (6–11); and "highly active" (≥12). For logistic analyses, these were dichotomized into "inactive-active" (≤11) or "highly active" (≥12). Second, the weekly number of physical exercise sessions for 1) strength, 2) cardio-respiratory fitness, and 3) neck training were reported and the numbers were collapsed into ≤1, 2, and ≥3 times per week; neck training was further collapsed and reported as yes/no. Lastly, self-rated health was reported regarding their 1) physical health, 2) mental health, 3) physical environment, 4) social environment, and 5) work ability, all rated on a 7-point scale. For logistic analyses, these were dichotomized into "less than excellent" (≤5) or "excellent" (≥6).[26]

The following physical performance tests were selected as possible risk factors. Movement control for the cervical, thoracic, and shoulder regions were assessed using eight tests [neck flexion in sitting, neck extension in sitting, neck rotation in sitting (left and right), neck flexion in supine, chest lift, pelvic tilt, and forward lean].[27] All tests were performed sitting with the feet in contact with the floor except for neck flexion in supine, which was performed lying supine on a bench with a small towel under the head, hands on the stomach, and legs extended. The tests have moderate-to-almost-perfect interrater agreement and fair-to-substantial test-retest agreement.[25]

Active ROM of the cervical spine was measured using the CROM 3 device (Performance Attainment Associates, Roseville, MN, USA) for flexion, extension, bilateral rotation, and lateral flexion movements. Maximal isometric neck muscle strength and submaximal endurance (50% of maximal voluntary contraction) of the cervical flexors and extensors were measured in an upright sitting position using fixed dynamometry (Macmesin, Advanced Force Gauge, Slinfold, West Sussex,

Fig. 1. The CROM3 device and set-up for neck muscle strength and endurance tests.

United Kingdom). **Fig. 1** demonstrates the set-up for ROM, strength, and endurance tests. Detailed descriptions of the tests have been presented elsewhere.[27]

Procedure

Fig. 2 demonstrates the study procedure. Possible risk factors were collected at baseline by using questionnaires and physical performance testing as presented in an earlier cross-sectional study.[27] All study subjects answered the MSP questionnaire and performed eight tests of movement control in the cervical, shoulder, thoracic, and lumbar spine regions, and active cervical ROM and isometric neck muscle strength and endurance in a standardized order at baseline. Only aircrew without cervico-thoracic pain at baseline were prospectively followed for 12 mo to investigate both the cumulative incidence of cervico-thoracic pain and if risk factors for cervico-thoracic pain could be identified at baseline. Questionnaires were distributed to the subjects about every third month, either when the researchers visited the air base or were provided by an administrator together with an envelope that was sealed after the questionnaires had been completed.

The test leader was blinded to the subjects' pain status during movement control and ROM testing in order to avoid bias. 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.

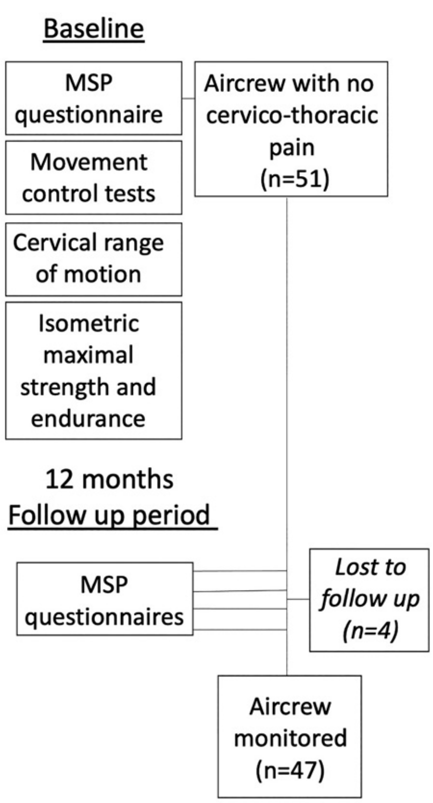

Fig. 2. The study procedure.

