Prevention of flight-related neck pain in military aircrew
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Prevention of flight-related neck pain in military aircrew
Neck strength, position sense, and motion in military helicopter crew with and without neck pain

Chapter 6
Abstract

Introduction: Neck pain in military helicopter pilots and rear aircrew is an occupational health problem that may interfere with flying performance. The aim of the present study was to investigate possible differences in the physical abilities of the cervical spines of helicopter pilots and rear aircrew with and without neck pain in the previous year.

Methods: The study included 61 male helicopter pilots and 22 rear aircrew without neck pain (Sx-) and 17 pilots and 17 rear aircrew with neck pain (Sx+). Active cervical range of motion (flexion-extension, right-left rotation, and right-left lateral flexion), neck position sense (reposition error back to neutral and defined positions after submaximal cervical movement) and maximum isometric neck muscle strength (flexion, extension and right and left lateral flexion) were measured. Two-way factorial analyses of variance were performed, in which the fixed factors were occupation (pilot or rear aircrew) and neck pain state (Sx+ or Sx-).

Results: On average, there was a trend toward lower values in strength (extension: 55(19)Nm vs. 58(20)Nm; flexion 22(8)Nm vs. 24(12)Nm) and smaller cervical range of motion (flexion-extension: 132(19)° vs. 137(15)°; rotation: 156(14)° vs. 160(14)°) in the total Sx+ crew, compared to their Sx- colleagues. However, the two-way factorial ANOVA revealed neither significant main effects nor significant interaction effects in any of the measured physical abilities.

Conclusion: The results suggest that having experienced neck pain was not significantly associated with differences in the physical abilities of the cervical spines of helicopter crew, as assessed in this study.
Introduction

Neck pain in military pilots is an occupational health problem that may interfere with their flying performance [17;22]. Consequently, this can lead to unsafe situations. Obviously, flight-related neck pain should be prevented when possible, and the etiology and mechanism that play a part in the development, occurrence and perpetuation of flight-related neck pain should first be identified [26].

Neck pain in fighter pilots is a well discussed issue, but only recent studies have recognized neck pain among helicopter pilots as a significant aero-medical problem, with reported 3- to 12-month prevalences ranging from 29% to 57% [1;6;22]. Although the etiology of flight-related neck pain in helicopter pilots is still the subject of research, specific ergonomic situations when flying a helicopter, namely unfavorable neck load caused by 1) static neck and body positions, 2) whole body vibration (WBV) and 3) heavy head-worn equipment, have been suggested as risk factors [23].

While the prevalence and etiology of neck pain in military jet and helicopter pilots has been the subject of research, cervical complaints of the non-piloting aircrew have been largely ignored up to now. However, military aircrew sitting in the rear of the helicopter deal with the same three suggested risk factors for neck pain as helicopter pilots. The main tasks of military rear aircrew are troop management, material handling, surveillance, and clearance tasks. These tasks require different body and head postures, including sitting forward, kneeling, standing positions with the trunk flexed and rotated and the head out of window and lying positions with the head outside the hatch for hooking and hoisting tasks [15]. When flying in darkness, not only the pilots but also the rear aircrew use night vision goggles, increasing the mass the head must bear, and perform the same tasks as mentioned above. Although in-flight studies on postures and head movements in helicopter pilots and rear aircrew are scarce, the important difference between these two occupations seems to be the rather static, unfavorable neck and body positions for helicopter pilots, while the rear aircrew have to deal with more extreme, but more variable head and body positions. Thuresson [23] revealed that all three suggested risk factors for flight-related neck pain in helicopter pilots (neck and body position, WBV and heavy, head-worn equipment) caused measurable changes in muscle activity, induced load and seat-to-head transmissibility; however, neck and body position caused the highest response.

