Prevention of flight-related neck pain in military aircrew

van den Oord, M.H.A.H.

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Summary
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Neck pain is a common musculoskeletal complaint in both the general and working populations. Several studies have suggested a relationship between neck pain and certain occupational exposures, and specific occupations have been associated with the risk of neck pain. Military pilots and rear aircrew members are occupations with several occupational exposures that might cause neck pain. In addition to the negative impact of neck pain on health, safety might be one of the main concerns for the military aviation because neck pain may interfere with flying performance. It might be obvious that for both employees and employers it is important to prevent flight-related neck pain. Before proposing an intervention that might be effective in the prevention or alleviation of neck pain in military aircrew, it is important to gain insight in its work-relatedness. However, because of the operational demands and regulations that come with military flying, interventions targeting work exposures are thought to be less feasible and have therefore seldom been proposed or studied. In addition, cockpit and cabin ergonomics in military aircrafts are not easily modified, and many of the aircrafts will remain operational for many years. Therefore, the focus of this thesis in preventing neck pain is on the individual. Some aircrew members develop neck pain and others do not, and it is important to identify the factors that characterise aircrew with and without neck pain. Furthermore, the experiences of the aircrew could provide important information in the development of interventions aimed at the prevention of work-related neck pain.

The main objective of this thesis is to study neck pain in military aircrew especially of the Royal Netherlands Air Force (RNLAF) and, in doing so, to generate knowledge regarding the extent of the problem, to identify associated factors concerning the aircrew’s capacity and work situation, and to learn about aircrew’s experiences in order to find and test feasible preventive measures.

The research questions are as follows:

1. What is the prevalence of flight-related neck pain in military aircrew?
2. What aspects of the aircrew members’ capacity and which work factors are associated with flight-related neck pain?
3. Can an optimised helmet fit reduce the neck load and pain during flight in helicopter aircrew?

The studies described in Chapters 2 and 3 represent a collaboration with the Belgian Air Forces (BAF) and address the first two research questions among F-16 pilots. Chapters 4 to 8 address all three research questions among the helicopter population (pilots and rear aircrew members) of the RNLAF.
To answer the first two research questions, all F-16 squadrons of the RNLAF and BAF and all helicopter squadrons of the Defence Helicopter Command\(^1\) (DHC) were visited by the research team on three to four consecutive days depending on the availability of the pilots and the rear aircrew members. Approximately 70% of the F-16 pilot population, 75% of the helicopter pilot population, and 80% of the helicopter rear aircrew population was reached. A questionnaire assessing individual characteristics, health-related issues, and work exposures and responses including flightlog information on work-related flight hours was administered. The physical capacity of the neck was assessed by measuring the active cervical range of motion (flexion-extension, right-left rotation, and right-left lateral flexion), the neck position sense (reposition error back to neutral and defined positions after submaximal cervical movement) and the maximal isometric neck strength (flexion, extension and right and left lateral flexion). Almost all pilots and rear aircrew members who were present in this period participated (96% response rate), and all were on active flying duty. The results of the questionnaire and physical tests are presented in Chapters 2 to 6.

**Chapters 2 and 3** address the first two research questions among F-16 pilots. In **Chapter 2**, the self-reported one-year prevalence of neck pain was estimated, and the individual characteristics and work- and health-related factors of F-16 pilots with and without neck pain were compared. There were 90 male F-16 pilots of the RNLAF and BAF who voluntarily completed the anonymous questionnaire. The reported one-year prevalence of any neck pain was 42%, and 19% experienced more than two episodes of neck pain that lasted for at least one day. Among the latter group, 77% indicated that their complaints were flight-related. Pilots were divided into the following two groups: a neck pain group (n=17) and a reference group (n=73). The neck pain group contained pilots with more than two episodes of neck pain that lasted for at least one day during the previous year. No significant differences were found between the two groups in terms of the total flight hours, the hours flown with night vision goggles, and in the individual characteristics. High-force demands (p<0.01), often sitting for a long time (p=0.04), frequently holding the neck in a forward bent posture (p=0.01), and being physically tired (p<0.01) were the physical work-related factors that were significantly more often reported in the neck pain group. A greater number of hours of computer work per day (p=0.05) was reported by the neck pain group compared to the reference group. The neck pain group also reported significantly more often to be mentally tired at the end of the day (p=0.01) and being annoyed by others at the workplace (p<0.01). The results of this study suggest that both physical and psychosocial factors could be important factors in the development or maintenance of neck pain in F-16 pilots.

In **Chapter 3**, the results of the assessments of the physical neck abilities of the 90 F-16 pilots...
pilots are given. There were no significant differences between the neck pain group (n=17) and the reference group (n=73) concerning neck muscle strength and neck position sense. Compared to the reference group, the neck pain group had a limited range of motion in the sagittal plane (p=0.01) and in the transverse plane (p=0.04). The suggestion that physical training programs might reduce neck pain is not established in this study. Further studies should investigate the effectiveness of this type of training program.