Statistical Analysis

Descriptive statistics of baseline data were analyzed for normality using Q-Q plots and Shapiro-Wilk tests. Data were presented as mean with SD for normally distributed data, median with 25^{th}–75^{th} percentiles, or proportions with a 95% confidence interval (CI). The cumulative incidence of cervico-thoracic pain was presented as a proportion of those at risk with a 95% CI.

Logistic regressions were used to identify potential risk factors for future cervico-thoracic pain. Based on a previous study[26] and clinical perspective, the following variables were selected from the MSP questionnaire as independent variables: age; height; Body Mass Index (BMI) ($kg \cdot m^{-2}$); total flight hours; annual flight hours; occupation group (FP, HP, RC); previous pain in the cervico-thoracic, lumbar, or shoulder region, respectively; physical activity level; physical health; mental health; work ability; and use of smokeless tobacco. Also, tests of movement control and flexibility, muscle strength, and endurance were selected. First, univariate analyses were performed on the independent variables and those associated at $P < 0.20$ with the dependent variable were added in the multiple model. Then a stepwise backward process was performed whereby nonsignificant ($P > 0.05$) independent variables were deleted one after the other until only significant variables remained. If two independent variables showed high risk for collinearity (Spearman's r > 0.6), the least plausible variable was to be deleted from the model. Confounding, defined as a >10% change in odds ratio (OR) between the adjusted and crude model, was checked a priori for possible confounders: age, group (i.e., FP, HP, and RC), and pain in adjoining body regions (i.e., lumbar and shoulder regions). No such change was evident and thus the crude model was presented. The Hosmer and Lemeshow test was used to assess goodness of fit of the model.[17] IBM SPSS Statistics for Windows, version 27 and 28 (IBM Corp., Armonk, NY, USA) were used to analyze the data. A P-value < 0.05 was considered statistically significant.

RESULTS

Few adverse events were reported during the baseline testing. Two aircrew members experienced worsening of neck symptoms during the strength test of neck extensors. The test was immediately aborted with no remaining worsening of symptoms post-test.

Table I and **Table II** show the univariate OR for cervico-thoracic pain within 12 mo and self-reported personal, health, and work-related factors. Two variables, previous pain in the cervico-thoracic region and rating the physical environment < excellent, were significant ($P < 0.2$) risk factors for reporting cervico-thoracic pain at the 12-mo follow-up.

Table III and **Table IV** show the univariate OR for baseline physical performance tests. Five of the physical performance tests were significant ($P < 0.2$) risk factors for reporting cervico-thoracic pain at the 12-mo follow-up: pelvic tilt, ROM of cervical flexion and extension, neck flexor strength, and neck flexor endurance.

Table V shows the multiple logistic regression model. The initial model included the seven univariately associated ($P < 0.2$) variables as risk factors for cervico-thoracic pain. The final model included three variables as significant ($P < 0.05$) risk factors for cervico-thoracic pain at 12-mo follow up: previous cervico-thoracic pain, cervical flexion ROM, and neck flexor endurance. The Hosmer and Lemeshow test ($P > 0.05$) indicated good fit of the model.

The cumulative incidence of cervico-thoracic pain over the follow-up period of 12 mo was 23.4% (95% CI: 13.6–37.2%). Their median numerical pain rating (0–10) was 3 (range: 1–8, with one missing data).