Despite the same work environment and selection criteria for each specific occupation, some pilots and rear aircrew develop neck pain, while others do not. To understand neck pain in military helicopter pilots and rear aircrew, it is interesting to quantify neck muscle function in these workers, since neck muscle function is essential for support and stabilization of the head on the cervical spine. For the purposes of prevention and intervention and, importantly, to keep the crew on active flying duty, early detection of cervical functional loss may be important. This may be especially true because pain, cervical dysfunction and control of movement can interact negatively with each other [9].
In order to provide a proper preventive training program for military helicopter pilots and rear aircrew, a battery of tests was used in the current study for assessing the physical abilities of the cervical spine. The main purpose of the current study was to investigate the physical abilities of the neck in helicopter pilots and rear aircrew with neck pain and compare them to pilots and aircrew without neck pain. We examined 1) active cervical range of motion, 2) neck position sense and 3) neck muscle strength.

Based on earlier research in non-flying populations [7;16] and in military pilots [2;3], we hypothesized that pilots and rear aircrew who experienced neck pain in the previous 12 months would have a smaller cervical range of motion, a greater reposition error (the outcome measurement of neck position sense testing) and lower muscle strength compared to pilots and rear aircrew without neck pain. Based on the differences in occupational postures causing different neck loading and requiring different abilities, we hypothesized more specifically that muscle strength and cervical range would be affected more greatly in rear aircrew, while the more static postures used by pilots would lead to a higher relative impairment of neck position sense.

**Methods**

**Subjects and Procedures**

The current study was a collaboration of the Royal Netherlands Air Force (RNLAF) and the Belgian Defense. A battery of tests was developed for the assessment of the physical abilities of the cervical spine by the Medical Component of the Belgian Defense. The results of these tests with Dutch and Belgian F-16 pilots have been published previously [10]. The battery of tests consisted of a test to measure cervical mobility, a test to assess neck position sense and a cervical strength test. All tests were performed on the same day, and participating pilots and rear aircrew had not flown on the day of the tests. Muscular strength was always measured last, to avoid the influence of muscular fatigue on the other tests. The pilots and rear aircrew filled in standardized questionnaires to record their ages, weights, heights, flying hours and experience and neck pain during the preceding 12 months. Each assessment had a permanent examiner, who was blinded to the subject history of neck pain.

Squadrons were verbally briefed about the study by the research team, and all pilots and rear aircrew received written information and gave written, informed consent. Next, each squadron was visited by the research team on three to four consecutive days between November 2006 and March 2008, depending on the availability of the pilots and aircrew. The intention was to test all helicopter pilots and rear aircrew of the RNLAF and RNLN and only the crew who were on deployment, sick- or holiday leave were not reached this way. Almost all pilots and rear aircrew present participated (response rate 96%). Pilots and rear aircrew were excluded if they had not been on flying duty during the previous year. Ethical approval was obtained from the Ethical Research Committee.
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A total of 113 helicopter pilots (103 males and 10 females) and 61 rear aircrew (59 males and 2 females) from the RNLAF and the RNLN participated. They flew six helicopter types: the ICH-47D Chinook, the AS-532 U2 Cougar, the Agusta-Bell 412, the Alouette, the Westland SH-14D Lynx helicopter and the AH-64D Apache. For reasons explained below, the female pilots and aircrew and those who reported only occasional neck pain in the previous 12 months were excluded from analysis. This led to the inclusion of 17 pilots with and 61 pilots without neck pain, 17 rear aircrew with and 22 rear aircrew without neck pain. Total means (SD) for height, weight and body mass index were 183.5 (6.9), 83.0 (9.7) and 24.6 (2.3), respectively, and not significantly different between the four groups. Of the total group, 36% was aged <30 years, 38% between 30-40 years and 26% between 40 and 55 years. In the pilot group, the Chi-Square test revealed a significant linear-by-linear association between neck pain and higher age (p=0.01). Total flying hours and flying hours the previous 12 months were 2830(1642) and 197(86) respectively for the pilots with neck pain and 1680(1265) and 152 (65) for the pilots without neck pain, and 1553(912) and 206(67) respectively for the rear aircrew with neck pain and 1537(1476) and 226(80) for the rear aircrew without neck pain. Within the pilot group, the Mann-Whitney U test revealed that these differences were significant for the total flying hours (p=0.008) as well as the flying hours in the previous 12 months (p=0.04). There were no significant differences in age and flying hours within the rear aircrew group.