Flying an F-16 is not the same as flying a helicopter, and research into neck pain in military helicopter pilots lacked the understanding of associated factors. Chapter 4 addresses the first research question and part of the second research question among helicopter pilots. In Chapter 4, the self-reported one-year prevalence of neck pain in military helicopter pilots of the Defence Helicopter Command was assessed, and work-related, individual and health-related factors of the pilots with regular or continuous neck pain (neck pain group) were compared with these factors in pilots without these complaints (reference group) in the previous year. There were 103 male and 10 female helicopter pilots who completed the questionnaire. The reported one-year prevalence of any neck pain was 43% and 20% for regular or continuous neck pain, respectively. Over 90% of participants in the neck pain group attributed their pain to flying. In the neck pain group (n=22), significantly more total flying hours (p<0.01) as well as flying hours in the previous year (p=0.02) were reported compared to the reference group (n=91). The type of helicopter flown or the type of flight helmet used was a work-related factor that was significantly associated with neck pain (p=0.03). The mean hours flown with night vision goggles for the total group was 81; night vision goggle hours did not significantly differ between the neck pain group and the reference group. Older age (p<0.01), being female (p=0.02) (individual factors), being physical fatigued at the end of the work day (p=0.02), having a history of neck pain (p<0.01), as well as having pain in the shoulder (p=0.04) and upper back (p<0.01) (health-related factors) were all significantly more often reported in the neck pain group than in the reference group. The findings in this chapter suggest that neck pain in military helicopter pilots is a significant work-related complaint and may be a consequence of longer exposure to flying.

Helicopter pilots and rear aircrew members perform different tasks in the helicopter. The pilots work in the cockpit and fly the helicopter that, depending on the type and mission, is used to transport troops and cargo, perform search and rescue missions, and provide close combat support for ground troops. The rear aircrew members work in the cabin of the helicopter, and their main tasks include troop management, material handling, hoist operation, rescue, surveillance and clearance tasks, and sensor operation. Although pilots and rear aircrew members both have to address specific factors that come with military helicopter operations such as wearing heavy headgear
while performing their tasks, their tasks differ, the work environments within the helicopter (cockpit versus cabin) differ, and consequently, the physical loads differ.

In Chapter 5, the one-year prevalence of neck pain in military helicopter rear aircrew members was estimated (first research question), and self-reported physical load was compared between pilots (n=113) and rear aircrew members (n=61). The one-year prevalence of neck pain among the rear aircrew members was 62% for any neck pain and 28% for regular or continuous neck pain, and 94% of the latter group attributed their neck pain to flying. Considering the exposures to physical load factors, significantly more rear aircrew members than pilots reported being often exposed to manual material handling (p<0.01), performing dynamic movements with their torsos (p<0.01), working in a prolonged bent or twisted posture with their torsos (p<0.01) or their necks (p<0.01), working with their arms raised (p<0.01), and working in awkward postures (p<0.01). Significantly more pilots than rear aircrew members reported often being exposed to prolonged work in the same position/posture during their job (p<0.01). Almost all pilots and rear aircrew members reported being exposed often to prolonged sitting and dynamic movements with their neck. These results suggest that rear aircrew members are more often exposed to a variety of physical loads compared to their colleagues who sit in the cockpit of the helicopter.

Chapter 6 addresses the second research question among the helicopter pilots and rear aircrew members. In Chapter 6, the results of the assessments of the physical abilities of the helicopter pilots and rear aircrew members are presented. The main purpose was to investigate the physical abilities of the neck in helicopter pilots and rear aircrew members with neck pain and to compare them to the physical abilities of pilots and rear aircrew members without neck pain. Furthermore, because pilots and rear aircrew members are exposed to a different variety of physical load factors, we hypothesised that a possible difference between the aircrew with neck pain compared to the aircrew without neck pain could be different for pilots compared to rear aircrew members. For the purposes of this study, pilots and rear aircrew who reported occasional neck pain in the previous year were excluded from the analysis in order to create as much contrast as possible between the groups. The study included 61 male helicopter pilots and 22 rear aircrew members without neck pain and 17 pilots and 17 rear aircrew members with neck pain. Two-way factorial analyses of variance were performed, in which the fixed factors were occupation (pilot or rear aircrew) and neck pain state (neck pain group or reference group). 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 neck pain group compared to the reference group. However, the two-way factorial ANOVA revealed neither significant main effects nor significant interaction effects in any of the measured physical abilities. These 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.