DISCUSSION

This prospective cohort study aimed to develop the evidence-based preventive MSP by presenting risk factors for cervico-thoracic pain in military aircrew. The main finding was that previous cervico-thoracic pain, lower cervical flexion range of motion, and lower neck flexor muscular endurance were associated with developed pain. Longitudinal studies that have investigated future cervico-thoracic pain among military aircrew are scarce.[33] Therefore, evidence about which factors should be included in screening programs is limited. This study found that of the 47 aircrew members who were pain-free in the cervico-thoracic region at baseline and subsequently followed longitudinally, 23% reported cervico-thoracic pain at the 12-mo follow-up. This incidence is in line with numbers for regular or continuous pain in the cervical region among Dutch helicopter crew.[30,32] However, the incidence is lower than earlier published numbers for prevalence of neck pain among military aircrew,[2,22,23] as well as our earlier studies on cervico-thoracic pain among Swedish military aircrew.[26,27] Reasons for these lower numbers may reflect the time interval of about every 3 mo between the repeated questionnaires. We believe this interval to be adequate to capture pain cases and it was reasonable to implement in the aircrews' activities. However, a closer time interval would likely have increased the incidence since we defined pain as "any reported ongoing complaints or injuries in the cervical and/or thoracic region", as this definition is in line with the MSP questionnaire and other studies.[18,19,27] It was considered important to use the already implemented MSP questionnaire since that system has been regulated for the Swedish Armed Forces.

A history of cervico-thoracic pain was a strong predictor for pain, suggesting that this process is recurrent for many military aircrew.[16] Previous pain in the cervical region has been found to be a risk indicator for new pain episodes in both 12-wk prospective[6] and cross-sectional[2] studies. This implies that secondary and tertiary measures are warranted for these primary episodes. We followed 92% of the available cohort from one Swedish airbase. The cohort was homogenous regarding demographic characteristics, which is similar to a previous study,[26] and may

Table I. Univariate Odds Ratios for Cervico-Thoracic Pain Within 12 mo for Self-Reported Personal Factors from the Baseline Questionnaire ($N = 47$).

	CERVICO-THORACIC PAIN WITHIN 12 mo						
	YES ($N = 11$)		NO ($N = 36$)				
FACTORS	MEAN	95% CI	MEAN	95% CI	OR	95% CI	P-VALUE
Age, yr	43	29–45	38	30–47	1.00	0.92–1.09	0.99
Height, m	1.81	1.77–1.86	1.79	1.76–1.87	0.66	0.00–65K	0.94
BMI, $kg \cdot m^{-2}$	25.6	23.8–26.5	24.3	23.4–26.2	1.12	0.82–1.52	0.47
Total flight hours	1100	600–2500	1462	700–2200	1.00	1.00–1.00	1.00
Annual flight hours	120	50–130	120	75–140	0.99	0.98–1.01	0.36

BMI = Body Mass Index; OR = odds ratio; CI = confidence interval.

Table II. Univariate Odds Ratios for Cervico-Thoracic Pain Within 12 mo for Self-Reported Work and Health-Related Factors from the Baseline Questionnaire (*N* = 47).