Neck Pain
Neck pain was defined as any pain, including aches and discomfort, in the previous 12 months, and a diagram was used to illustrate and define the specific body region. Within each occupational group (pilots or rear aircrew), subjects were divided into a symptomatic group (Sx+) (those reporting regular or continuous neck pain) and an asymptomatic group (Sx-) (without neck pain), based on their answers to the four possible responses about neck pain on the questionnaire (never, occasional, regular and continuous). For the purposes of this study, pilots and rear aircrew who reported occasional neck pain were excluded from analysis to create as much contrast as possible between groups.

Cervical Range of Motion
Active cervical range of motion (CROM) was measured with a three-dimensional motion analyzer, Zebris CMS20, WinSpine version 1.79 (Zebris Medizintechnik GmbH, Isny, Germany). Measurement was based on determination of the spatial coordinates of the ultrasound (US) transmitters by a fixed system of three microphones which was positioned at a special stand close by. Specially designed headgear (adjustable to adapt to individual head sizes), on which a series of three miniature US transmitters
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were attached, was fixed to the subject’s head. For isolating cervical spine movements from the rest of the spine, a thoracic belt (velcro bands adjustable to the individual torso) attached to a series of three miniature US transmitters, was fixed to the subject’s torso, serving as a reference.

Each subject was seated in an upright position on a stool without a backrest. The subject’s hands were placed on his thighs, and hips and knees were bent at 90°. To be sure that the subject’s starting position between moving in different directions was the same, a narrow mirror was placed so that the subject was able to see his own eyes in this position. The device was calibrated before the start of the first movement. After each movement, the subject was asked to look at his eyes in the mirror. The maximal full CROM was measured for flexion-extension, right-left rotation and right-left lateral flexion. Each measurement consisted of three repetitions for each movement. For each direction, the mean of the three repetitions was recorded. The reproducibility of the CROM test is described by Cagnie et al. [7] and was shown to be high for all directions. Intraclass correlation coefficients (ICCs) ranged from 0.92 to 0.94 for inter-rater reliability and from 0.80 to 0.87 for intra-rater reliability.

Neck Position Sense

The three-dimensional motion analyzer Zebris CMS20, using Windata version 2.20 (Zebris Medizintechnik GmbH, Isny, Germany), was used to measure neck position sense. The subject was seated in an upright position on a stool without a backrest. The subject’s hands were placed on his thighs; hips and knees were bent 90°. The subject was blindfolded for this test. The point of departure was the neutral neck position defined by each subject. The test consisted of two parts. In the first part, the subject was instructed to return to his own neutral position after an active sub-maximum range cervical flexion-extension and right and left rotation. In the second part, the subject was asked to return to a position defined by the researcher (30° right or left rotation). For the first part, the absolute reposition error (RPE) was calculated in the sagittal plane and transversal plane, as a mean of 10 repetitions. For the second part, the absolute RPE was calculated in the transversal plane for right and left rotation, as a mean of five repetitions in each direction. The test’s reproducibility was confirmed by analysis of 15 healthy, civilian volunteers. The ICC for the reposition error to the neutral position was 0.87 for inter-rater reliability and 0.72 for intra-rater reliability. For the absolute RPE in the repeated-matching test to 30° rotation, the ICC for the inter-rater reliability was 0.67 and 0.61 for the intra-rater reliability (De Loose V, Cagnie B. Unpublished data; 2006).