The results from Chapters 4 and 5 suggest that neck pain is a work-related complaint in both helicopter pilots and helicopter rear aircrew members. Although both occupations are exposed to a different variety of physical load factors that might be risk factors for developing neck pain, there are also some similarities. Both pilots and rear aircrew members are often exposed to dynamic movements with their neck, and they wear the same headgear. These results have implications for prevention, and modification of this headgear could be advantageous for both pilots and rear aircrew members. As a first step in trying to improve the ergonomic situation with respect to the headgear, it is important to know what the in-flight experiences of pilots and rear aircrew members are concerning their helmet configurations in relation to their experienced neck load.

We interviewed 12 pilots and 11 rear aircrew members using semi-structured interviews (Chapter 7). The interviews were transcribed verbatim, and qualitative analyses were performed. Various factors as well as their interrelations and relation to experienced neck load emerged as the analysis progressed. Factors that were directly related to the experienced neck load were type of flight operations and tasks as well as the weight and the weight distribution of the flight helmet. Factors that indirectly contributed to the experienced neck load were the stability of the helmet, the helmet fit and the comfort of the helmet.

The next step in preventing flight-related neck pain in military helicopter pilots and rear aircrew members was to develop and test an intervention aiming to improve the helmet fit and the helmet stability, taking comfort into account (research question 3). The main purpose of the study in Chapter 8 was to improve the helmet fit of military helicopter aircrew members and evaluate its effect on the experienced neck load and neck pain, helmet stability (helmet gliding), hot spots (pressure points), irritation/distraction, and overall helmet comfort during night flights. A within-subject design was used over a three-month period that consisted of the following two consecutive interventions to optimise the fit of the aircrew’s helmets: 1) development of a new helmet fit using a renewed protocol and 2) replacement of a thermoplastic inner liner with a viscoelastic foam inner liner. The optimised helmet fit was evaluated during night flights because during the interviews (Chapter 7), pilots and rear aircrew members indicated that they experienced the most neck load during night flights and that they suffered the most from an unstable helmet when flying with night vision goggles attached to their helmets. A total of 18 pilots and rear aircrew members rated the outcome measures using Visual Analogue Scales immediately after their night flights, with a total of three night flights per measurement period. The optimised helmet fit resulted in a significant decrease in the experienced neck load (p=0.02), helmet gliding (p<0.01),
and pressure points (p<0.01), a decreased trend in the experienced neck pain (p=0.06) and irritation/distraction (p=0.06), and a significant increase in the experienced overall helmet comfort (p<0.01) during flight. These results demonstrate the importance of achieving an optimised helmet fit for military helicopter aircrew and that an optimised helmet fit might have implications for both health and safety concerns.

In Chapter 9, the main research findings are summarised and discussed, and recommendations for further research and practice are presented. A strength of the study was the intention to include the entire population of F-16 pilots, helicopter pilots and rear aircrew members and that 70-80% of potential participants were reached and ultimately participated. The one-year prevalence of regular or continuous neck pain in F-16 pilots, helicopter pilots and helicopter rear aircrew members was 19%, 20% and 28%, respectively, and over 75% of them reported their complaints to be flight-related (first research question). The division of the aircrew in the neck pain group and the reference group was based on self-reported neck pain. It was discussed in Chapter 9 whether these self-reports were a reliable and valid measure and whether the contrast between the two groups might have been distinctive enough for the analysis to answer the second research question. Based on the literature and the fact that more than 75% of the pilots and rear aircrew members attributed their neck pain to flying, we concluded that this outcome measure was reliable and valid. Concerning the second research question, several individual, health- and work-related factors that have previously been associated with neck pain in the general working population were also associated with neck pain in this specific occupational population of military pilots and rear aircrew members. The helicopter pilots in the neck pain group reported significantly more flying hours compared to their colleagues in the reference group, suggesting that their neck pain may be a consequence of longer exposure to flying. The experienced neck load during flight was significantly and highly correlated to the experienced neck pain during helicopter flights. F-16 pilots in the neck pain group had a smaller range of motion compared to the reference group. No differences were found in strength, cervical range of motion or neck position sense between helicopter pilots and rear aircrew members in the neck pain group compared to their colleagues in the reference group. It was discussed in Chapter 9 whether the physical abilities as assessed in this study represent the critical abilities required during flight. For example, muscle fatigue was not assessed, although it might play an important role in flight-related neck pain, especially because helicopter flights of 6 to 8 hours are now common. Factors that were identified to be related to the experienced neck load during flight were the type of flight operation, the weight and the weight distribution, the stability of the headgear, and the fit and comfort of the helmet. An optimised helmet fit resulted in a more stable and comfortable helmet fit and decreased the experienced neck load during flight (third research question).
These findings lead to the recommendation that an optimised helmet fit should be provided to all pilots and rear aircrew members. Recommendations for further research include the study of the weight and the weight distribution of the headgear with respect to neck load, taking the in-flight head and neck positions and movements into account. There is a need to assess the in-flight exposures in more detail, and these assessments could provide information about the physical abilities required during flight. The industry is encouraged to develop custom-made flight helmets.