	CERVICO-THORACIC PAIN WITHIN 12 mo						
	YES (*N* = 11)		NO (*N* = 36)				
FACTORS	%	95% CI	%	95% CI	OR	95% CI	*P*-VALUE
Occupation							
Fighter pilots	27	14–46	73	54–86	1.29	0.21–7.76	0.78
Helicopter pilots	22	6–55	78	45–94	1.00	Reference	
Rear crew	17	5–45	83	55–95	0.70	0.08–6.22	0.75
Previous CT-pain							
Yes	73	43–90	28	16–44	6.93	1.53–31.51	0.01
No	27	10–57	72	56–84	1.00	Reference	
Previous lumbar pain							
Yes	55	28–79	33	20–50	2.40	0.61–9.49	0.21
No	45	21–72	67	50–80	1.00	Reference	
Previous shoulder pain							
Yes	27	10–57	22	12–38	1.31	0.28–6.14	0.73
No	73	43–90	78	62–88	1.00	Reference	
Physical activity level							
Inactive/Active	36	15–65	36	23–52	1.01	0.25–4.12	0.99
Highly active	64	35–85	64	48–78	1.00	Reference	
Strength training/w (n)							
0	27	10–57	30	18–47	0.90	0.15–5.58	0.92
1–2	46	21–72	42	27–58	1.11	0.22–5.73	0.90
≥3	27	10–57	28	16–44	1.00	Reference	
Cardio training/w (n)							
0	9	2–38	6	2–18	2.75	0.16–46.79	0.48
1–2	73	43–90	64	48–78	1.91	0.35–10.56	0.46
≥3	18	5–48	30	18–47	1.00	Reference	
Neck training							
Yes	36	15–65	19	10–35	1.00	Reference	
No	64	35–85	81	65–90	0.42	0.10–1.86	0.25
Physical health/state							
Excellent	55	28–79	42	27–58	1.00	Reference	
<Excellent	45	21–72	58	42–73	0.60	0.15–2.32	0.45
Mental health/state							
Excellent	73	43–90	72	62–88	1.00	Reference	
<Excellent	27	10–57	28	16–44	0.98	0.22–4.43	0.97
Physical environment							
Excellent	91	62–98	44	30–60	1.00	Reference	
<Excellent	9	2–38	56	40–71	0.08	0.01–0.69	0.02
Social environment							
Excellent	55	28–79	56	40–71	1.00	Reference	
<Excellent	45	21–72	44	30–60	1.04	0.27–4.05	0.95
Work ability							
Excellent	91	62–98	81	65–90	1.00	Reference	
<Excellent	9	2–38	19	10–35	1.55	0.51–4.70	0.44

CT-Pain = cervico-thoracic pain; OR = odds ratio; CI = confidence interval.

be regarded as a representative sample of male Swedish military aircrew. Previous studies have identified older age,[13] shorter body height,[12] and the total number of flight hours[12,13,28] as associated with pain in the cervical region. In our study, no other personal or work-related factors gathered from the MSP questionnaire except a history of cervico-thoracic pain were significant risk factors for new episodes. However, factors not reaching significance in our study may still be relevant to include in future investigations in similar cohorts.

Decreased neck flexion ROM and neck flexor muscle endurance were also significant predictors for future cervico-thoracic pain and may inform the development of screening tests for clinical intervention. In an earlier study on the same population as in this study, reduced flexion ROM was associated with ongoing cervico-thoracic pain.[27] This has further been reported in cross-sectional studies on fighter[7] and helicopter pilots,[4] which found lesser flexion-extension and bilateral rotation for those with pain. Conversely, no such differences were found in another study on helicopter pilots and rear crew.[31] However, an adequate 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 be painful.[24]

We also found that lower cervical flexor muscle endurance performed at 50% of their maximal isometric strength at

Table III. Univariate Odds Ratios for Cervico-Thoracic Pain Within 12 mo for Movement Control Tests from Baseline Test (*N* = 47).

	CERVICO-THORACIC PAIN WITHIN 12 mo						
	YES (*N* = 11)		NO (*N* = 36)				
MOVEMENT CONTROL	%	95% CI	%	95% CI	OR	95% CI	*P*-VALUE
Neck flexion in sitting							
Controlled	45	21–72	58	42–73	1.0		0.82
Uncontrolled	55	28–79	42	27–58	1.17	0.30–4.54	
Neck extension in sitting							
Controlled	45	21–72	25	14–41	1.0		0.21
Uncontrolled	55	28–79	75	59–87	0.40	0.10–1.63	
Neck rotation left in sitting							
Controlled	64	35–85	47	32–63	1.0		0.35
Uncontrolled	36	15–65	53	37–68	0.51	0.13–2.06	
Neck rotation right in sitting							
Controlled	45	21–72	39	25–55	1.0		0.70
Uncontrolled	55	28–79	61	45–75	0.76	0.20–2.98	
Neck flexion in supine							
Controlled	55	28–79	58	42–73	1.0		0.82
Uncontrolled	45	21–72	42	27–58	1.17	0.30–4.54	
Chest lift							
Controlled	64	35–85	61	45–75	1.0		0.88
Uncontrolled	36	15–65	39	25–55	0.90	0.22–3.64	
Pelvic tilt							
Controlled	82	52–96	42	27–58	1.0		0.03
Uncontrolled	18	5–48	58	42–73	0.16	0.30–0.84	
Forward lean							
Controlled	82	52–96	75	59–87	1.0		0.64
Uncontrolled	18	5–48	25	14–41	0.67	0.12–3.68	