Strength

Maximum isometric neck muscle strength was measured with a David F-140 device (David International, Ltd., Germany). Each subject was seated in an upright position with outstretched legs, with only the heels touching the floor, and arms relaxed against
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the side of the body. The seat height, motion axis of C7-T1 (in line with the axis of the moving arm of the testing unit) and chest support were adjusted for each subject. The subject performed a standardized warming-up for the neck and shoulders before any measurements were taken. Isometric tests were then performed in four directions: flexion, extension and left and right lateral flexion. The same order of testing was used for all subjects. Three maximum voluntary isometric contractions (MVCs) were executed in each direction. The subject was encouraged to press his head against the resistance pad with increasing force up to a maximum voluntary contraction of 6 seconds. Within one series, there were 30 seconds of rest, and in between the tests of different directions there was a rest period of 3 minutes. The highest peak value (Nm) was used for further analysis. The reproducibility was confirmed by tests on 15 healthy, civilian volunteers. The ICC ranged from 0.94 to 0.95 for the peak value (Nm) of the different strength tests for both the inter- and intra-rater reliability (De Loose V, Cagnie B. Unpublished data; 2006).

Analyses
The number of female pilots and rear aircrew was small and proportionally unequal in the four groups. Since females possess lower cervical strength [12], and inconsistent and limited results have been reported on the effect of gender on neck mobility and neck position sense [8;11;13], it was decided to exclude the female subjects from analysis. Statistical analyses were performed with the SPSS 16.0 software package (SPSS Inc., Chicago, IL). The dependent variables were MVC, CROM, and RPE. Means and standard deviations were used to describe the data. Two-way factorial analysis of variance (ANOVA) was used, in which the fixed factors were occupation (pilot or rear aircrew) and neck pain state (Sx+ or Sx-). When significant interactions were found, simple effects (the effect of one independent variable at the individual level of the other independent variable) were examined with simple effects analysis [14]. Since every dependent variable was analyzed separately, an adjusted p value of 0.01 was considered statistically significant in all tests.

Results
The results for the helicopter aircrew with neck pain (Sx+) and crew without neck pain (Sx-) within each occupation (pilot and rear aircrew) are summarized in Table I.

For the extensors and flexors, the total Sx+ crew scored lower mean values (55 (19) Nm and 22 (8) Nm, respectively) compared to the Sx- crew (58 (20) Nm and 24 (12) Nm, respectively). Within each occupation, the Sx+ helicopter pilots scored lower mean values (51 (20) Nm and 22 (9) Nm, respectively) compared to their Sx- colleagues (58 (18) Nm and 24 (12) Nm, respectively), and the Sx+ rear aircrew scored equal values for the extensors and lower values for the flexors compared to the Sx- rear aircrew.
However, the two-way factorial ANOVA revealed neither significant main effects (neck pain state; $F_{1,110}=0.7$, $p=0.4$ and $F_{1,110}=0.3$, $p=0.6$ for the extensors and flexors, respectively) nor significant interaction effects (neck pain state x occupation; $F_{1,110}=0.7$, $p=0.4$ and $F_{1,110}=0.02$, $p=0.9$, for the extensors and flexors, respectively). Also, for the right and left lateral flexion muscles, the Sx+ crew scored lower mean values (29(19) Nm and 30(20)Nm, respectively) compared to the Sx- crew (31(20)Nm and 32(20)Nm, respectively) and within each occupation these differences were more obvious in the rear aircrew. However, these differences were not significant, since there were neither significant main effects (neck pain state; $F_{1,110}=0.8$, $p=0.4$ and $F_{1,110}=0.3$, $p=0.6$ for the right and left lateral flexion muscles, respectively) nor significant interaction effects for both variables (neck pain state x occupation; $F_{1,110}=0.3$, $p=0.6$ and $F_{1,110}=0.05$, $p=0.8$ for the right and left lateral flexion muscles, respectively).

For the neck position sense variables, greater reposition errors indicate lower accuracy in bringing the head back to a neutral or defined position. No significant main effects or interaction effects were found in any of the proprioception variables.