OR = Odds ratio. CI = Confidence interval.

baseline was significantly associated with a higher risk of reporting cervico-thoracic pain at the 12-mo 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 a "deep neck flexor endurance test" was significantly shorter for Spanish military personnel with chronic nonspecific neck pain and kinesiophobia when compared to their pain-free colleagues.[20] Also, among individuals (i.e., civilians) with nonspecific neck pain, shorter flexor and extensor endurance time was shown when compared to pain-free individuals.[21] Not only shorter endurance time, but also fatigue, as indicated by electromyographic assessment, has been shown for helicopter pilots with neck pain.[3] 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 in neck extensor endurance time.[1] Flexor endurance of neck muscles 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.

An earlier Swedish study including helicopter pilots highlighted that deep neck flexor muscle exercises might be important to include in training programs to improve motor

Table IV. Univariate Odds Ratios for Cervico-Thoracic Pain Within 12 mo for Cervical ROM, Neck Muscle Strength, and Endurance from Baseline Test (*N* = 47).

	CERVICO-THORACIC PAIN WITHIN 12 mo						
	YES (*N* = 11)		NO (*N* = 36)				
ROM, STRENGTH AND ENDURANCE	MEDIAN	25^{TH}–75^{TH}	MEDIAN	25^{TH}–75^{TH}	OR	95% CI	*P*-VALUE
Flexion (Degrees)	55.0	50.0–56.0	61.0	52.3–66.5	0.88	0.78–0.98	0.02
Extension (Degrees)	73.0	67.0–78.0	67.0	60.0–74.8	1.05	0.98–1.13	0.15
Rotation left (Degrees)	70.0	60.0–80.0	70.0	60.0–75.0	1.01	0.93–1.10	0.81
Rotation right (Degrees)	64.0	57.0–70.0	60.0	60.0–69.3	0.97	0.89–1.07	0.54
Lateral flexion left (Degrees)	41.0	37.0–45.0	40.0	35.0–44.8	1.04	0.95–1.15	0.41
Lateral flexion right (Degrees)	42.0	32.0–45.0	38.0	35.0–41.5	1.02	0.92–1.13	0.67
Flexor strength (Nm)	28.4	26.5–35.0	23.4	23.5–31.7	1.07	0.98–1.17	0.12
Extensor strength (Nm)	41.0	37.0–47.3	37.4	34.6–44.6	1.04	0.96–1.13	0.35
Flexor endurance (s)	48.0	38.0–61.0	56.0	48.0–72.5	0.94	0.89–1.00	0.05
Extensor endurance (s)	81.0	75.0–107.0	97.0	76.0–136.5	0.99	0.96–1.01	0.21

Missing data for strength and endurance tests; *N* = 3 in pain-free aircrew. ROM = range of motion; OR = odds ratio; CI = confidence interval; Nm = Newton meters; s = seconds.

Table V. Multiple Regression Analyses with Initial and Final Odds Ratios for Cervico-Thoracic Pain Within 12 mo.