For cervical range of motion in the sagittal plane, the Sx+ crew showed a smaller CROM compared to the Sx- crew (132(19)° and 137(15)°, respectively) but no significant main (neck pain state; $F_{1,113}=2.1$, $p=0.1$) or interaction effects were revealed (neck pain state x occupation; $F_{1,113}=0.8$, $p=0.4$). Furthermore, in the transversal plane, the total Sx+ crew with neck pain showed a smaller CROM (156(14)°) compared to their Sx- colleagues (160(14)°), but within each occupation this difference was only shown in the pilots. However, in this variable, as well, neither main (neck pain state; $F_{1,111}=1.0$, $p=0.3$) nor interaction effects were found (neck pain state x occupation; $F_{1,111}=0.9$, $p=0.3$).

**Discussion**

Neck function in helicopter pilots and rear aircrew was examined by measuring the active cervical range of motion, neck position sense and neck muscle strength. The results did not support our hypotheses that neck function would significantly be altered in helicopter pilots and rear aircrew with neck pain compared to the pilots and aircrew without neck pain, and that the possible differences between neck pain and healthy subjects would be significantly different for pilots compared to rear aircrew. These results suggest that, with the tests used in this study, deficits in cervical physical abilities because of neck pain cannot be detected. Moreover, they suggest that, based on these tests, military helicopter pilots and rear aircrew cannot be advised on an individualized preventative training program.
Table I. Mean (SD) values for neck muscle strength (Nm), neck position sense (degrees) and cervical range of motion (degrees) for pilots and rear aircrew with (Sx+) and without (Sx-) neck pain.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Helicopter Pilot Sx+</th>
<th>Helicopter Pilot Sx-</th>
<th>Rear Aircrew Sx+</th>
<th>Rear Aircrew Sx-</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neck Muscle Strength (Nm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensors</td>
<td>51 (20)</td>
<td>58 (18)</td>
<td>60 (18)</td>
<td>60 (23)</td>
</tr>
<tr>
<td>Flexors</td>
<td>22 (9)</td>
<td>24 (12)</td>
<td>21 (8)</td>
<td>22 (10)</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>28 (18)</td>
<td>30 (18)</td>
<td>29 (20)</td>
<td>35 (24)</td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>29 (19)</td>
<td>30 (18)</td>
<td>32 (22)</td>
<td>36 (25)</td>
</tr>
<tr>
<td><strong>Neck Position Sense (°)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPE* sagittal plane after submaximal flexion-extension</td>
<td>2.8 (1.0)</td>
<td>3.1 (1.2)</td>
<td>3.3 (1.4)</td>
<td>3.0 (0.8)</td>
</tr>
<tr>
<td>RPE transversal plane after submaximal rotation</td>
<td>1.9 (0.6)</td>
<td>1.8 (0.6)</td>
<td>2.1 (0.8)</td>
<td>2.1 (0.7)</td>
</tr>
<tr>
<td>RPE transversal plane after right 30° rotation</td>
<td>2.5 (1.1)</td>
<td>2.8 (1.5)</td>
<td>2.8 (1.9)</td>
<td>3.0 (1.3)</td>
</tr>
<tr>
<td>RPE transversal plane after left 30° rotation</td>
<td>2.7 (1.8)</td>
<td>2.6 (1.5)</td>
<td>3.0 (1.2)</td>
<td>2.5 (1.0)</td>
</tr>
<tr>
<td><strong>Cervical Range of Motion (°)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal plane</td>
<td>130 (18)</td>
<td>138 (15)</td>
<td>134 (17)</td>
<td>136 (16)</td>
</tr>
<tr>
<td>Frontal plane</td>
<td>82 (15)</td>
<td>82 (15)</td>
<td>83 (15)</td>
<td>83 (14)</td>
</tr>
<tr>
<td>Transversal plane</td>
<td>154 (12)</td>
<td>160 (14)</td>
<td>158 (16)</td>
<td>158 (16)</td>
</tr>
</tbody>
</table>

*RPE=reposition error
Interestingly, the results for the neck strength variables and range of motion variables were always higher in the pilots and aircrew without neck pain, and, on average, there was a trend toward lower values in strength and cervical range of motion in the pilots and aircrew with neck pain, compared to their colleagues without pain.

While interpreting the results of this study, some considerations should be taken into account, and the results should be viewed within the limitations of the study as it was performed. First, the results may depend on the definition of neck pain, which here was considered to be any pain, including aches and discomfort, during the previous 12 months. In terms of frequency, the pilots and rear aircrew could report their pain as occurring never, occasionally, regularly or continuously. The division of pilots and rear aircrew into subjects without neck pain and neck pain subjects was based on these self-reports and, thus, relied on the memory of the subjects over a period of 12 months. This problem could have been avoided by use of a prospective design, for example, by having the pilots and aircrew keep “neck pain diaries”, resulting in a more reliable assessment of neck pain in pilots and aircrew. By excluding the pilots and rear aircrew who reported occasional neck pain and, thus, only including the pilots and aircrew with regular or continuous neck pain in the neck pain group, we tried to create as much contrast as possible between the subjects without neck pain and neck pain subjects. Furthermore, by only including the pilots and crew with regular or continuous neck pain, we tried to ensure that these subjects could truly be considered cases of neck pain, as compared to those who reported only occasionally neck pain.

We assessed the physical abilities of the necks of the military helicopter pilots and aircrew by measuring strength, mobility and position sense. These three measures are often used in the practice of civilian physiotherapy. A limitation of the current study, however, is that we did not monitor flying ability, in-flight postures or head movements. It would have been preferable to test physical abilities more applicable to in-flight abilities. Muscle fatigue or endurance was not assessed, for example, although either might play an important role in flight-related neck pain. Helicopter flights of 6 to 8 hours are no longer the exception in the RNLAF or RNLN. In line with Ang et al. [2], we propose that muscle activity associated with flying a helicopter may be generally lower than with flying high Gz-aircrafts. However, dealing with the loading factors for hours probably causes muscle fatigue over time. Because of practical considerations, and the lack of good methods to measure muscle fatigue that would also fit in our test-battery setting without the risk of sore muscles the next day (pilots and crew were to be able to fly directly after the test and the next day), we decided not to measure cervical muscle fatigue. It would be interesting, however, to measure in-flight cervical muscle fatigue as an extra functional measure in future studies.

The strength of the current study is that, by visiting the different squadrons with the battery of tests, more than 75% of all Dutch military helicopter pilots and almost 80% of rear aircrew were reached, and almost all participated. This makes the present sample highly representative of the helicopter pilot and rear aircrew populations of the
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RNLAF and RNLN. Furthermore, to the best of our knowledge, this is the first study that measured neck function in rear aircrew, while neck pain is a prevalent complaint in this population [25].

In the present study, no differences were observed in neck position sense between pilots and aircrew without neck pain and pilots and aircrew with neck pain, nor was there any difference between the pilots and rear aircrew. Several studies have observed greater reposition errors in subjects with cervical pathology [16;19]. However, other studies did not observe any differences in neck position sense accuracy between neck pain patients and healthy individuals [5;20]. As suggested by Armstrong et al. [4], impaired position sense might depend on the severity of the complaints and the magnitude of problems with daily functioning [21;24]. Our pilots and rear aircrew were still on active flying duty, and, thus, their functioning might still have been on a reasonable level.