	INITIAL MODEL			FINAL MODEL		
	OR	95% CI	*P*-VALUE	OR	95% CI	*P*-VALUE
Previous CT pain (y/n)	22.83	0.94–551.48	0.05	22.39	1.79–280.63	0.02
Physical environment	0.08	0.01–2.13	0.13			
Pelvic tilt—uncontrolled	0.36	0.02–7.19	0.50			
Flexion ROM (Degrees)	0.78	0.60–1.02	0.06	0.78	0.64–0.96	0.02
Extension ROM (Degrees)	1.04	0.92–1.18	0.56			
Flexor strength (Nm)	1.06	0.88–1.29	0.54			
Flexor endurance (s)	0.93	0.85–1.03	0.17	0.91	0.83–0.99	0.03

CT pain = cervico-thoracic pain; ROM = range of motion; OR = odds ratio; CI = confidence interval; Nm = Newton meters; s = seconds.

coordination.[5] Since then it has been described that motor adaptations, such as redistributed activity within and between muscles, are believed to have a role in the recurrence of spinal pain.[15] We therefore included movement control tests in the test battery using a dichotomous rating (i.e., could or could not perform the movement according to the predefined grading criteria). We found, however, that none of the movement control tests were identified as a risk factor for cervico-thoracic pain. A previous study, using the same cohort and methods to investigate movement control as in this study, found that performance in the "neck flexion in sitting" test was associated with having cervico-thoracic pain.[27] Further, a previous study including Swedish helicopter pilots also reported that altered movement coordination strategies for neck flexors were associated with neck pain.[4] These findings suggest that motor adaptations may be more an indicator of ongoing, rather than future, pain episodes. In future studies, we suggest that the methodologies for the assessment of movement control need to be refined, perhaps by using a more comprehensive scoring system,[9] or electronic devices[14] could be useful to investigate movement coordination strategies in military aircrew.

The main strength of this study was the longitudinal design to investigate potential risk factors for cervico-thoracic pain. Another strength is that we included all employed aircrew listed on flight duty at one Swedish air base (cohort). We thereby gained knowledge of aircrew members' potential risk factors for future cervico-thoracic pain episodes to inform the practice of the Air Force health service. Furthermore, the MSP questionnaire has already been implemented in the Swedish Armed Forces and it is a strength that the same questionnaire was used in this study.

The wide confidence intervals of the ORs in the logistic regressions indicate that the sample size was rather small and, thus, should be considered as a limitation of this study and the precision of the estimates is therefore limited. Further, the low number of significant risk factors included in the model for developed pain is probably not only explained by the sample size. Instead, we believe that the distribution of test results was generally equally distributed among pain-free military crew and those reporting pain at the 12-mo follow-up. Lastly, we analyzed fighter pilots, helicopter pilots, and helicopter rear crew as one group since earlier studies indicated no differences in pain prevalence[26] and few differences in physical performance were shown,[27] and there was no difference between groups in this present data. This supports that the pain experience is not only caused by specific work-related physical exposure, rather it should be considered multifactorial and be viewed within a biopsychosocial framework.[29]

The relationship between pain, loading, dosage of exposure, and general health in military aircrew is complex.[29] However, this study indicates that important risk factors can be identified when using a screening tool consisting of a questionnaire and clinical tests. Aircrew with reduced cervical flexion ROM and muscle endurance should be considered for targeted physical training as primary prevention. Furthermore, since a history of cervico-thoracic pain is a consistent risk factor for a new episode, aircrew with previous complaints or injuries should receive individually tailored secondary prevention. Future research should include larger samples to test the potential primary and secondary preventive effect of identifying risk factors for different groups of military aircrew in longitudinal studies, preferably with repeated follow-ups and the inclusion of organizational interventions. Other methods, including qualitative or single-subject experimental studies, can also be valuable to gain in-depth knowledge regarding experiences of pain and physical symptoms affecting the work of aircrew.

This study indicates that risk factors for a 23% cumulative incidence of cervico-thoracic pain could be identified using the MSP. Previous pain episodes, low cervical flexibility, and low muscle endurance were all included in the final model. The link between cervico-thoracic pain and previous pain, as well as lower performance of neck range of motion and muscular endurance, highlights the need for primary and secondary preventive action. The findings from this study can facilitate the development of such pain prevention programs for aircrew.

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