In the present study, the results for the neck strength variables followed the same pattern, which consisted of a downward trend from participants without neck pain to neck pain subjects, but the differences were not significant. The largest difference within the strength values was observed in the extensors of the pilots with neck pain compared to the pilots without pain, while the aircrew with and without neck pain scored similar values. We did not measure left- and right rotation strength, which would have provided us more information about the strength status. However with the device used for measuring strength (David F-140) it is not possible to measure rotation strength. We used this device because we have quite some experience with it and good reproducibility data. The results do not confirm our expectations, because we hypothesized that possible differences in strength between the neck pain group and the group without neck pain would be greatest for the rear aircrew. This hypothesis was based on the assumption that rear aircrew would be exposed to greater peak loads on the cervical musculature, as compared to pilots. Aircrew with lower maximum strength might develop neck complaints because their strength capacity would not be sufficient to deal with the high peak loads. However, the neck loads that rear aircrew and pilots were exposed to were not examined in the current study, and research about the actual in-flight neck loads in helicopter pilots and rear aircrew is scarce. Ang et al. [2] measured neck strength in military helicopter and fighter pilots. They hypothesized that, because fighter pilots are exposed to higher peak loads (caused by +Gz forces) compared to helicopter pilots, neck strength values would be altered in fighter pilots with neck pain compared to their colleagues without neck pain, while this would not be the case for helicopter pilots. Indeed, they found their hypothesis to be true, but the cervical demands on fighter pilots may not be comparable to those on rear helicopter aircrew.

We should also take into consideration that the pilots as well as the rear aircrew population of the RNLAF and RNLN represented a pre-selected population and had to meet medical and physical standards before they started their jobs. Peolson et al. [18] measured the strength of the cervical extensors in healthy employed men with the same
equipment and in a similar way as in the current study. They observed an average of 42 Nm (CI: 40-44 Nm) in that study, which is considerably lower than the overall observed mean of 58 Nm in our pilots and aircrew. This suggests either that the military pilots and aircrew already have good genetically defined physical capacities (aircrew self-select to military/aviation service and are screened to eliminate individuals with potentially disqualifying conditions) or that the neck load exposure in flight has a training effect and makes them stronger. Either explanation points to a situation where extra strength training might not result in the desirable effect, as suggested by others [27]. The cervical strength in our population might have been sufficient to deal with the typical in-flight cervical load. Furthermore, since none of the aircrew had neck pain severe enough to keep them from work for a longer period, there might be a healthy worker effect in play. Caution should be taken, however, to extrapolate general conclusions to individuals, since the variation in the cervical strength values was rather high.

The CROM results showed no significant differences between pilots and aircrew with neck pain and their colleagues without pain, nor was there any effect of occupation. However, in line with the cervical strength results, the results for the subjects without pain were always higher than the results for the neck pain subjects, and a trend of smaller CROM values in the sagittal and transversal planes was seen for the helicopter pilots with neck pain. Reduced range of motion in the sagittal and transversal planes has been reported in other neck pain populations [5;7] and in military helicopter pilots [3]. In this latter study, however, the authors differentiated between helicopter pilots with acute neck pain and subacute neck pain, and the pilots with subacute neck pain did not demonstrate lower CROM values in any plane when compared to pilots without neck pain. In our study, we did not differentiate between acute and subacute neck pain, and this might be the reason that we did not find any significant differences. However, post hoc we made a comparison of the pilots and aircrew with prior neck pain and the pilots and aircrew reporting neck pain at the moment of performing the tests. The analyses did not reveal any differences between these groups, either.

To the best of our knowledge, no CROM data for helicopter rear aircrew have been published before. We hypothesized that, especially in this group, CROM would be lower in the neck pain subjects compared to the subjects without neck pain. With the surveillance and clearance tasks of the rear aircrew, they have to adopt extreme postures, with their head out of the window and rotated. We suggested that rear aircrew with a smaller cervical range of motion have to stress their cervical spine more to adopt these extreme postures, which could result in pain. The results, however, did not support our hypothesis.

Pilots and rear aircrew with neck pain did not differ in neck muscle strength, neck position sense or active cervical range of motion, compared to their colleagues without pain. These results suggest that these physical abilities, as assessed in this study, are not associated with neck pain in this population.

It has been suggested that, since the pilots and aircrew are a pre-selected population
with excellent physical capacities, the solution to flight-related neck pain may not be found in improving their physical abilities but, rather, in decreasing neck load. This might be accomplished by ergonomic improvements in the equipment used by pilots and rear aircrew.
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References